REPUBLIC OF TURKEY

INSTITUTE OF HEALTH SCIENCES

CLINICAL COMPARISON of SELF-LIGATING BRACKETS VERSUS CONVENTIONAL BRACKETS

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DOCTORATE THESIS

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ISTANBUL-2009

DECLARATION

I declare that this thesis is a result of my own studies and there is no non-ethical act from the begining to the end at any stage. All the information in this thesis is acquired in the borders of academical and ethical rules. The information and the comments mentioned that are not a part of my own study are referred and all the references have a part in the reference list. During this study and writing of this thesis I did not have any prohibiting act on patent and copyright laws.

15.11.2009

Burcu USTA SELAMET

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1) SUMMARY

Clinical efficiency of self-ligating brackets and conventionally ligated straight-wire brackets were compared using digital models, lateral and postero-anterior cephalograms. Clinical efficiency was also evaluated by overall treatment time, chair time, number of bracket loss, number of loss of ligation/clip deformation. Study group consisted of 13 and control group consisted of 10 patients. Quick brackets (Forestadent Bernhard Forester GmbH, Westliche, Pforzheim, Germany) were applied to the patients in the study group. Conventionally ligated MIB (MIB, France) brackets were used for the patients in the control group. Both groups had their comprehensive orthodontic treatment completed. Digital models were measured initially at the start of the treatment, before switching to Ni-Ti rectangular wires, before switching to rectangular stainless-steel wire and at the end of the treatment for both of the groups. Lateral and postero-anterior cephalometric x-rays were taken and analysed initially and at the end of the treatment. The dentoalveolar expansion gained in both groups was not statistically significant between groups, except the upper first premolar area which was significantly higher for study group. Similar amount of tipping was observed in upper and lower canine, premolars and first molar area. Upper and lower insicor proclinations were similar at the end of the treatment. The total treatment time, the number of bracket loss was comparable for both arches in groups. The difference in ligation times for all arches were statistically lower for study group compared to control group. In conclusion, both systems were found to be similarly effective in the treatment of severely crowded Class I cases.

Keywords: Arch Expansion, Arch Ligating Time, Digital Model, Self-ligating Bracket, Treatment Time

2. ÖZET

KAPAKLI BRAKETLERLE KONVANSİYONEL BRAKETLERİN KLİNİK KARŞILAŞTIRMASI

Kapaklı braketlerle konvansiyonel braketlerin klinik etkinlikleri dijital modeller, lateral ve ön-arka yönlü sefalometrik röntgenler kullanılarak karşılaştırılmıştır. Ark bağlama süresi, tedavi süresi, kırılan braket sayısı, ligatür kaybı/kapak deformasyon ya da kırılma sayısını içeren klinik etkinliğe ait ölçümler de değerlendirilmiştir. Çalışma grubu 13, kontrol grubu 10 hasta içermektedir. Çalışma grubundaki hastalara kapaklı Quick braketler (Forestadent Bernhard Forester GmbH, Westliche, Pforzheim, Germany) uygulanmıştır. Kontrol grubundaki hastalar için konvansiyonel MIB (MIB, France) braketler kullanılmıştır. Her iki grubun ortodontik tedavileri tamamlanmıştır. Dijital modeller her iki grup için tedavi başlangıcında, Ni-Ti köşeli tellere geçilmeden, köşeli çelik tellere geçilmeden ve tedavi sonunda ölçülmüştür. Lateral ve ön-arka yönlü sefalometrik röntgenler tedavi başlangıcı ve bitiminde alınarak analiz edilmiştir. Her iki grupta elde edilen dentoalveolar genişleme, çalışma grubu için anlamlı düzeyde yüksek olan üst birinci premolar bölgesi hariç, gruplar arası karşılaştırmada istatiksel olarak anlamlı bulunmamıştır. Her iki arkta kanin, premolarlar ve birinci molarda benzer düzeyde devrilme tespit edilmiştir. Tedavi sonunda üst ve alt keser açılarındaki artış benzerdir. Toplam tedavi süresi, kırılan braket sayısı her iki ark için gruplarda benzerlik göstermektedir. Ark bağlama süreleri çalışma grubunda kontrol grubuna göre istatistiksel olarak anlamlı düzeyde küçüktür. Sonuç olarak, ciddi Sınıf I çapraşıklıkların tedavisinde her iki sistemin etkisinin benzer olduğu bulunmuştur.

Anahtar Kelimeler: Ark Bağlama Süresi, Ark Genişlemesi, Dijital Model, Kapaklı Braket, Tedavi Süresi

3- INTRODUCTION and AIM

It is certainly desirable for fixed appliances to be placed in the oral cavity for as short time as possible; these appliances increase plaque accumulation, make tooth brushing more difficult and can promote both caries and periodontal disease. Therefore any appliance system that can increase the rate of tooth alignment is a potential clinical advance. It is also important to evaluate side effects of any new appliance system promoted for rapid alignment.

Self-ligating brackets have been promoted to reduce treatment time by decreasing friction, decrease chair time by their easy way of ligating; decrease the need of extraction by increasing arch expansion. They have been evaluated for friction manner in laboratory studies. Clinical studies comparing conventional brackets with self-ligating brackets are comparebly less.

Digital models in orthodontic is a new era. They have been proven to be reliable in diagnosis, treatment planning and model analyses. Model analyses in this study have been performed on digital models.

We aimed to compare the self-ligating and conventionally ligated systems by lateral and postero-anterior cephalometric x-rays, digital models and clinical effciency factors. The main concern is to evaluate if there is a difference between the mechanism of both systems.

4- LITERATURE REVIEW

4.1. Evolution of Ligation

The vast majority of fixed orthodontic appliances have stored tooth-moving forces in archwires which are deformed within their elastic limit. For this force to be transmitted to a tooh, wires need a form of connection to the bracket which is in turn fixed to the tooth. This connection has for many years been referred to as 'ligation' because the early forms of connection were most frequently a type of ligature and this remained the situation for several decades. All more recent forms of connection between the bracket and archwire have retained the title of ligation. The development of ligation forms are:

A- Stainless Steel Ligatures: The earliest ligatures were often made from silk which had long been used in surgery for suturing. When stainless steel ligatures became available, this was universally adopted. Stainless steel ligatures have several inherent qualities. They are cheap, robust, essentially free from deformation and degradation and to an extent they can be applied tightly or loosely to the archwire. They also permit ligation of the archwire at a distance from the bracket. This distant ligation is particularly usefull if the appliance tends to employ high forces from the archwires, because this high force prevents sensible full archwire engagement with significantly irregular teeth (113).

B- Begg Pins: In the 1950s, Raymond Begg developed his light wire technique using Angle's ribbon arch brackets with round archwires. A key feature of the technique was the use of brass pins as the method of ligation. These pins constituted the fourth (gingival) wall of the bracket slot and formed a rigid metal wall analogous in some ways to that of a molar tube. The pins were designed with shoulders to keep from binding the archwire in the early alignment stages and as 'hook-pins' they held the archwire in a more precise vertical position when thicker wires and auxilleries were added later in the treatment (15).

C- Elastomeric Ligatures: Elastomeric ligatures became available in the late 1960s and rapidly became the most common means of ligation, almost entirely because of the greatly reduced time required to place and remove them when compared with steel wire ligatures. It was also easier to learn the skills required to place them. The main disadvantage of elastomerics is that they may fail to fully engage an archwire when it is intented (49).

D- Self-Ligation: Conventional ligation methods represent some limitations. Clinicians have become accustomed to tolerating these deficiencies. Self-ligating brackets have been suggested to replace the conventional ligation methods of elastomeric and stainless steel ligatures to increase clinical efficiency. Self-ligation offers the opportunity for significant improvements relative to all of these factors. The idea self-ligating brackets arouse from is easy and quick ligating and decreased friction levels (51).

An ideal ligation system should have the following properties:

a) be secure and robust,

b) ensure full bracket engagament of the archwire,

c) exhibit low friction between bracket and arcwire,

d) be quick and easy to use,

e) assist good oral hgyiene,

f) be comfortable for the patient (51).

A- Secure And Robust Ligation

An ideal ligation system should be resistant to inadvertent loss of ligation. Wire ligatures are good in this respect whereas elastomeric ligatures are less so, especially if left too long without renewal. Elastomeric ligatures are polyurethane based polymers and studies have verified that these materials undergo stress relaxation and slow hydrolytic decomposition over time (6). Secure ligation can be compromised by the stress relaxion of regular modules (49).

B- Full Bracket Engagement

Ligation systems are required to fully engage the archwire in the bracket slot and maintain there with certainity. Wire ligatures do not stretch to an extent that engagement once achieved at ligation is subsequently lost, so they can meet this requirement.

Elastomeric modules loose their ability to exert enough force even with small diameter flexible wires due to subsequent degradation of their elastic performance. Elastomeric modules will generate approximately 225 grams of force with subsequent decay due to elastic relaxation, while stainless steel ligation can range from 50 to 300 gram (121).

C- Low Friction

Friction between the archwire and bracket is a force that must be overcome before the intented tooth movement begins. Higher friction results in need of higher and unpredictable forces to be applied.

A deformable elastomeric ring can not provide and sustain sufficient force to maintain the archwire fully in the slot without actively pressing on the archwire to an extent that significantly increases friction. Conventionally ligated edgewise brackets incur inreased levels of frictional resistance via the elastomeric attachment between bracket and arch-wire (110).

Wire ligatures produce lower friction forces than elastomerics (113,14). Still the forces generated by wire ligation reach high and variable levels relative to force levels optimal for tooth movement (63).

Taylor and Ison (124) reported that the frictional force declined slowly over a three week period following initial placement of the elastic module. After three weeks, the greater friction initially encountered for rectangular wires approached the low level of friction for round wires. They found that by pre-stretching elastomeric ligatures or loosely tying stainless steel ligatures, the frictional resistance would be reduced.

Bednar et al (14) found that lightly ligated stainless steel ligatures produced lower friction than conventional elastomeric ligatures. Bazakidou et al (12), on the other hand, found no significant trend for friction with either elastomeric or steel ligation. Yet there was up to three times greater variability in friction with stainless steel ligation than elastomeric ligation, even though it was attempted to standardize both methods of ligation.

Even between different types of elastomeric modules Downing et al (32) found significant differences with regard to friction. Sims et al (115) demonstrated that tying elastic ligatures in a figure eight pattern around identical brackets raised the frictional resistance 70-220% depending on the wire dimensions. No significant trend in frictional resistance was observed when conventionally tied elastomeric ligatures were compared with stainless steel ligatures tightened with 7 turns.

Bayrı (11) compared conventional brackets tied with metal ligatures, elastomeric ligatures and Slide (Leone Slide) brackets in aligned and non-aligned configurations. He concluded that, for the brackets utilised, there was no statistically significant difference between elastomeric ligatures and stainless steel ligatures. However Leone slide ligatures presented the least friction at crowded configuration. When aligned configuration was tested, he stated that elastomeric ligatures presented higher friction than both sytems.

Low friction ligatures were also investigated in clinical studies. A study by Franchi et al (37), found increases of 2.30 mm in upper intercanine width (cusps), 1.96 mm in intercanine width (lingual points); 1.7 mm (central fossa) increase and 0.04 mm decrease (lingual points) in inter-molar width.

D- Quick and Easy to Use

This is a significant disadvantage of wire ligation and the principal reason for the decline in their use. It has been shown that process of wire ligation is very slow compared with elastomeric ligature (75). In a clinical study the use of wire ligatures added almost 12 minutes to the time needed to remove and replace two archwires (113).

E- Maintenance of Optimal Oral Hygiene

It is well known that elastomerics accumulate plaque more than wire ligatures do (42). There is also some evidence that the use of wire ligatures reduces bleeding on probing of the gingival crevice when compared with elastomeric ligatures (131). However, a scanning electron microscopy study found no difference in bacterial morphotypes when using elastomerics or steel ligatures (120). The latter area requires further investigation; however, current evidence suggests that a reduction in the bacterial challenge through an absence of elastomeric ligation is a reasonable hypothesis (51).

F- Comfortable for the Patient

Elastomerics are good in this respect, but wire ligatures require careful tucking in of the ends to avoid soft tissue trauma and even then can occasionally be displaced between appointments and cause patient discomfort (3).

4.1.1. History of self-ligating brackets

Self-ligating brackets have an in-built metal labial face, which can be opened and closed. They do not require an elastic or wire ligatures to secure the arch-wire. The Russell-Lock edgewise attachment was the first self-ligating edgewise bracket described by Stolzenberg in 1935 (119) . The Russell attachment was an attempt to enhance clinical efficiency by reducing ligation time. Many designs have then been patented, altough a minority have become commercially available.

Self-ligating brackets can be sub-divided in two groups: Those with active springs and those with passive slides. Active brackets posses a spring clip that presses against the arcwire. Passsive brackets have a slide which ideally does not press against the archwire. Actually they are only passive when the teeth are well aligned in three dimensions (torque, angulation, bucco-lingual direction). Examples of active brackets are: In-Ovation (GAC International, Bohemia, NY), Speed (Strite Industries, Cambridge, Ontario, Canada) and Time (American Orthodontics, Sheboygan, Wis). Examples in the passive group are the Activa ('A' Company, San Diego, Calif), the Twin lock (Ormco/ 'A' Company, Orange, Calif), Damon bracket

(Ormco, Glendora, Calif.), the Smart Clip bracket (3M Unitek, Monrovia, Calif.), Paraxis Gide (Lancer, California), the Carriere LX (Ortho Organizers, California) and the Vision LP (Appendix American Orthodontics, Wisconsin) (Rinchause and Miles 2007). A list of active and passive brackets are shown in Table 1.

Table 1: Active and passive self-ligating brackets.

Active Brackets	Passive Brackets
In-Ovation (GAC International, Bohemia, NY)	Activa ('A' Company, San Diego, Calif)
Speed (Strite Industries, Cambridge, Ontario, Canada)	Twin lock (Ormco/ 'A' Company, Orange, Calif)
Time (American Orthodontics, Sheboygan, Wis)	Damon brackets (Ormco, Glendora, Calif.)
Quick (Forestadent, Pforzheim, Germany)	Smart Clip bracket (3M Unitek, Monrovia, Calif.)
Oyster (Gestenco Inc., Sweeden)	Paraxis Gide (Lancer, California)
	Carriere LX (Ortho Organizers, California)
	Vision LP (Appendix American Orthodontics, Wisconsin)

Edge-Lock Brackets

Edge-lock brackets (Ormco Corp., Glendora, Calif.), introduced in 1972, were the first self-ligating bracket to be produced in siginificant quantities. The mechanism for retaining archwire involved sliding a labially positioned cap across the top of the archwire slot and into the locked position (Picture 1.). Disadvantages include inadequate rotational control, bulkiness and some inconvenience with opening and closing (140).
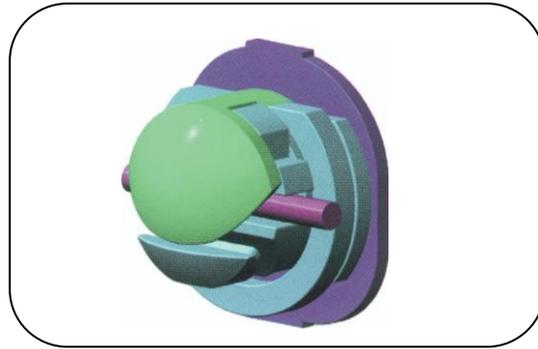
Picture 1: Edgelock brackets

Speed Brackets

The Speed brackets (Strite industries Ltd., Ontario, Canada) have remained in successful production since 1980. The Speed clip that entraps the arcwire is made of superelastic nickel-titanium alloy (Picture 2.). It possesed a spring-loaded property (19). The problem of displaced or distorted clip has been adressed but unfamiliarity for clinicians of a bracket with no tie wings hindered the wider popularity of speed in previous years.

Garino and Favero (44) stated the advantages of the self-ligating Speed system as the low levels of force used, low friction, and precise control of tooth movements.

Mobil-Lock Brackets

Mobil-Lock brackets (Forestadent Bernhard Forester GmbH, Westliche, Pforzheim, Germany), introduced in 1980, had a rotating cam, which was turned with a "screwdriver," thus covering part of the labial surface of the slot (Picture 3.). The wire could be tightly or loosely engaged by the degree of rotation of the cam. A major limitation was the narrowness of the resulting labial face of the slot. This gave very poor rotational control to the extent that upper incisor brackets were given twin cams to increase the effective bracket width. Another problem was the difficulty of access to open and close premolar brackets with the straight screwdriver (51).

Activa brackets

Activa brackets ("A" Company, San Diego, CA), introduced in 1994, had a rotating slide, which therefore gave a concave inner radius to the labial surface of the slot (Picture 4.). This increased the effective slot depth with small diameter wires,

diminishing labiolingual alignment with such wires. The slide was retained on the mesial and distal ends of the slot and this made for a wider than average bracket, which reduced the interbracket span with the consequent disadvantages. The absence of tie wings was a problem when placing elastomeric chain and the unfamiliar shape of the early bonding base made bracket positioning more difficult. Finally, a combination of the design features substantially reduced bond strength (53).

Picture 2: Speed brackets
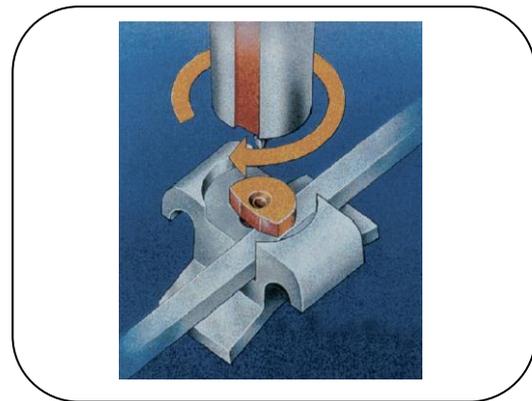
Picture 3: Mobil-lock brackets

Time Brackets

The Time bracket (Adenta GmbH, Munich, Germany) superficially resembles a Speed bracket, but the Time clip rotates into position around the gingival tie wing and rotates toward the occlusal rather than the gingival wall of the slot (Picture 5.). The bracket body is a cast (metal injected model), one-piece twin design with an integral bonding base (133).

The bracket clip is easily opened with a hand-instrument by engaging the hole of the clip and rotating in a gingival direction and closed in the opposite direction with same ease. The gingival undercut area of the bracket allows co-ligation of elastomeric chains or elastics. The low-profile of the bracket supports comfort for the patient. The intercorporated interactive design allows minimal force and friction (passive) in the early stages of the treatment and helps in torque and rotational control (active) in the middle and finishing stages (133).
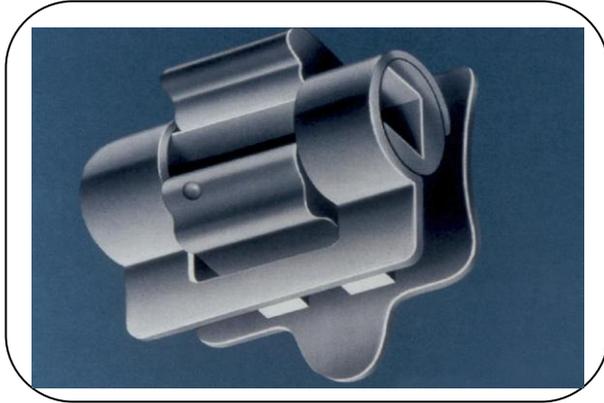
Picture 4: Activa brackets   **Picture 5:** Time brackets
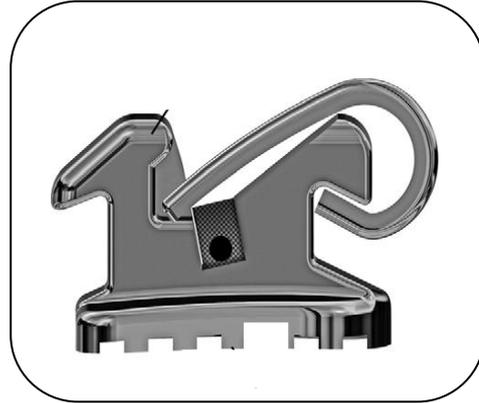
Damon SL brackets

Damon SL brackets (SDS Ormco, Orange, Calif) also became available in the mid 1990s and had a slide that wrapped around the labial face of the bracket. A tiny U-shaped wire spring lay under the slide and clicked into the two labial "bulges" on the slide to provide positive open and shut positions (Picture 6.). These brackets suffered two significant problems —the slides sometimes opened inadvertently and they were prone to breakage.

The Damon philosophy is based on the principle of using just enough force to initiate tooth movement- the threshold force. The underlying principle behind the threshold force is that it must be low enough to prevent occluding the blood vessels in the periodontal membrane to allow the cells and the necessary biochemical messengers to be transported to the site where bone resorption will occur and thus permit tooth movement (29).

Damon2 brackets

Damon2 brackets (SDS Ormco, Orange, Calif) were introduced to address the imperfections of Damon SL. They retained the same vertical slide action and U-shaped spring to control opening and closing, but placed the slide within the shelter of the tie wings (Picture 7.). Combined with the introduction of metal injection molding manufacture, which permits closer tolerances, these developments almost completely eliminated inadvertent slide opening or slide breakage (52).

Damon 3 and Damon 3 MX brackets

Damon 3 and Damon 3 MX brackets (SDS Ormco, Orange, Calif) have a different location and action of the retaining spring, and this has produced a very easy and secure mechanism for opening and closing (Picture 8, 9.). In addition, Damon 3 brackets are semiesthetic. However, early production Damon 3 brackets suffered three significant problems: a high rate of bond failure, separation of metal from reinforced resin components, and fractured tie wings. These three problems all received rapid and effective investigation and correction (51).

Picture 6: Damon SL bracket

Picture 7: Damon2 bracket

Picture 8: Damon 3 bracket
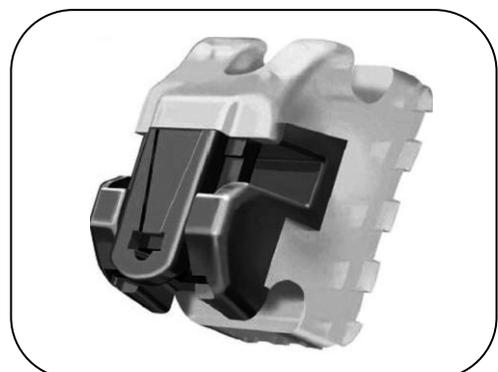
Picture 9: Damon 3MX bracket

System R brackets

System R brackets (GAC International Inc., Bohemia, NY), originally called In-Ovation brackets, are very similar to the Speed bracket in conception and design, but of a twin configuration with tie wings (Picture 10.). It was released in 1999. The bracket clip is made of stainless steel.

In 2001, smaller brackets for the anterior teeth became available — In-Ovation R (Reduced, referring to the reduced bracket width) and this narrower width was effective in terms of greater interbracket span. The bracket subsequently became known as System R (Picture 11.).

More recently released In-Ovation C is the world's first esthetic self-ligating bracket (Picture 12.). It has rodium-coated interactive clip.

Some brackets of this type are difficult to open and this is more common in the lower arch where the gingival end of the spring clip is difficult to visualize. Excess composite at the gingival aspect of brackets in the lower arch can be difficult to see and may also hinder opening. Similarly, lacebacks, underties, and elastomerics placed behind the archwire are competing for space with the bracket clip (93).

Picture 10: In-ovation bracket

Picture 11: In-Ovation R bracket

Picture 12: In-Ovation C bracket

SmartClip bracket

The SmartClip bracket (3M Unitek 3M Center, St. Paul, MN 55144-1000), produced in 2004, retains the wire by two C-shaped spring clips on either side of the bracket slot (Picture 13.). The instrument or finger pressure required to insert or remove an archwire is therefore not applied directly to the clip, but to the archwire, which in turn applies the force to deflect the clips and thus permits archwire insertion or removal. This mechanism therefore has to cope with providing easy insertion and removal through the jaws of the clips and it must also prevent inadvertent loss of ligation for both small, flexible archwires and large, stiff archwires. The design has to find a difficult compromise between the best requirements for the wide range of orthodontic archwires. Other spring clips, such as on Speed and System R brackets with their vertical action, have a rigid bracket component to assist the spring in resisting a loss of ligation. It became apparent with wider clinical use that the force required for insertion and removal of thick stainless steelwires from SmartClip brackets was uncomfortably high. A recent modification has addressed this difficulty by lowering the effective stiffness of the spring clips (52).

Oyster Brackets

Oyster brackets (Gestenco Inc., Sweeden), produced in 2001, is an esthetic active self-ligating bracket made of resin polymer (Picture 14.). They were originially found to be insufficiently robust. Recently they have incorporated a metal hinge with the intention of improving this (35).

Picture 13: Smart-clip bracket
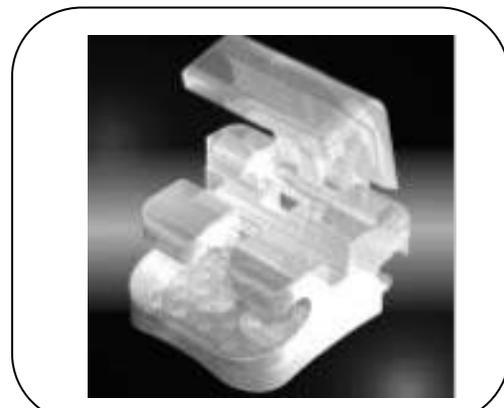
Picture 14: Oyster bracket

OPAL Bracket

Opal (Ultradent Inc., South Jordan) brackets, produced in 2004, was also composed of resin polymer (Picture 15.). They have an ingenious design to address the challange of the same material being very flexible in one part of the bracket to create a hinge, whilst providing as a rigid bracket slot and as reliable a clip as possible. Opal is a passive bracket which can be opened with its specially designed Opal key. This was not completely successful, but remains an imaginative use of polymer material (35).

Clarity SL Brackets

Clarity SL brackets (3m Unitek Corp., Monrovia, CA), have been produced as ceramic bracket with metal clips (Picture 16.) (73).

Picture 15: OPAL bracket   **Picture 16:** Clarity SL bracket

Quick Brackets

Quick brackets (Forestadent Bernhard Forester GmbH, Westliche, Pforzheim, Germany), produced in 2005, have addressed the difficulty in opening clips by providing a labial hole or notch in the clip in which a probe or similar instrument can be inserted to open the bracket (Picture 17.).

The Forestadent Quick bracket features one piece bracket body construction made from NiFree steel suitable for all patients, unique patented bracket basis with 30% increased bond strength and easy, reliable and efficient debonding. Quick brackets posses both .018'' and .022'' slot designs in Roth system. The prescription of Roth system Quick brackets are shown in Table 2.

Table 2: The prescription of Roth system Quick brackets.

UPPER	Left Premolars	Left Canine	Left Lateral	Left Central	Right Central	Right Lateral	Right Canine	Right Premolars
Torque values	-7	-2	+8	+12	+12	+8	-2	-7
Angulation	0	+11	+9	+5	+5	+9	+11	0
In/out	0,9	0,9	1,5	1,5	1,5	1,5	0,9	0,9
Rotation	2 distal	4 mesial					4 mesial	2 distal
LOWER	Left Premolars	Left Canine	Left Lateral	Left Central	Right Central	Right Lateral	Right Canine	Right Premolars
Torque values	-22	-11	0	0	0	0	-11	-22
Angulation	0	+7	0	0	0	0	+7	0
In/out	1,0	1,2	1,8	1,8	1,8	1,8	1,2	1,0
Rotation	4 distal	2 mesial					2 mesial	4 distal

The clip has two different openning mechanisms. It can be either slided to open from gingival aspect or using the hole from vestibular aspect. The clip remains passive up to an archwire dimension of .018''x .018'' or .016'' x .022''. Wires up to these dimensions move freely in the slot. With increasing archwire dimensions the clip becomes more active giving the clinician increasing control over tooth movement.

Picture 17: Quick brackets in open and closed positions

More recently Quick2 brackets have been developed to adress the problem of distorted clip mechanism with Quick brackets (Picture 18.). A reinforced clip reduces unintended deformation through incorrect opening. The new clip is designed with a slightly higher initial tension and remains easy to open. The enhanced geometry of the clip allows an accurate, friction-free and secure hold of the arch. As a result, thinner wires (BioStarter .010", .012" or .014") are kept safely in position even while moving heavily rotated teeth.

The Quick2 lower incisor brackets feature a low profile design with rounded edges and a flattened profile. (Picture 19.). Patient comfort is improved with the aid of lesser soft tissue irritations (www.orthobond.be/quick.brackets.php, 15.11.2009).

Picture 18: Quick2 brackets in open and closed position

Picture 19: Profile of Quick2 brackets compared with Quick brackets

4.1.2. Features of self-ligating brackets

The potential core advantages of self-ligation are faster archwire removal and ligation, more certain archwire ligation, less or no chairside assistance. Self-ligating brackets have been advocated mainly for the lower friction variants and the feature of

lower forces attributed to the increased archwire-slot clearance because of the lack of contact points of ligature and wire.

With every self-ligating bracket, wheather active or passive, the movable forth wall of the bracket is used to convert the slot into a tube. This results in an increased intraslot wire play, which in turn reduces friction (23). Such a reduction in friction might help shorten overall treatment time, especially in extraction patients in whom translation is achieved by sliding mechanics. It is suggested that due to increased intraslot wire play resulting in less friction and reduction in the magnitude of the generated forces, treatment time is shortened (104).

Harradine (50) stated a mean reduction of four visits during active treatment with Damon brackets. Eberting et al (34) found a reduction of seven visits for Damon self-ligating brackets compared with conventional brackets. They also showed reductions in treatment times of 4 months and 7 months respectively.

The study by Gerber (46) also confirmed that overall treatment time was 10 months shorter with Damon2 brackets compared with mini-twin brackets in ClassI non-extraction cases.

When aligning stage of treatment was considered solely; for moderate crowding with an irregularity index of smaller than 5 mm, there is evidence that the Damon2 brackets can produce faster correction although this becomes more insignificant for more severe crowding (88).

Alpern (3) also confirmed that treatment times were on average 5.7 months sooner with self-ligating In-Ovation brackets compared with conventionally ligated brackets.

One case report stated a treatment duration of 10 months for a premolar extraction case using Damon brackets (72). It was argued that such an extraction treatment would take approximately 24 months with conventional bracket systems.

Beceti (13), in his thesis study, compared the clinical effects of Damon2 and traditionally ligated brackets. He concluded that the overall treatment time was 6 months less with Damon2 self-ligating system.

In contrast with these studies; a randomised clinical trial revealed neither initial nor overall difference in rate of mandibular insicor alignment (111). The study by Miles et al (82) also agreed with this finding that Damon2 brackets performed no better than conventional twin brackets in aligning stage of treatment. In a similar study, Smart-Clip passive self-ligating brackets were found to be no more efficient during initial alignment with identical wire sequences and cross-sections (80).

Miles (81) also studied the difference in time required to close the extraction space during en-masse retraction with self-ligating Smart-clip brackets and conventional brackets. He concluded that there was no difference in time and closure rate among the brackets tested.

Fleming et al (40) compared the efficiency of mandibular arch alignment in three dimensions with SmartClip self-ligating bracket system and a conventional Victory twin in non-extraction cases. They stated that the mean duration of alignment and levelling was 250.1±37,7 days overall: 247.2±36,8 in the self-ligating group and 253±39 days in conventional group. This duration involves the period 8 weeks after stainless-steel wire is passively engaged. The authors concluded that overall bracket type had little influence on alignment efficiency, and it was highly correlated to pretreatment irregularity.

Arch development is a therapeutic effect of fixed appliances in non-extraction treatment protocols. Treatment of a crowded dental arch on a non-extraction basis, without tooth size reduction, requires an increase in arch perimeter to allow resolution of crowding and achievement of optimum arch levelling and allignment. Without active distal movement, changes typically involve both transverse expansion and proclination (139).

Dentoalveolar expansion leading to changes in archform and size has been documented in studies on the effectiveness of fixed appliances in orthodontic patients. A clinical study comparing extraction, non-extraction and RPE treatment results on dental arches concluded that there is no difference on distance between upper canine tubercules and distances between upper premolar and molar teeth show the greatest change in RPE group followed by non-extraction treatment (58).

Changes in transverse measures of the maxillary arch include increases in intercanine width from 0.55 mm (64) to 2.13 mm (16), interpremolar width (at second premolars) from 2.10 mm (64) to 4.94 mm (16) and intermolar width from 1.53 mm (64) to 2.96 mm (16). Proclination of incisors contibute to increase in arch depth. It has been shown that for every 5 degrees of anterior inclination, about 1 mm of arch lenght is generated (98). These modifications have an impact on arch perimeter with consequent production of space to accomodate teeth. The reported increase in arch perimeter or arch lenght range from 0.22 mm (20) to 1.8 mm (91).

Damon (29) stated that orofacial musculature impacts the alignment of teeth as well as arch width. By balancing the body's forces, the arch expansion becomes more posterior in nature and alleviates crowding through a balance in the delivery system, the blood supply, and the muscles. This phenomenon allows the operator to treat non-extraction cases without the flaring of the anterior teeth or forcing these anterior teeth through the cortical bone. Damon claims that the bracket design serves as a 'mini-lip bumper' and that the forces of the lips and cheeks help to move the teeth to their physiologic positions. This lip bumper effect combined with the frictionless situation that exists between arcwire and the bracket allows the oxygen tension in the periodontium to be uncompromised by the decreased vascular supply normally seen in tooth movement.

The same author, presented cases with Computed Tomographies before and after orthodontic treatment with Damon brackets. He stated that the dental arch expansion occurred with the alveolar expansion following it. By the way arch expands by the bodily movement of posterior teeth, without unwanted tilting (29).

On the contrary, a recent study compared the pre- and post-treatment CBCT scans of 48 patients, treated with either active or passive self-ligating brackets. The 3D models generated from the scans were superimposed. Changes in maxillary alveolar bone and dental arch were assessed using 3D colour-coded mapping. It was stated that for both systems, expansion of the dental arches occurred increasingly from the canine to the 2nd premolar, and mainly occurred as a result of tipping. No transverse augmentation of basal bone could be detected. Also they found no statistically significant difference in torque-control of the 2 self-ligating systems,

though a tendency towards more torque-control was noticed with the active self ligating system (28).

Similar with these findings, Paventy (94) evaluated facial bone changes using CBCT after arch development using the Damon System in nonextraction treatment of moderate to severe crowding cases. He concluded that posterior teeth showed significant facial bone height loss. Additionally, that all teeth showed significant mean facial bone width loss. They concluded that the Damon System effectively expanded both dental arches. However, facial bone did not correspondingly adapt after arch development was completed. In fact, facial bone decreased significantly in height and width for nearly all teeth measured.

Yu et al (143), in their study comparing RPE and Damon bracket effects, stated that upper and lower inter-canine width increased significantly 2.9 mm and 1.3 mm respectively in RPE group, while there was no significant change in Damon group. The significant posterior expansion of upper and lower arch width was comparable in two groups in upper inter-bicuspid width and lower inter-molar width. The upper inter-molar width in RPE group was siginificantly higher. Both groups showed buccal tipping of bicuspids and molars, with more extend of bicuspid tipping in Damon group. The maxillary base width increased 2.1 mm in RPE group, which was significantly larger than that of 0.6 mm in Damon group. The upper and lower incisors in Damon group were tipped forward by 9.2 degrees and 7.5 degrees respectively, while the change in RPE group was not significant (p<0.05). They concluded that both RPE and Damon technique can successfully increase the arch width and correct moderate dental crowding with non-extraction approach. Damon appliance protrudes the upper and lower incisors and expands the dental arch by buccal tipping of bicuspids and molars.

The Damon appliance utilizes a broad Damon archform, typically producing significant expansion in the premolar and molar regions. Particularly in the upper arch the expansion can be up to 10 mm but more commonly 6 mm. Mikulencak (79) conducted a retrospective study to compare tipping produced by rapid maxillary expansion with the tipping produced by the Damon sytem appliance and found no difference in the amount of molar tipping associated with the increase in arch width

between the two methadologies. An inverse relationship was found between pre-treatment molar arch-width and change in molar angulation with the Damon system.

Tao et al (123) concluded that self-ligating system can successfully increase the arch width and correct moderate dental crowding with non-extraction approach by expanding the dental arch by buccal tipping of bicuspids and molars. During the correction of upper arch crowding with non-extraction Damon technique, they stated that arch perimeter is gained by the increase in both arch length and inter-bicuspid arch width, in addition to the labial movement of incisors.

A thesis study comparing difference in the expansion of inter-molar and inter-canine width with Damon2 brackets and conventionally ligated MBT brackets, found no difference between two brackets (47).

Birnie (19) stated that self-ligating brackets reduce need of extractions to facilitate orthodontic mechanics because alignment is not hindered by frictional resistance from ligatures. However, Tang et al (122) in a clinical study with Damon 3 and Damon MX brackets stated that Damon appliance can not rescue extraction cases. They concluded that straight soft tissue profile and upright incisor position are prerequisite for non-extraction treatment initially. And a harmonious chin and lip position is the key leading to the successful non-extraction treatment with Damon appliance.

Self-ligating brackets –due to their unique mechanism of ligation and design- are also promoted to require less chair time and less need of chair-side assistance because they are faster and easier for archwire removal and ligation (130). Self-ligating mechanism also provide consistent archwire engagement and elimination of need for frequent visits for the replacement of ligatures.

Turnbull and Birnie (130) assesed the relative speed of archwire changes, comparing the Damon2 self-ligating brackets with conventional elastomeric ligation methods. They found that Damon2 brackets had a significantly shorter mean archwire ligation time for both placing and removing wires. This difference in ligation time became more marked for larger archwire sizes used in later stages of treatment.

Similarly, a study by Berger and Byloff (18) stated that self-ligating brackets are faster to tie and untie, saving up to 2-3 minutes compared with modules and 6 or 7 minutes compared with stainless steel ligatures per arch. They found a mean ligation time with stainless steel ligature for maxillary arch as 280 seconds in one office and 328 seconds in the second one. For the mandibular arch the times measured was 292 seconds and 355 seconds respectively. For Damon1 bracket 26 seconds and 28 seconds were recorded in upper and 27 seconds and 28 seconds in lower arches.

The study by Shivapuja and Berger (113) also displayed a significantly less chair time for arch wire removal and insertion.

An article by Maijer and Smith (75) demonstrated a four-fold reduction in ligation time compared with wire ligation of conventional brackets.

In particular, the use of self-ligating appliance systems results in a dramatic improvement in chair-side efficiency when compared to insertion of archwires using stainless-stell wires. This saving of time can be used to schedule more patients, increase efficiency, improve patient relationships or allow oral hygiene reinforcement (75).

But, a clinical study including 25 consecutive cases in treatment for more than 1 year with Damon SL brackets reported 31 broken and 11 inadvertently opened slides between visits. This compared with 15 broken and lost elastomeric ligatures in 25 consecutively treated cases with conventional brackets, so the difference in ligation fragility was not enormous (50).

And from the patient's perspective, due to lack of additional ligation, they are generally smoother and more comfortable (113).

Removal cutting of the stainless stell ligature can lead to one loose end propelling either into or out of the oral cavity and creates risks for the patient. The loosened end impinching into soft tissues create an emergency for the patient to visit the clinic. This risk of emergency is not present with self-ligating brackets as a ligation is not involved (3).

Percutenous injury to the index finger or thumb during arch wire changes is reported to account for 57, 9 % of all clinical injuries sustained by the orthodontists. Self-ligation reduces the risk of such injuries and potential transmission of contagious problems like HIV, HBV or HCV (10).

Also Shivapuja and Berger (113) stated improved infection control, when compared with polyurethane elastomeric and stainless steel tie wire ligation for ceramic and metal twin brackets.

Self-ligating brackets were promoted to be easier to clean due to lack of an additional ligation (13). However, Pandis et al (90) followed self-ligating and conventional bracket cases for 18 months for plaque index, gingival index, calculus index, and probing depth. No difference was found in the indices recorded between the two bracket studied. They concluded that the self-ligating brackets do not have an advantage over conventional brackets with respect to the periodontal status of the mandibular anterior teeth.

A recent in-vitro report, comparing the microbial adhesion on different self-ligated and conventional bracket types, used premolar brackets of each system and determined the colony-forming units after incubating brackets in brain heart infusion medium containing saliva and bacteria of two orthodontic patients for 72 hours. The concluded that Damon, Clarity and Mystique had high adhesion; Speed had intermediate adhesion and other conventional brackets had the lowest adhesion (134).

The self-ligating and conventional brackets were also compared in the manner of patient acceptance and pain. A split mouth design clinical study by Miles et al (82) stated that patients preferred the look of conventional bracket design over the Damon2 when silver modules are used and they reported no significant difference in comfort to lips. The Damon2 brackets were initailly less painfull than the conventional twin bracket with first archwire but more painfull when tying the second archwire.

Fleming et al (39) investigated difference in pain experience with Smart Clip and conventional bracket and in contrast to Miles et al (82), concluded that the

overall pain experience at each time interval is independent of bracket type. Similar to previous study they agreed self-ligating brackets to enhance pain with rectangular archwires. The aggrevated pain with rectangular archwires in the previous study was stated to be related with greater irregularity index at the time of rectangular archwire placement although it was not the case with former study because it was not a split mouth design.

The study by Scott et al (113) found no evidence to suggest that Damon3 self-ligating brackets are associated with less discomfort than conventional pre-adjusted brackets during initial tooth alignment, regardless of age or gender.

The introduction self-ligating brackets provoked the investigation of archwire ligation on external apical root resorption. One of the first reports on the subject was by Blake et al (21) who tested the hypothesis that an active self-ligating bracket with an active clip might induce external apical root resorption; however their findings did not confirm this hypothesis.

A thesis study in 2002 evaluated the amount of root resorption with the Damon2 brackets and compare with the root resorption induced with mini-twin brackets. They stated that there was no serios damage to the root apices was observed on the teeth even though the treatment was completed 10 months earlier with the self-ligating system (46).

Later in 2008, Pandis et al (86) studied the same subject with passive self-ligating brackets. They included only maxillary incisors and stated that no difference was evident between conventional and self-ligating brackets for apical root resorption.

Pandis et al (89) compared torque delivery capacity of self-ligating Damon2 brackets and conventional brackets in extraction and non-extraction cases. They compared angular measurements of the Sella-Nasion and Nasion-A point to maxillary incisor axis. The study revealed no difference in the mean difference of the two angles measured for the two bracket groups studied. They concluded that self-ligating brackets seem to be equally efficient in delivering torque to maxillary incisors relative to conventional brackets in extraction and non-extraction cases.

A laboratory set up, using the Orthodontic Measurement and Simulation System (OMSS) tested the levelling effectiveness of nine self-ligating brackets (Quick – in active and passive variants-, Time, In-Ovation, Damon2, Damon 3MX, Opal-M and Opal-2, Speed). The study included one conventional bracket for reference purposes. The study revealed no significant difference in terms of their levelling effectiveness and torque expression (36).

The active self-ligating brackets have a better torque control due to active clip forcing the wire into the bracket slot. It was stated that they express higher torque values than the passive self-ligating brackets at clinically usable torsion angles (0-5) and the clinically applicable range of torque activation is greater for active self-ligating brackets (9).

On the contrary a recent report comparing the torquing moments of brackets included a passive self-ligating bracket –Damon–, active self-ligating bracket –Speed– and conventional bracket tied with elastomer and stainless steel ligatures. They concluded that the Damon bracket is comparable to conventional brackets tied with either ways. Besides, Speed –the active self-ligating bracket- represented the lowest torquing moments (56).

The principal problems encountered with self-ligating brackets were:

● Difficulties in either achieving complete rotational corrections or maintaining them once corrected,

● Inadequate torque control,

● Lessened levels of hygiene due to bracket size and profile (133),

● Higher bracket failure (82),

● Not being amenable to recycling (26),

● Cost,

● Being more problematic clinical managament due to frequent failure of the clips (43).

Miles et al (82) reported five times greater failure rate by Damon2 brackets over conventional twin brackets. A higher failure rate results in extra visits for the patient and additional chair time required for repairs.

The most significant drawback in the study by Harradine and Birnie (53) is the bond failure rate for Activa brackets which is currently higher than with conventional brackets from the same manufacturer.

On the contrary Pandis et al (87) stated no difference in failure rate between self-ligating Damon2 and edgewise brackets. Yu and Qian (142) also found no significant difference between ligating loss rate of self-ligating bracket and conventional bracket.

4.2. Friction in Orthodontics

Friction is defined as 'the resisting force tangential to the common boundries between two bodies when, under the action of an external force, one body moves or tends to move relative to the surface of the other' (100). The classical equation is that the frictional force depends only on the friction coefficient and normal force: $F = pN$, where p=coefficient of friction and N=force applied. The coefficient of friction has a value that is between zero and one. Its magnitude is dependent mainly on the nature of the materials in contact.

Sliding a tooth along an archwire is a very common orthodontic procedure to translate a tooth, especially during closure of spaces in the dental arch. Sliding mechanics involve a relative displacement of wire through bracket slots. So whenever sliding occurs, a frictional type force is encountered (101). It is a function of the dynamic relationship among arcwires, brackets and ligation in the oral environment. During sliding mechanics, the biological tissues respond and tooth movement occurs only when optimal forces applied exceed the friction on the bracket-wire interface.

Resistance to sliding in the preadjusted edgewise system is a combination of classical friction, arcwire-bracket binding and archwire notching (68).

Problems of loss of applied force due to friction during sliding mechanics have been recognized for a long time. When friction prevents the tooth from moving, friction can reduce the available force by almost 40%, resulting in anchorage loss (135). If frictional forces are high, the efficiency of the system is affected and the treatment time may be extended or the outcome may be compromised because of little or no tooth movement and/or loss of anchorage (33, 61). Applying high levels of force to overcome high frictional forces can result in the the loss of bracket bonding, associated with either little or no dental movement.

Reduction of friction can mainly be achieved either by decreasing the friction coefficient of the bracket or wire materials or by decresing the force of ligation acting on the wire (101).

4.2.1. Types of friction

The resistance of friction is characterized by static and kinetic types of force. Static friction is the force required to produce the initial movement and is always stronger than the kinetic (dynamic) force, which keeps the body in motion The coefficient of static friction is always larger than kinetic friction (132).

The theoretic considerations and clinical implications of friction during sliding mechanotherapy have been thoroughly evaluated. Tooth movement associated with sliding mechanics is a series of steps involving tooth tipping and uprighting rather than a smooth, continous process (33). So overcoming the static force between the bracket and the wire is a prerequisite for tooth movement.

4.2.2. Factors related with friction

Friction in orthodontics is multifactorial. The orthodontic literature demonstrates numerous variables that affect the levels of friction between the bracket and arch wire. Resistance during tooth movement may be due to physical or biological parameters. Biological considerations are saliva, plaque and corrosion. Physical parameters include factors like design and type of the bracket, wire size and morphology, bracket-wire clearance, torque and types of motion at the bracket-wire

interface, inter bracket width, the ligation technique, force applied, second order angulations and sliding velocity (25).

A. Biological Factors

1. Saliva

The presence of saliva had an incostent effect on the static frictional resistance, in some cases with saliva functioning as lubricant and at other times acting to increase friction. Investigators evaluating stainless steel brackets suggested that friciton might increase, decrease or not change when tested in saliva.

Stannard et al (116) compared frictional resistance when using artificial saliva and in the dry state. In this study artificial saliva was found to increase the static coefficient of friction for stainless steel, beta titanium and nickel titanium sliding against stainless steel. Shivapuja and Berger (113) also agreed that artificial saliva substitute produce higher frictional resistance.

Saunders and Kusy (109) evaluated the difference between the dry and wet states using real saliva. They reported that friction was reduced in the presence of saliva for ceramic brackets against wires of titanium alloys, but not for stainless steel or cobalt-chromium.

Similar results were observed with zirconia brackets coupled with TMA wires. It was suggested that saliva increased the adhesiveness of stainless steel and cobalt-chromium wires by breaking down their oxide layers (corrosion), while it provided a lubricant film for nickel titanium and TMA archwire (70).

Human saliva also appeared to increase the friction of elastomeric and stainless steel ligatures while it decreased the friction of Teflon-coated stainless steel ligatures (127).

However, Andreasen and Quevedo (4) found that saliva was not a significant factor in lubricating the surfaces of the archwire and bracket. Ireland et al (57) tested frictional resistance in the dry and wet states by pouring water over brackets that were moved at a fixed angulation to the archwires. And he stated that saliva plays an

insignificant role in frictional resistance because point contacts between archwire and a sliding bracket will produce enough force to expel any saliva present at their interface.

2. Vibration

Vibration and perturbation of the bracket wire system through the occlusal contacts during mastication, deglutition, speech and other functions can cause repeated, random, intermittent, minute relative movements at the bracket archwire interface, significantly reducing, if not completely eliminating frictional resistance.

Braun et al (22) conducted an in vitro study in which they attempted to emulate the dynamic environment of the oral cavity by applying random perturbations in three planes of space during friction testing. The results showed that frictional resistance was effectively reduced with each perturbation.

The validity of laboratory friction studies conducted in the steady state has also been questioned. For example, comparision of clinical and laboratory measurements has shown that less force was needed when test jigs were used to measure resistance to tooth movement intraorally than in laboratory. It was suggested that this was due to the effect of occlusal forces on tooth movement in the mouth. This view is supported by the observation that simulated occlusal forces can temporarily abolish friction for some bracket/archwire combinations (74, 22).

A study by Iwasaki et al (59) demonstrated that intra oral vibration decreased the apparent coefficient of static friction. When ligation forces were introduced, it was determined that intra oral vibration did not demonstrate a decrease in intra oral friction.

3. Corrosion

When stainless steel interacts with oxygen, a passivated layer consisting of chromium oxide and chromium hydroxide is produced on the surface of the metal. This protective layer provides the corrosion resistance of stainless steel. When the integrity of this layer is undermined or broken down, metal ions from the stainless steel are released and corrosion occurs (92).

Various types of corrosion have been implicated: crevice corrosion, pitting corrosion due to halide ions galvanic corrosion and inter granular corrosion due to excessive heating. Crevice corrosion has been the suggested mechanism for the corrosion of orthodontic brackets. An acidic chloride environment which is reducing in nature diminishes the stability of the stainless steel oxide film and consequently facilitates corrosion. The oral cavity may therefore potentiate corrosion due to factors such as temperature, the pH of plaque, the chloride in saliva, the physical and chemical properties of nutrition and general oral health (78).

B. Physical Factors

1- Factors related to bracket

Material and Manufacturing Process

The two main categories of brackets are metal brackets and esthetic brackets. Metal brackets are currently manufactured from stainless steel, chromium-cobalt and titanium. Stainless steel brackets are usually produced from type 300 stainless steels and can be further distinguished as either sintered or cast according to their manufacturing process. The esthetic brackets can be subdivided into alumina ceramic brackets, zirconium oxide (zirconia), ceramic brackets and ceramic-reinforced composite brackets. The alumina brackets are further distinguished by their crystalline structure as either polycrystalline or monocrystalline as well as by their manufacturing process as either sintered or injection molded. Some of the composite and ceramic brackets also have metal slots.

Ceramic brackets have higher coefficients of friction (67) and greater frictional resistances (14). Stainless steel brackets have been shown by numerous investigators to have lower frictional forces than ceramic brackets (62, 14). The suggestion is that metal brackets have smoother surfaces compared to ceramic brackets (67).

Under scanning electron microscopy, ceramic brackets display a crystalline structure containing many pores while stainless steel brackets slots are smoother with fewer irregularities. This rougher surface finish of the ceramic bracket slots has been implicated as the reason for the higher frictional force (32).

Keith et al (62) using a full dimension wire with straight-line traction, observed ceramic brackets to cause an abrasive wear of the archwire. Kusy and Whitley (68) suggested that the behavior of ceramic brackets might be because of their intrinsic chemical structure rather than the roughness.

To improve the sliding perfomance of ceramic brackets, metal inserts have been placed in the slots to reduce friction. Loftus et al (73) found that Clarity (Unitek Corp., Monrovia, CA) ceramic brackets with a metal slot insert have the same results as well as conventional stainless steel brackets in friction tests.

Plastic brackets have shown higher frictional resistances than stainless steel brackets (105, 132); however Riley et al (105) suggested this resulted from deformation of the plastic brackets due to tightening of the steel ligatures that lead to compression of the slot and binding of the wire. Recently introduced composite brackets with and without metal slots faired better in friction studies.

The manufacturing process of brackets result in some variation in sizes and characteristics, including dimensional accuracy and torque prescription consistency. Various bracket manufacturing processes such as injection molding, casting, and milling can affect the accuracy of the prescribed torque values and this has been reported to be 5% to 10% (48).

Discrepancies in the manufacture of slot size was reported to be 5% to 17% more than the actual size. Recent investigations found that sintered stainless steel brackets reduced friction by as much as 40 to 45% relative to cast stainless steel bracket. This was attributed to the sintering process resulting in smooth, rounded corners, whereas cast brackets had sharper edges resulting from the milling or cutting process (24).

Bracket Design and Slot Size

The design of the bracket and size of slot also effect the friction at the archwire-bracket combination.

Ogata et al (84) found that bracket designs, which restricted the amount of force placed on the wire by the ligature, generated lower frictional forces. An example is

the Synergy bracket (RMO, Denver, CO) that has six tie-wings for variable ligation. Ligation of only the center wings limits the force of the ligature on the wire. Therefore, the normal force can be markedly reduced.

Kuroe et al (65) claimed that the design of Friction Free brackets (American Orthodontics, Sheboygan,WI) prevented ligature wires or elastomers from exerting their force on the arch wire. These Friction Free brackets were found to have considerably less frictional resistance during straight line traction than conventional edgewise stainless steel brackets.

Most investigators have found slot size to have no influence on frictional resistance (66, 128).

A number of studies (38, 96) attempted to evaluate frictional characteristics of brackets and archwires utilizing experimental designs that did not permit a change in bracket-to-wire angulation during movement. They generaly agreed that wider brackets produce greater friction than narrow brackets. Kapila et al (61) suggested that the greater friction observed with wider brackets at non-binding angulations may be due to higher forces of ligation that were generated as a result of the need for greater stretching of the elastomeric liagtures on the wider brackets.

However, studies by Andreas and Quevedo (4) and Rock and Wilson (107) suggested that frictional resistance decreased as slot size increases from 0.018 inch to 0.022 inch due to reduced binding probably from increased wire stiffness.

Wider brackets have been reported to produce less friction than narrow brackets by allowing less angulation change of the archwire, and hence less binding It was reported that greater tipping occurs with narrower brackets, thus leading to a more acute angle of interface between the bracket and the archwire (33, 114). It was concluded that friction is proportional to applied force and inversely proportional to bracket width by allowing an angulation change between bracket and archwire (33, 128). More recently, Bednar et al (14) and Yamagutchi et al (141) reported that when retraction force was applied at the level of bracket, it produced significantly higher frictional for narrow brackets than for wider brackets.

There are conflicting results as to the effcet of interbracket distance on frictional resistance. Studies that do not product changes in the second order angulation of the bracket relative to the arch wire typically demonstrate that bracket width and inter bracket distance have an insignificant effect on frictional resistance compared to variables as ligation force and arch wire or bracket surface characteristics (4). The main concern is when the angulation of the archwire reaches the binding angle, the inter bracket distance becomes more important at the point of friction.

2. Factors related to archwire

Material

Archwire material has a great influence on frictional resistance during sliding mechanics. Its contribution can be subdivided into the effect of the archwire surface characteristics and that of archwire stiffness. These properties are interdependent to a degree and are difficult to distinguish.

In the fields of orthodonthics, arch wire materials can be classified mainly as below:

1. Stainless Steel Arch Wires

2. Chromium-Cobalt Alloy Archwire

3. Nickel Titanium Archwires

4. Beta-Titanium Wires.

5. Fiberoptic and Plastic Wires

6. Composite Wires

Kusy and Whitley (69) stated that classical friction is the dominant factor controlling frictional resistance during sliding mechanics below a critical bracket arch wire contact angle. Once the critical contact angle is exceeded, binding and notching become the dominant variables determining frictional resistance. Thus, studies whose designs are based on a straight line traction model are likely to differ significantly from those where tipping to the point of binding and notching occurs.

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The frictional coefficients of archwires of different alloys against stainless stell or polycryistalline alumina brackets has been shown to be (in decreasing order): beta titanium (the highest), nickel-titanium, cobalt-chromium and stainless steel (the lowest) (33, 71, 135).

Kusy et al (71) demonstrated that the order of surface roughness is lowest for stainless steel and highest for cobalt-chromium, beta- titanium and nickel-titanium. Caccifesta et al (2004) found that beta titanium archwires showing higher frictional resistance than that of the stainless steel wires and nickel titanium wires. He also found no statistical significance difference between stainless steel and nickel titanium archwires.

Stiffness is the resistance of the wire against bending. It has been demonstrated that friction and stiffness are inversely related due to the stronger atomic bonds within harder materials which increase the resistance to adhesion. This was confirmed with orthodontic materials. It was found that the softer titanium alloy archwires had more friction than the harder stainless steel and chromium cobalt archwire.

Articolo and Kusy (5) found that as the stiffness of the archwire increases, the frictional resistance is also increasing when the angulation between the archwire and the bracket increased. At a passive configuration, stainless steel wires showed the lowest friction while beta titanium wires showed the highest however in active configuration stainless steel wires showed the highest friction because of its high stiffness.

Cross-Sectional Shape and Size

It is accepted that as the size of the wire increases, the frictional force is also increased. Vaughan et al (135) found that when the size of the archwire increases, the frictional force also increase proportionally and that rectangular wires showing higher frictional forces than round wires.

Bednar et al (14) tested the significance of archwire size upon steel, ceramic and self-ligating brackets. All three types of brackets exhibited increased friction with increasing wire dimension.

Stronger frictional forces are developed when either wire size or bracket-wire angulation increase. At the 0 degree bracket-wire angulation (free of binding or notching) the frictional forces are almost unffected by the wire size (61).

Frank and Nikolai (38) also found that increasing the size of a wire resulted in increased frictional resistance at the bracket archwire interface. However, they found that the effect of cross-sectional shape is depended on the bracket angulation. At non-binding (passive) angulations, rectangular wires exhibited greater frictional resistance presumably due to larger contact areas generated between the slot and archwire compared to round wires. At binding angulations, however, stiffness and cross-sectional shape have different influences, making their effects difficult to quantify.

Round wires exhibit a point contact with the bracket, as opposed to the line contact exhibited with a rectangular wire/bracket combination. Thus, the smaller contact area generated with round wires result in a greater force because the normal force produced will be distributed over a smaller area than with rectangular archwires.

3. Type and Amount of Force Applied

The point of application of the retraction force on the bracket had a significant influence on frictional resistance. Studies showed that a more cervical point of application resulted in a decrease in friction. The higher friction associated with a more occlusally positioned force was a consequence of the increased binding between the bracket and archwire secondary to the larger moments created.

Kusy and Whitley (66) found that coefficients of friction might vary with extremes in velocity for certain archwire alloys. According to the results of their study, the coefficients of frictions for the stainless steel and nickel-titanium archwires were relatively constant. Interestingly, the same testing conditions showed

that coefficients of friction for cobalt-chromium wires increased, while those for beta-titanium wires decreased. This is contrary to the third law of friction that states that the coefficient of friction is independent of velocity. However, it has been recognized that this law is not usually followed.

Ireland et al (57) performed a pilot study varying the cross-head speed of the Instron Universal testing machine from 0.5 up to 50 mm/minute using stainless steel and nickel-titanium wires sliding in stainless steel and ceramic brackets. Results showed no significant differences in friction among the various speeds no matter what combination of brackets or archwires was used.

4. Ligation of Archwire to the Bracket

Ligation is thought to influence frictional resistance in two ways, by increasing the normal force applied by the ligature to the archwire and by introducing friciton between the archwire and the ligature material.

In the absence of binding between the archwire and bracket, the force of ligation was shown to have a dominant influence on the level of friction in orthodontic appliances. It was generally found that a positive linear relationship existed between the force of ligation and the friction at the bracket-archwire interface. The significance of ligation to frictional resistance depends on the force of ligation, ligation material and method of ligation.

Self-ligating brackets have also been thought as applying less ligation force and hence producing less friction than conventionally ligated brackets.

Thomas et al (125) stated that self-ligating bracket produced less friction than elastomerically-tied conventional edgewise brackets. These self-ligating brackets tested did not exert pressure on the arch wires**.**

Sims et al (115) also confirmed self-ligating brackets having less frictional resistance than conventionally tied brackets.

Cacciafesta et al (23) showed that the Damon II self-ligating brackets produced significantly lower static and kinetic frictional forces than both conventional stainless-steel and esthetic self-ligating brackets.

These investigations were done with static straight line traction that was not subjected to change in second order angulation.

A model designed to simulate first and second order corrections revealed that In-ovation R showed a 40% force reduction in the lingual direction when compared to conventional brackets (85).

One study used typodont models having different degrees of malocclusion to simulate low and high friction sceneraios. Self-ligating brackets outperformed conventional brackets when smaller archwires were engaged. But when larger arch-wires were engaged, the two bracket types were more comparable (55).

Another in-vitro study, investigating various active and passive self-ligating brackets and conventional brackets, revealed that Damon 3 brackets presented the least frictional force (11).

Read-Ward et al (100) investigated various self-ligating brackets compared to conventional brackets. Results suggested self-ligating brackets had lower frictional resistance in the passive configuration, but frictional resistance increased for the self-ligating brackets as second order angulation increased such that they were comparable to conventional brackets.

Sims et al (114) reported that increasing angulation had a more profound effect on self-ligating brackets than conventional brackets, but they still produced less friction.

Pizzoni et al (97) found self ligating brackets to have less friction at all angulations than conventional brackets. Also noted that passive self-ligating brackets exhibited significantly lower friction than active ones.

Bayrı (11), in his thesis study, also concluded that active self-ligating brackets presented higher frictional forces compared to passive brackets at non-aligned configuration. The frictional forces were more comparable at aligned configuration.

Shivapuja and Berger (113) found self-ligating brackets with both active and passive spring clips displayed significantly lower level of friction than conventional stainless steel and ceramic brackets.

Sims et al (115) noted that self-ligating brackets without an active spring clip had about fifteen times less frictional resistance than self-ligating brackets with an active spring clip .

Using a buccal segment model, Taylor and Ison (124) reported similar findings with passive self-ligating brackets. The brackets had significantly less frictional resistance than self-ligating brackets with an active spring-clip and conventionally tied brackets.

In contrast, Bednar et al (14) testing self-ligating brackets with an active spring clip and Loftus et al (73) testing self-ligating brackets with a passive spring clip found these bracket types performed no better than conventional stainless steel brackets ligated by either elastomers or steel ties in friction tests using an approximated center of resistance that permitted free second order tipping.

Another in-vitro study investigating frictional force differences between several types of brackets and wires in passive configuration, revealed that among conventionally ligated brackets ceramic ones produced the highest frictional force and Opal and Damon 3 passive esthetic brackets produced the lowest frictional forces for all combinations tested (129).

A recent report by Voudoris et al (137) compared frictional forces of interactive self-ligating brackets (ceramic and metal-slot or all-metal) and conventionally ligated brackets (ceramic or metal) using several archwires. They concluded that the self-ligating brackets exhibited the lowest frictional forces irrespective of the bracket material and the wire size. The self-ligating ceramic brackets produced the lowest

frictional force among the self-ligating group. Besides the conventionally ligated ceramic brackets produced the greatest friction.

4.3. Digital Models

Succesfull orthodontic treatment is based on comprehensive diagnosis and treatment planning. Orthodontic records include anamnesis, intra and extra oral photographs, radiographs and plaster casts of the patient.

Of these records, plaster casts are one of the most fundemantal tools. They have traditionally served for two main purposes in orthodontics: as a permanent, three-dimensional record of the malocclusion and as a source of information for diagnosis and treatment planning. Plaster casts are also required in some cases for assesment of treatment progress and outcome (102).

As a static record of dental classification, models are used to visualize the morphology and position of the teeth in their respective dental arches, as well as the degree to which the teeth are malpositioned. In addition, diagnostic set-ups of treatment options are accompolished by sectioned models (95).

Orthodontic models document initial conditions, treatment progress, and the final treatment result. Orthodontists also use these models to present their treatment results to collegues and patients for the purposes of education, evaluation and research (95).

Several features in particular have contributed to their usefullness: 1) production is routine and predictable; 2) they are relatively easy and inexpensive to produce; 3) they are easy to examine and measure; 4) they can be mounted to stimulate articulation; and 5) until recently, casts have been the only 3D medium available to accurately represent malocclusion (118).

Study models are a reliable and popular form of diagnostic record. Since they are a dimensionally accurate representation of the dentition, a number of measurements, analysis such as tooth size-arch length discrepancy and prediction of permanent tooth size can be obtained from plaster study models. However, model analysis is a time consuming procedure (144).

In addition, because of their physical nature, however, plaster casts have inherent shortcomings in terms of storage, retrieval, transferability and diagnosis (102).

Long-term storage is required for patient records. Models are usually kept in boxes to keep them from physical and chemical damage. This is the reason why they present a storage dilemma, due to their size and weight (118).

Communication is difficult when only one set of models exist. The orthodontist might have to duplicate a patient's models, a process that is both costly and and time consuming to communicate with other dentists and specialists. They require lobor-intensive cataloguing and retrieval. In most cases, casts are rarely consulted after their original diagnosis.

They can be lost or damaged and are troublesome to transfer. Continued use for measurements and display can wear away plaster, decreasing accuaracy and increasing the likelihood of fracture (95).

Today, many orthodontists are incorporating digital orthodontic records into their clinical practices and using computer software to assist with diagnosis and treatment planning as well as to alleviate storage constraints for records.

There are three basic requirements needed to utilize digital models. A personal computer with internet acces is the most basic requirement. Internet acces can be DSL, cable, or dial-up. It is important to note that DSL and cable internet access can provide a fast download time of the electronic information from the company that produces the digital models. A software program is needed that allows the electronic information to be retrieved and generates the images of the digital models. This software is usually provided free of charge by the company chosen to generate the digital models (76).

Digital model companies recommend that the alginate imppressions be sent to the company within a day sealed in a plastic bag or wrapped in humid towels (60, 108). Impressions and wax bites are shipped to chosen company for being converted into a virtual 3-dimensional computerized image. The image is the available to the

orthodontist for downloading from the company's web site within 5 days. Software from the imaging companies allows the orthodontist to wiev the image and manage it in a virtual 3D environment (117).

Currently, five companies worldwide are producing digital models commercially. Three of these companies are in the United States, one is in The Netherlands, and one is in Poland. These companies accept high-quality alginate impressions with 100 hours' dimensional stability and disposable impression trays (1).

Alcan et al (1) studied the possible dimensional distortions of alginate that might occur until the impression is shipped to company. In all, 21 stone models were poured and immediately were scanned, and 21 digital models were prepared. The remaining 84 impressions were poured after 1, 2, 3, and 4 days, respectively. Five linear measurements were made by three researchers on the master model, the stone models, and the digital models. They concluded that both the stone models and the digital models were highly correlated with the master model. Significant deformities in the alginate impressions were noted at different storage periods of 1 to 4 days. Storing alginate impressions in sealed plastic bags for up to 4 days caused statistically significant deformation of alginate impressions, but the magnitude of these deformations did not appear to be clinically relevant and had no adverse effect on digital modelling.

OrthoCad was the first company to introduce a digital model service to the orthodontic market in early 1999. OrthoCad is operated by Cadent Inc, located in Fairwiev, NJ.

Emodels (GeoDigm, Chanhassen, Minn) was founded in 1996 as Interactive Reflective Imaging System. It has changed its name and has grown considerably. Emodels became available to the profession at the American Association of Orthodontists National Meeting 2001.

Orthomodel was founded in 2008 in Turkiye. It utilizes 3D model scanner (3Shape D250; 3Shape A/S). The digital models are analyzed by 3Shape Orthoanalyzer Software (3Shape A/S).

Digital models are not subject to physical damage and do not create any mess. They also require negligable storage space. The digital information for each case can be stored on an office computer's hard-drive, on portable storage devices such as Cds or on a central server.

Retrieval is fast and efficient because the models are stored by patient's name and number. Another advantage is that it is possible to wiev digital models at multiple locations from any office computer linked to the practice's central server, allowing patients to be treated at multiple sites with easy access to their records. The electronic files in JPEG format contain all of the model information of numerous views of the models and can be transferred electronically. This decreases time and expense of model dublication and shipment (103).

Digital models are also an excellent tool for patient education. They can be shown to patients and their parents during treatment conferences, during treatment and and at the conclusion of treatment to illustrate the improvement in thier dentition. Ultimately, digital models improve communication between clinician and the patient, enhancing informed consent (95).

In summary adavantages of digital models can be summarised as follows: (1) efficiency of having patient records instantly accessible on the computer screen vs retrieving plaster models from a storage area; (2) saving money on the monthly cost of storage space needed for thousands of traditional plaster models an orthodontist accumulates on his or her carrier; (3) accuracy, efficiency and ease of measurements of tooth and arch sizes and dental crowding; (4) accurate and simple diagnostic setups of various extraction patterns; (5) the ability to send virtual images anywhere in the world for instant referral or consultation as needed or for internet study clubs; and (6) objective rather than subjective model grading analyses for American Board of Ortodontics certification (54).

The disadvantages of digital models include loss of data due to degradation of electronic storage media over time, dependance on the supplier for technical support of the software and the fact that digital models lack true 3-dimensional presentation (77).

If diagnosis, treatment golas and mechanics are to be made on digital models, they must be as accurate, if not more than, conventional models. A few studies have evaluated the accuracy of digital models.

Thomassetti et al (126) studied the accuracy and efficiency of doing Bolton's tooth size analysis using manual measurements with a vernier caliper and 3 computerized methods. Although they found no statistically significant differences among the tested methods, there were clinically siginificant differences for all methods.

A study by Garino and Garino (45) showed that there was a reduction in the dispersion of the variance around the means when using the OrthoCad software compared with a digital caliper on a stone model.

DeLong and coworkers (31), using the Virtual Dental Patient System, compared standart measurements from the actual object and from the stone model to the measurements obtained from a digitalized model. The results showed that the digital models were clinically acceptable.

Zilbermann et al (144) tested the accuracy of measuring tooth size and arch width on conventional plaster models and OrthoCad (Cadent Inc, Carlstadt, NJ) digital models and stated that both methods had clinically acceptable levels of accuracy and reproducibility.

Santoro et al (108) evaluated the accuracy of measuring tooth size, overbite, and overjet using OrthoCad models compared with plaster models. They reported a statistically significant difference for tooth size and overbite. While the digital model measurements were consistently smaller than the plaster model measurements, the magnitude of these differences were considered clinically insignificant. There was no difference in overjet between plaster and digital models.

Quimbly et al (99) used a plastic model occlusion as a gold standart to evaluate the errors associated with plaster and computer-based models of OrthoCad. They demonstrated that only measurements of maxillary and mandibular space available made on computer-based models differed from measurements made on the

dentoform. They concluded that computer-based models appear to be clinically acceptable alternative to conventional plaster models.

Costalos et al (27) evaluated the accuracy of digital model analysis for American Board of Orthodontics objective grading system for dental casts. They stated that the means of the total score were not significantly different. However, the means for alignment and bucco-lingual inclination were significantly different.

Another study comparing dental stones with OrthoCad digital models from the point of PAR index also confirmed that digital models are a valid alternative (77).

Rheude et al (106) evaluated treatment plannings of orthodontist for same patients fist by digital models (Geodigm Emodels) and then with dental stone models. The outcome was a change only in 6% treatment planning after presentation of stone models. They concluded that digital models could replace stone models for treatment plannings.

Stevens et al (117) studied emodels. They also confirmed that digital models are a clinically acceptable replacement for plaster casts for routine measurements made in most orthodontic practices. The study revealed no siginificant difference in PAR analysis and its constituent measurements clinically between plaster and emodel media. Thus they stated that digital models would not cause an orthodontist to make a misdiagnosis of malocclusion.

Mullen et al (83) also confirmed that emodel software for measuring a patient's dentition and calculating the Bolton ratio is just as accurate and faster than using digital calipers with plaster models and that diagnosis are confident.

The thesis study by Ateş (7) compared the mesurements of dimensional changes of maxilla and mandible after rapid maxillary expansion on plaster models, calibrated photographs and digital models to evaluate the validity of these systems. No siginificant difference between three methodologies was observed. He concluded that digital models can be an alternative method for plaster models.

A recent report compared the standart plaster models with their digital counterparts for the applicability of the Index of Complexity, Outcome and Need

(ICON). Two examiners, calibrated the in the ICON, scored the digital and plaster models of 30 patients' pre and post records. They concluded that ICON scores performed on computer based models to be as accurate and reliable as those in plaster models (136).

Under the highlighting of numerous literatures mentioned, digital models are a reliable way of planning and evaluating treatment protocols. In our study we aimed to evaluate the dental arch changes that occur in Class I non-extraction patients both with conventional and self-ligating brackets and compare them by digital models.

5. MATERIAL AND METHOD

5.1. Case Selection Criteria

30 patients with Class I malocclusion were selected among the patients seeking orthodontic treatment at Marmara University Department of Orthodontics. The patients received comprehensive orthodontic treatment in the study. Models, photographs, lateral and postero-anterior cephalometric x-rays were evaluated.

15 patients were selected as the study group and 15 patients were selected as the control group.

The research group was established according to following criteria:

- The subjects will have their permanent dentition completed with no missing teeth,

- Ages of the subjects will range between 10-24 years (Table 3.),

- Skeletally and dentally Class I malocclusion will be present,

- The crowding index will be between 9-12 mm,

- None of the subjects will have previous orthodontic treatment,

- All subjects will have normal growth and development pattern without any genetic or hormonal disorder.

Attention was paid to the fact that patients would not use any medicine which can interfere with orthodontic tooth movement. All the subjects and the families were given information about the project and Marmara University Health Sciences Ethical committee confirmation report was taken for the research.

All patients were educated for oral hygiene. Treatment was not started before optimum hgyiene was established and dental problems were solved. Brackets were directly placed from second molar to second molar in both arches.

7 patients were discluded out of groups during the course of treatment: 1 patient from each group moved to another city; 3 patients from control group had an intervation due to oral hgyiene problems and 1 patient from each group failed to follow appointment intervals.

Table 3: Age and sex distribution in study and control group.

		Study Group Average±SD	Control Group Average±SD	[+]p
Age (Year and month)		16,22±3,73	14,57±2,20	*0,229*
		n (%)	n (%)	[++]p
Sex	Female	10 (76,9 %)	7 (70,0 %)	*1,000*
	Male	3 (23,1 %)	3 (30,0 %)	

5.2. Treatment Procedure

The study group subjects received orthodontic treatment with 18-slot, Roth prescription Quick (Forestadent Bernhard Forester GmbH, Westliche, Pforzheim, Germany) self-ligating brackets. The control group received orthodontic treatment with 18-slot, Roth prescription MIB (MIB; France) brackets.

Treatment involved non-extraction protocol. 'BioStarter12' archwire (Forestadent Bernhard Forester GmbH, Westliche, Pforzheim, Germany) was the initial wire for both groups and wire sequence was 0.016 Ni-Ti, 0.16x0.22 Ni-Ti followed by 0.16x0.22 SS wires. 0.016 SS was also involved when needed.

No expansion appliances, no extra-oral appliance were coupled. Chain elastomers, intra-oral elastics, open (9 or 12 mm) and closed coil (short and long) springs was included in the study. Stripping protocol was accompolished according to Bolton analyses requirements, after levelling and aligning stage was over and rectangular wires were switched. Cinch-back was not performed until stainless-steel wires were used.

All teeth including second molars, if existed, were included in the arch. Stainless-steel ligature wire was used for ligation purposes in the control group.

Patients were examined at 6 weeks intervals. Loss of bracket or any failure with the wire necessiated extra appointments. Patients underwent treatment until Class I dental occlusion is reached and stablised (Picture 20-1,2,3,4; 21-1,2,3,4; 22-1,2,3,4; 23-1,2,3,4).

5.3. Patient Records

The recording sytem was same for both control and study groups. At the first appointment intraoral and extraoral photographs, upper and lower jaw impressions with wax bite, panoramic, lateral and postero-anterior cephalometric x-rays were taken for all patients before starting treatment. The impressions were repeated at the sessions when wire was switched from 0.012 BioStarter to 0.016 NiTi, then to 0.16x0.22 NiTi and to 0.16x0.22 SS. Intraoral photographs were taken at arch renewals. Records, including intraoral and extraoral photographs, upper and lower jaw impressions with wax bite, panoramic, lateral and postero-anterior cephalometric x-rays, were renewed at the finish of the treatment.
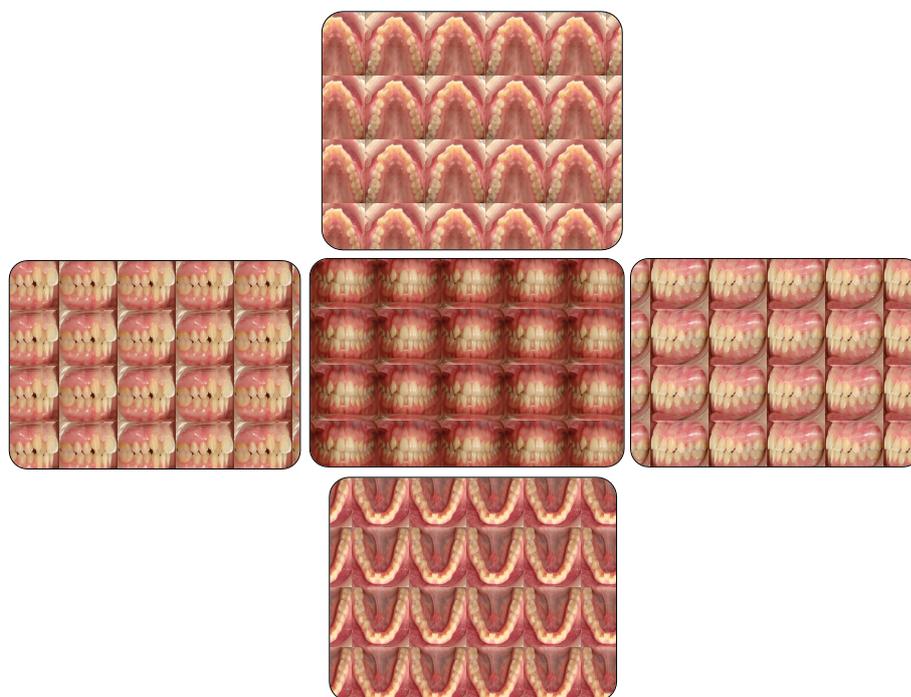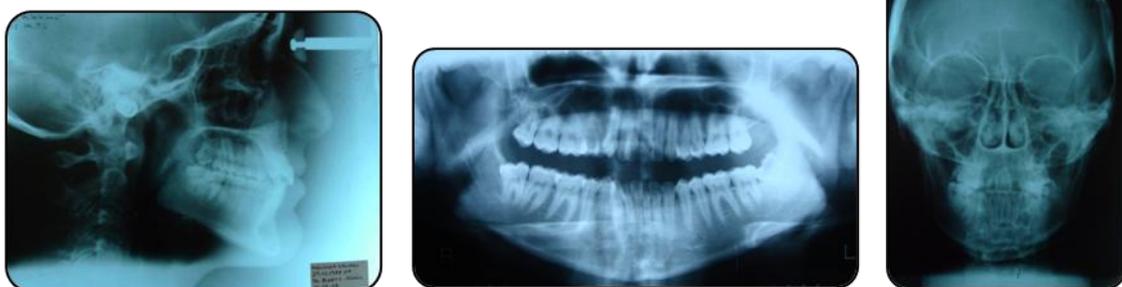
Picture 20-1: Initial records of a patient -Study group.
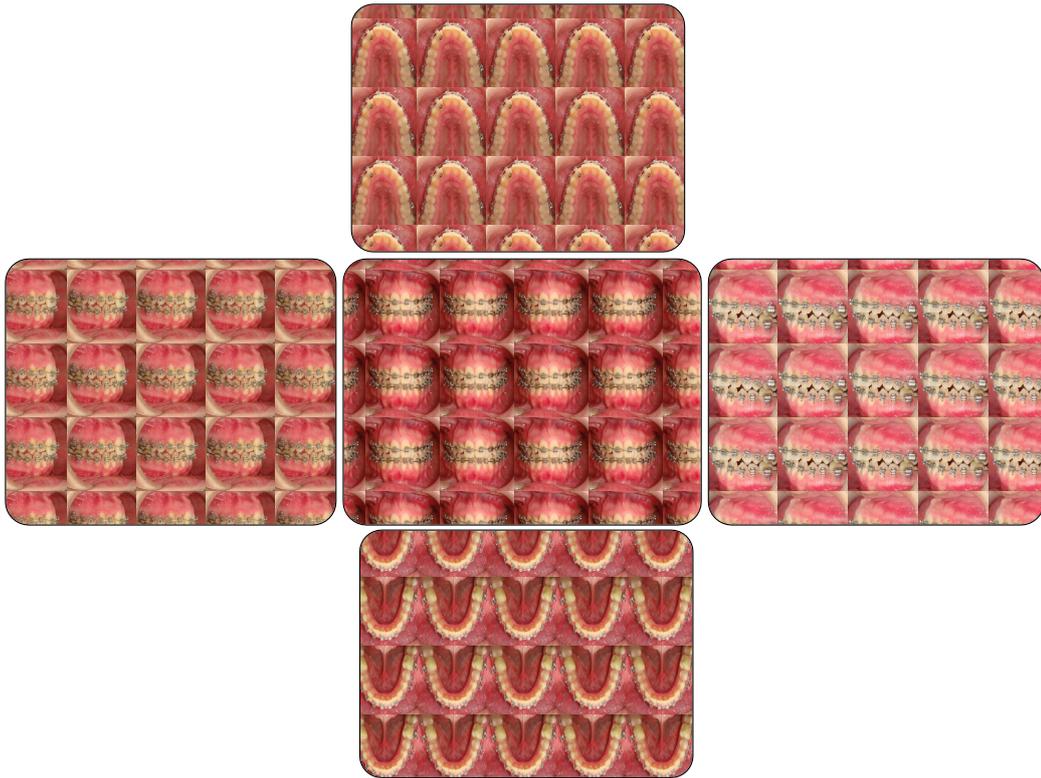
Picture 20-2: T1 time intraoral photographs (16-22 inch Ni-Ti) -Study group.
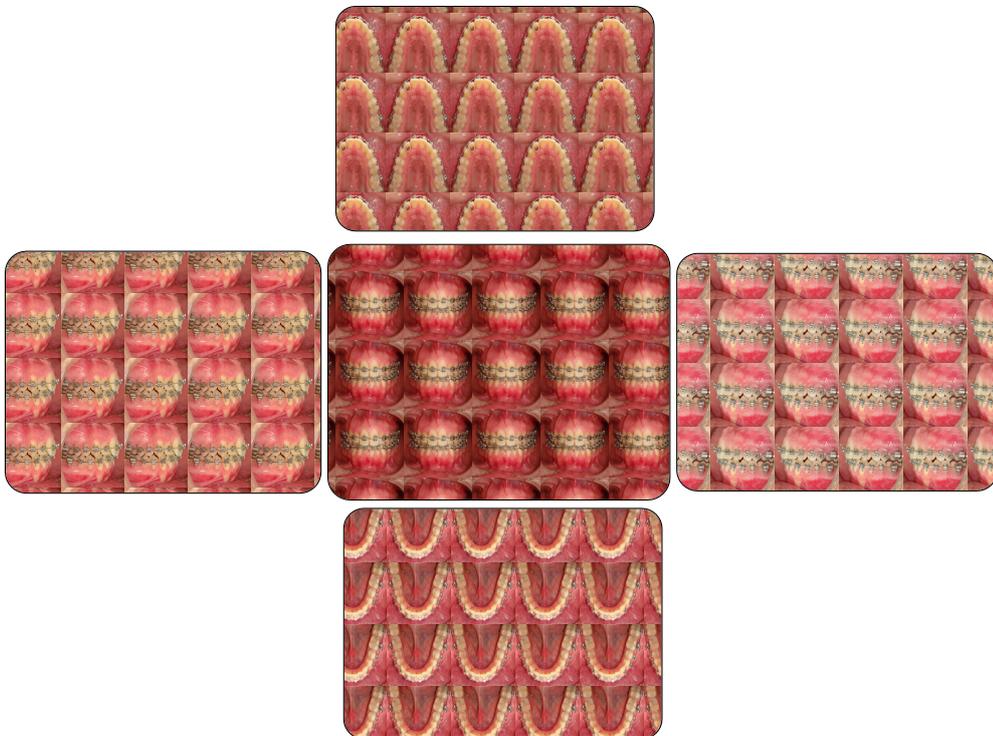
Picture 20-3: T2 time intraoral photographs (16-22 inch SS) -Study group.
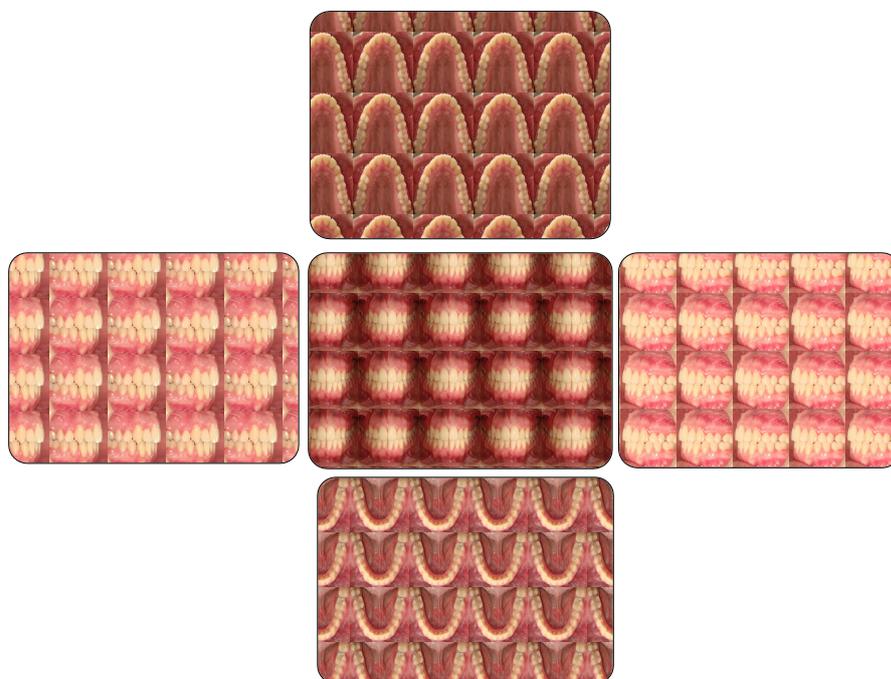
Picture 20-4: Post-treatment records -Study group.
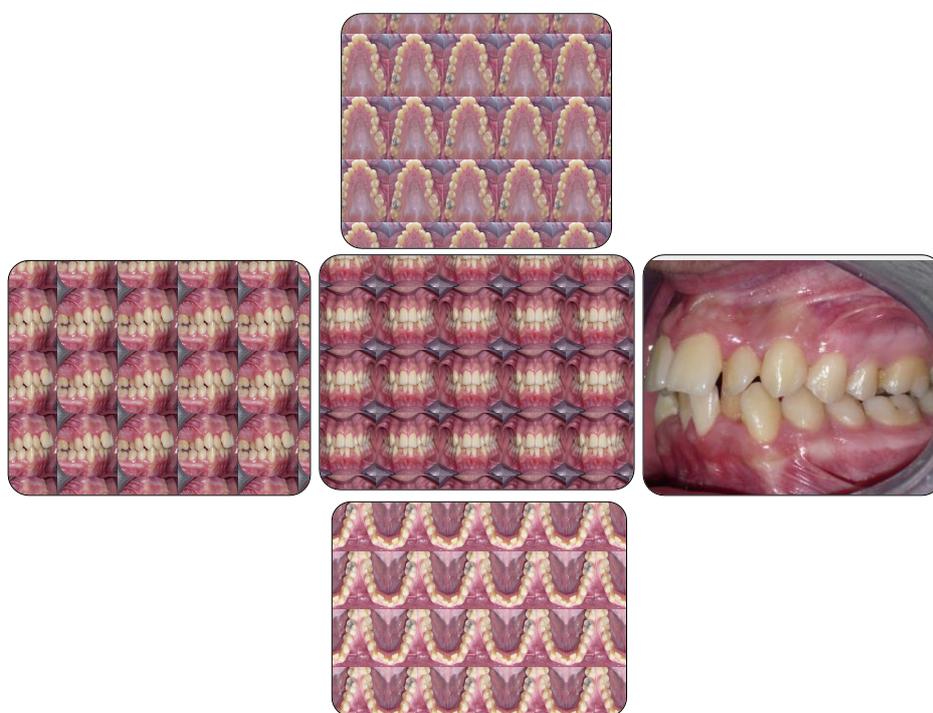
Picture 21-1: Initial records of a patient -Study group.
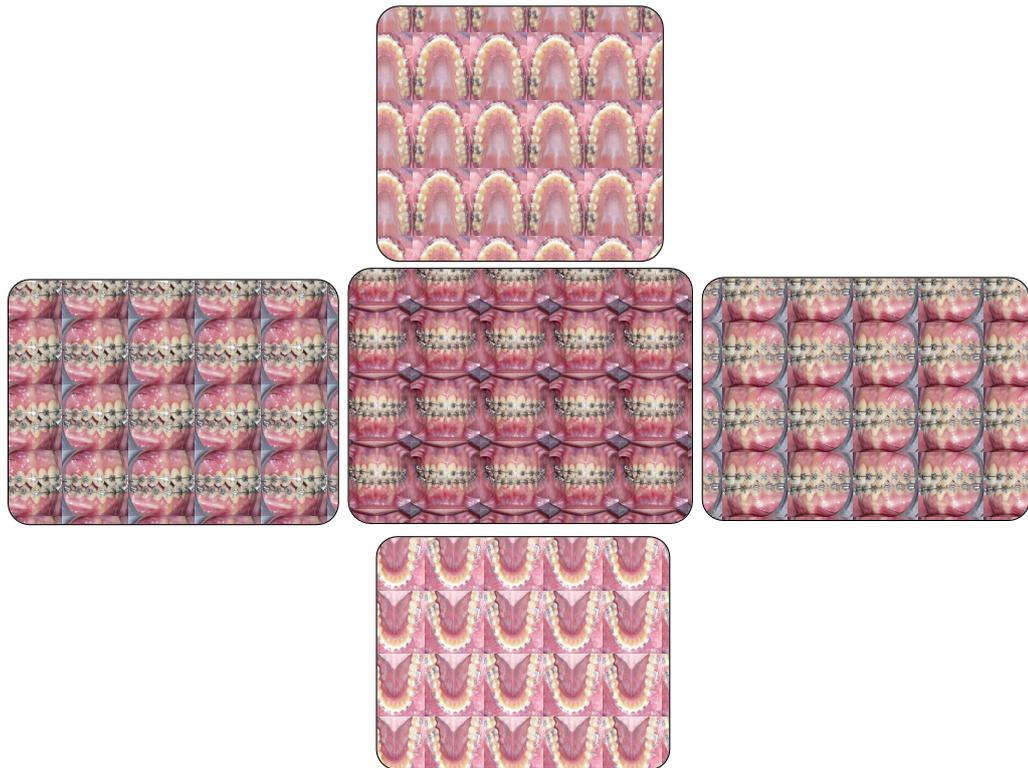
Picture 21-2: T1 time intraoral photographs (16-22 inch Ni-Ti) -Study group.
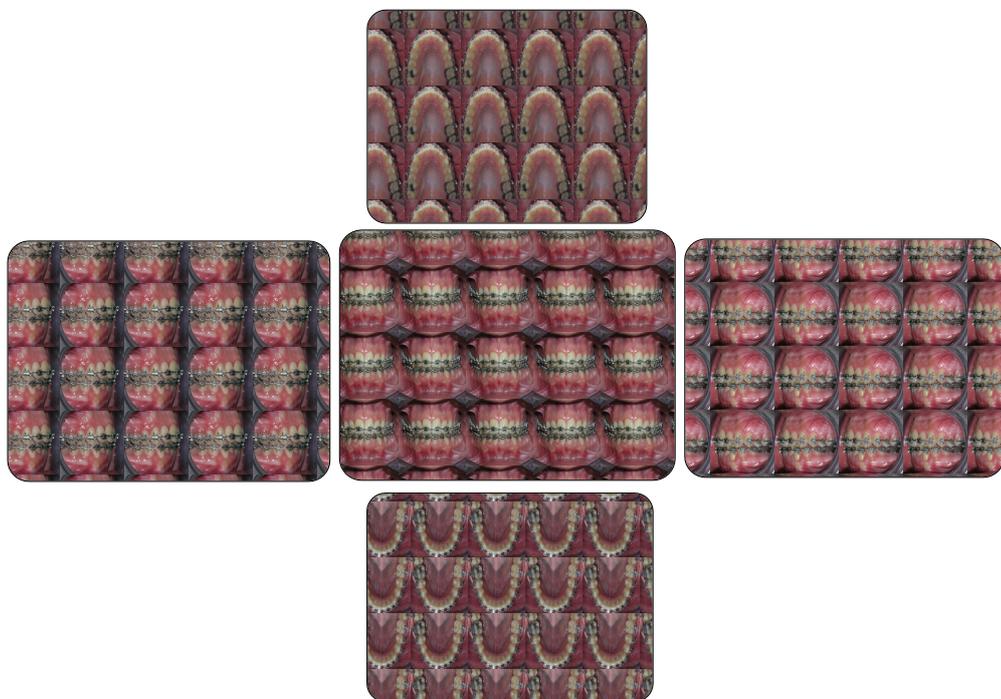
Picture 21-3: T2 time intraoral photographs (16-22 inch SS) -Study group.
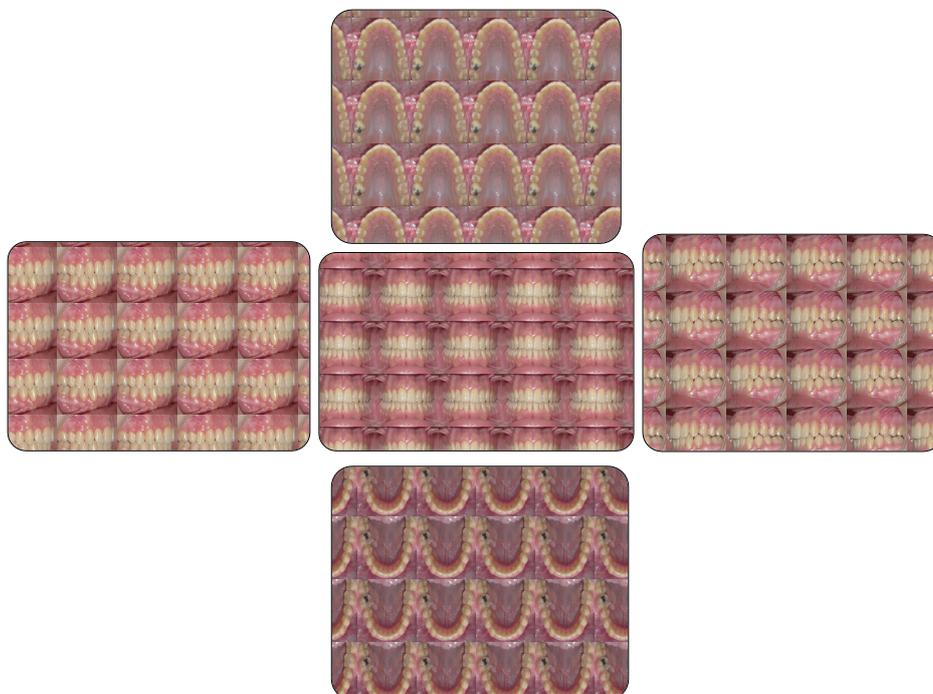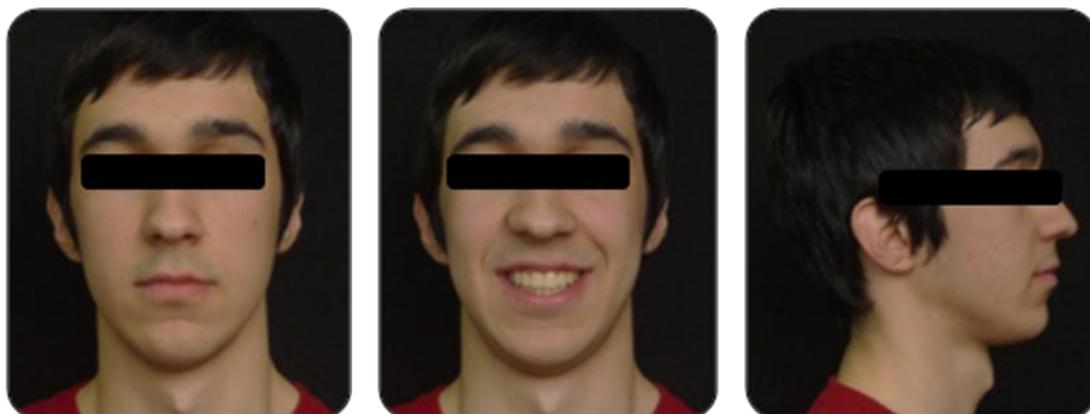
Picture 21-4: Post-treatment records -Study group.
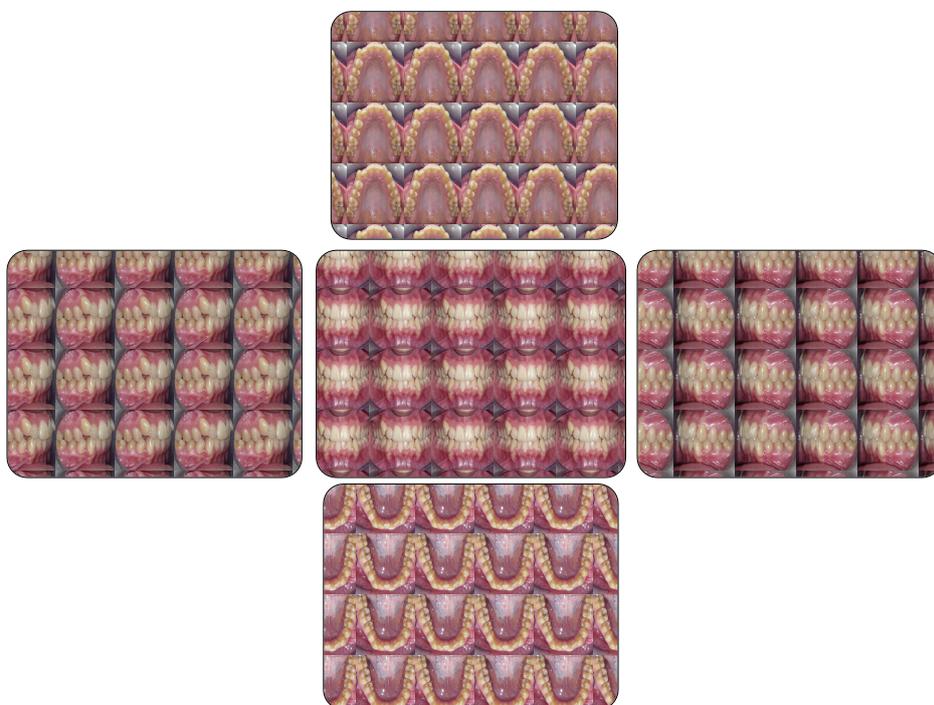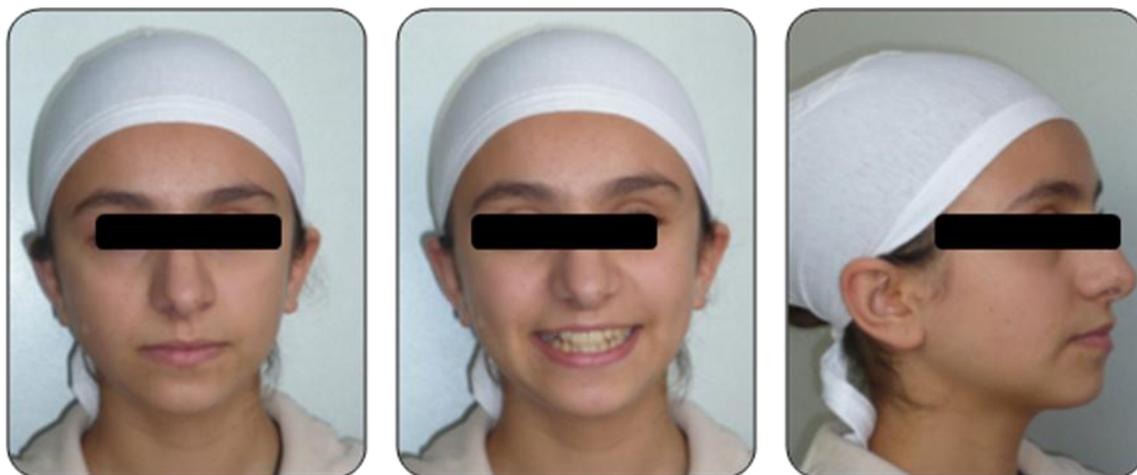
Picture 22-1: Initial records of a patient -Control group.
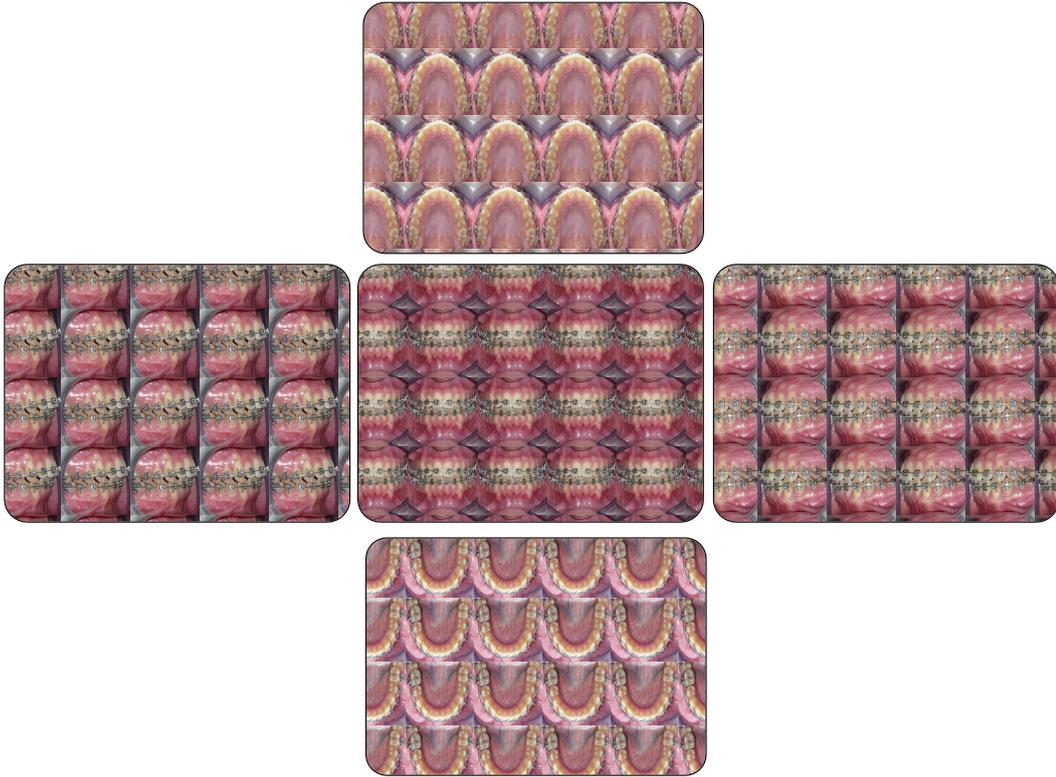
Picture 22-3: T2 time intraoral photographs (16-22 inch SS) -Control group.

Picture 22-2: T1 time intraoral photographs (16-22 inch Ni-Ti) -Control group.
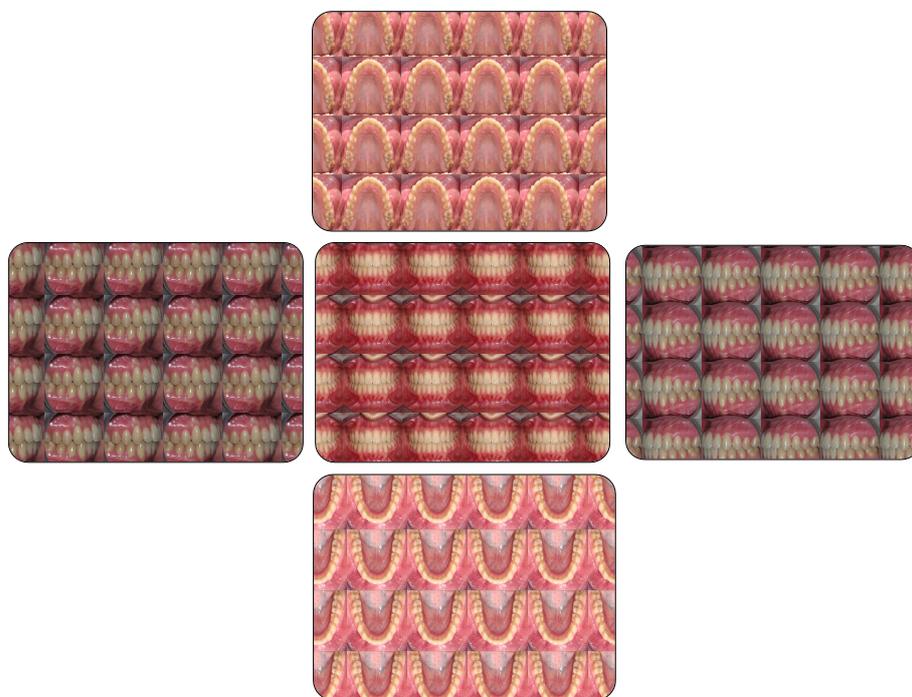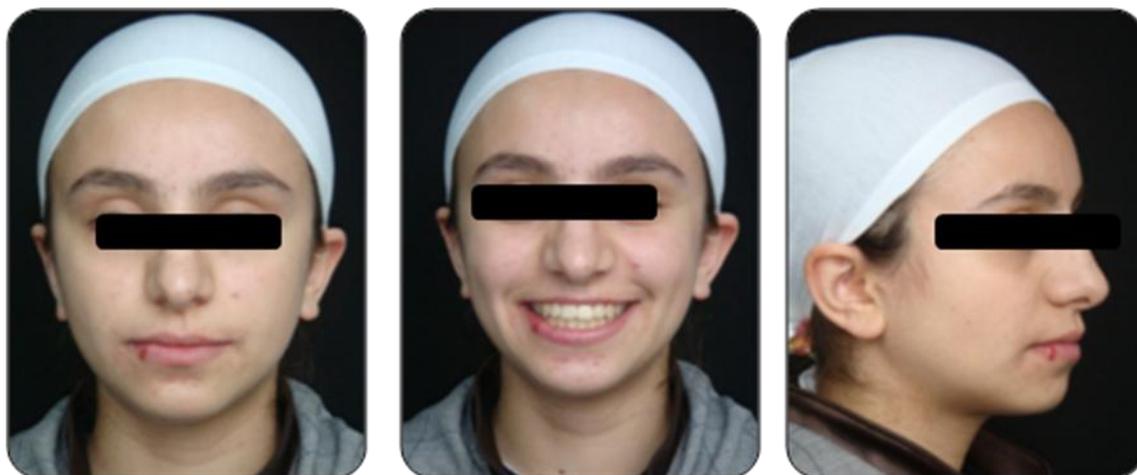
Picture 22-4: Post-treatment records -Control group
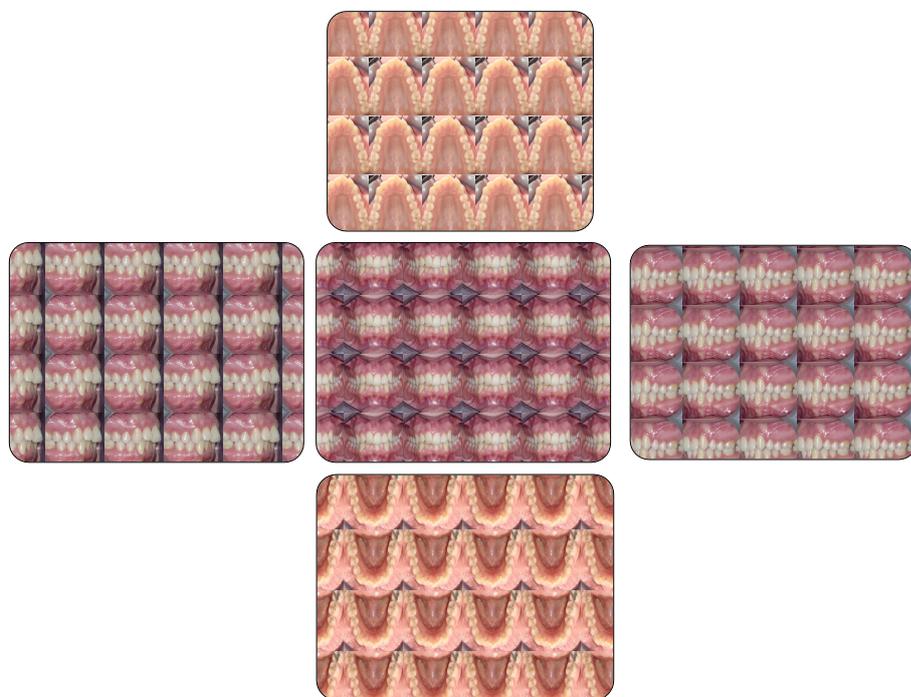
Picture 23-1: Initial records of a patient -Control group.
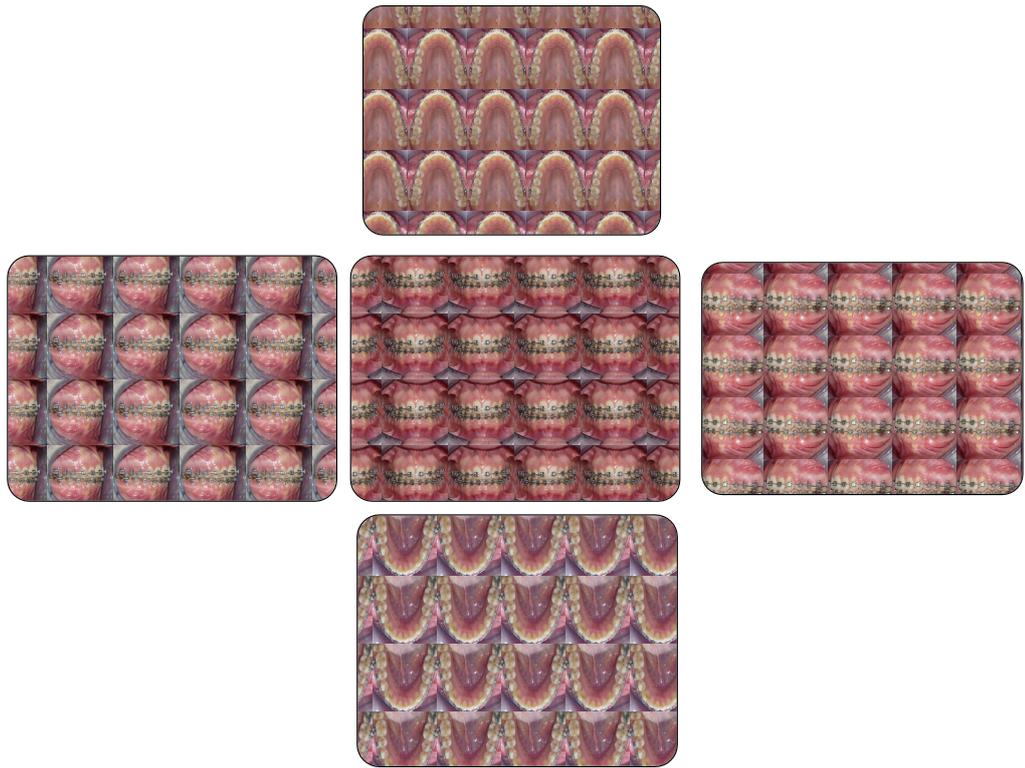
Picture 23-2: T1 time intraoral photographs (16-22 inch Ni-Ti) -Control group.
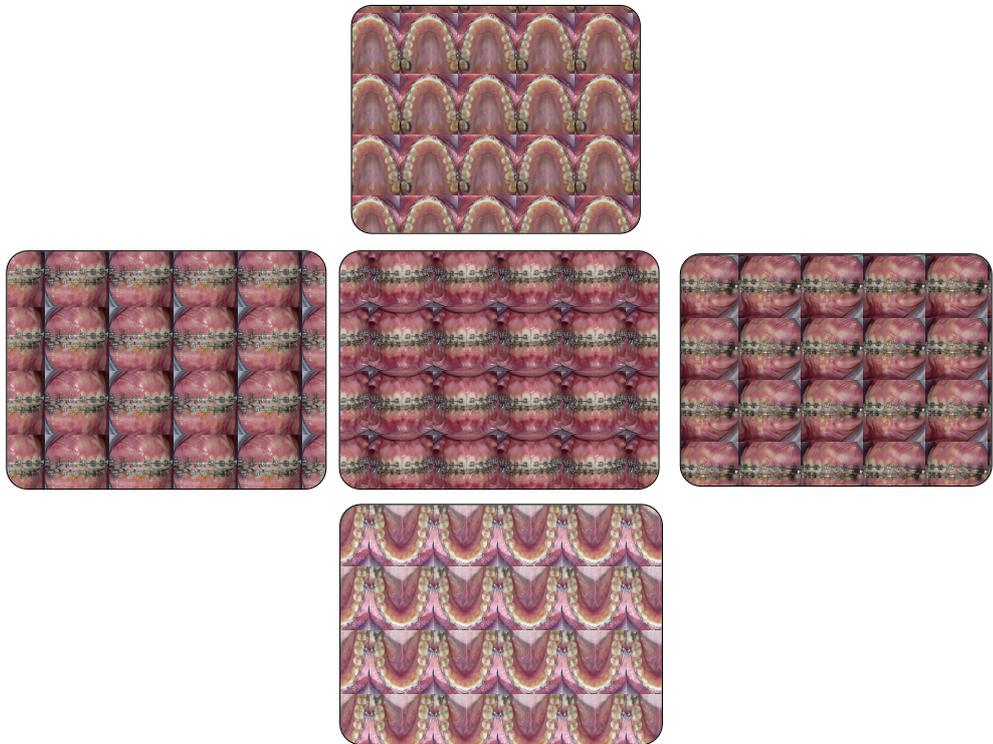
Picture 23-3: T2 time intraoral photographs (16-22 inch SS) -Control group.
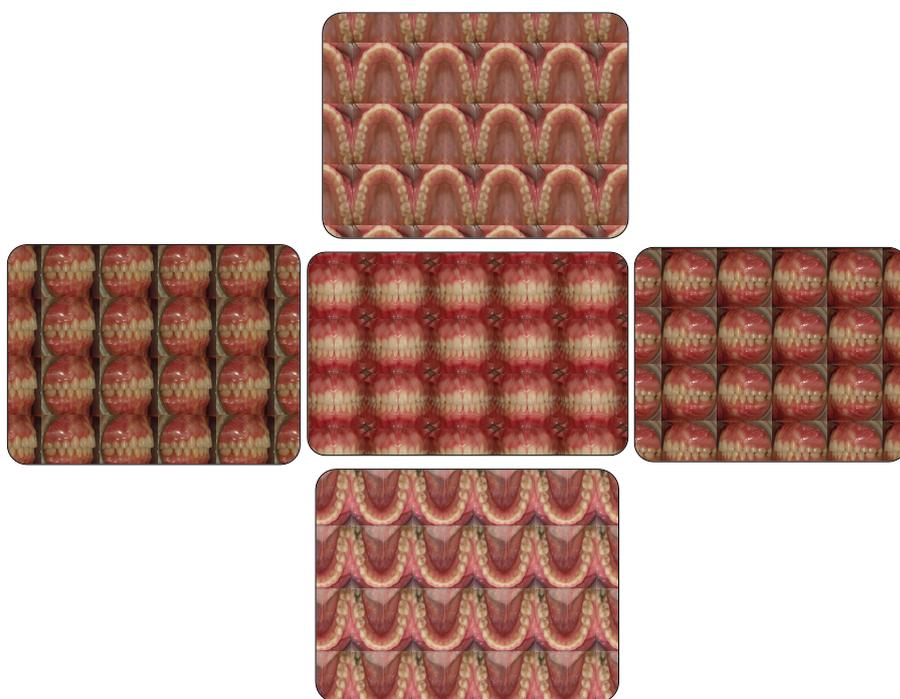
Picture 23-4: Post-treatment records -Control group.

5.4. Cephalometric Evaluation

All the cephalometric x-rays were taken by the same machine. The cephalometric evaluation form present in Marmara University Faculty of Dentistry Department of Orthodontics was used in order to evaluate cephalometric tracings. The cephalometric points, planes and angles are listed below.

5.4.1. Machines used in cephalometrics

Lateral and postero-anterior cephalometric x-rays were taken in Marmara University Faculty of Dentistry Oral Diagnosis and Radiology Department. Morita Veraviewapocs machine was used. The distance between the x-ray source and subjects' ortho-axial plane was 180 cm and the distance between the x-ray film and subjects' ortho-axial plane was 12 cm. The subjects were posed for 1,2 seconds for lateral cephalometric x-rays and 1,3 seconds for postero-anterior cephalometric x-rays.

In order to reduce the method error, x-rays were traced by the same observer and double images were centered while tracing.

5.4.2. Landmarks used in lateral cephalometric x-rays

1- (S): Sella; the centre of hypophyseal fossa (sella turcica).

2- (N): Nasion; the fronto-nasal suture at its most superior point on the curve at the bridge of the nose.

3- (A): A point; subspinale; the most posterior point of the curve between ANS and supradentale.

4- (B): B point; supramentale; the most posterior point of the bony curvature of the mandible below infradentale and above gonion.

5- (Me): Menton; the lowest point on the symphyseal outline of the chin.

6- (Go): Gonion; the most posterior inferior point at the angle of the mandible.

7- (NT): Soft tissue nasal tip.

8- (SPog): Soft tissue pogonion.

9- (UIT): Upper insicor tip; the incisal tip of the most anterior maxillary central incisor.

10- (LIT): Lower incisor tip; the incisal tip of the most anterior mandibular incisor.

11- (UIA): Upper incisor apex.

12- (LIA): Lower incisor apex.

13- (LS): Labiale superior; the most anterior point of soft tissue upper lip.

14- (LI): Labiale inferior; the most anterior point of soft tissue lower lip

(Figure 1.).

5.4.3. Planes used in lateral cephalometric x-ray

15- SN: Sella-Nasion plane; line passing through S and N points.

16- X axis: (CFH); constructed Franfurt horizontal plane; an artificial horizontal reference plane starting from S point, displaying 7 degree angle under SN plane.

17- Y axis: An artificial reference plane drawn perpendicular to X axis starting at S point .

18- NA line: Line passing through N and A points.

19- NB line: Line passing through N and B points.

20- MP: Mandibular plane; line passing through Go and Me points.

21- UI: Upper incisor axis; line passing through UIA and UIT.

22- LI: Lower incisor axis; line passing through LIA and LIT.

23- E Line: Line passing through soft tissue nasal tip and pogonion (Figure 2.).

5.4.4. Angular measurements used in lateral cephalometric x-rays

24- SNA: Antero-posterior position of maxilla to cranial base.

25- SNB: Antero-posterior position of mandible to cranial base.

26- ANB: Antero-posterior relationship between maxilla and mandible.

27- SN-MP: Cranial base to mandibular plane angle.

28- UI-SN: Angle of maxillary incisor to cranial base.

29- IMPA: Angle of mandibular incisor to mandibular plane.

30- NLA: Naso-labial angle (Figure 3.).

5.4.5. Linear measurements used in lateral cephalometric x-rays

31- UIT-Y axis: Distance from upper incisor edge to Y axis, perpendicular to Y axis.

32- UIT- NA : Distance from upper incisor edge to NA line.

33- UIA-Y axis: Distance from upper incisor apex to Y axis, perpendicular to Y axis.

34- LIT-Y axis: Distance from lower incisor edge to Y axis, perpendicular to Y axis.

35- LIT-NB :Distance from lower insicor tip to NB line.

36- LIA-Y axis: Distance from lower incisor apex to Y axis, perpendicular to Y axis.

37- LS-Y axis: Distance from labiale superior to Y axis, perpendicular to Y axis.

38- LS- E Line: Distance from labiale superior to E Line.

39- LI-Y axis: Distance from labiale inferior to Y axis, perpendicular to Y axis.

40- LI- E Line: Distance from labiale inferior to E Line (Figure 4.).

5.4.6. Landmarks used in postero-anterior cephalometric x-rays

41- ULM: Most prominent point of upper left molar crown.

42- URM: Most prominent point of upper right molar crown.

43- MPR: Right maxillary point; intersection of outline of right tuberosity of maxilla and zygomatric buttress at jugal process.

44- MPL: Left maxillary point; intersection of outline of left tuberosity of maxilla and zygomatric buttress at jugal process (Figure 5.).

5.4.7. Linear measurements used in postero-anterior cephalometric x-rays

45- Upper intermolar width (UIMW): The distance between upper right and left first molars.

46- Maxillary width (MW): The distance between upper right and left maxillary points (Figure 6.).
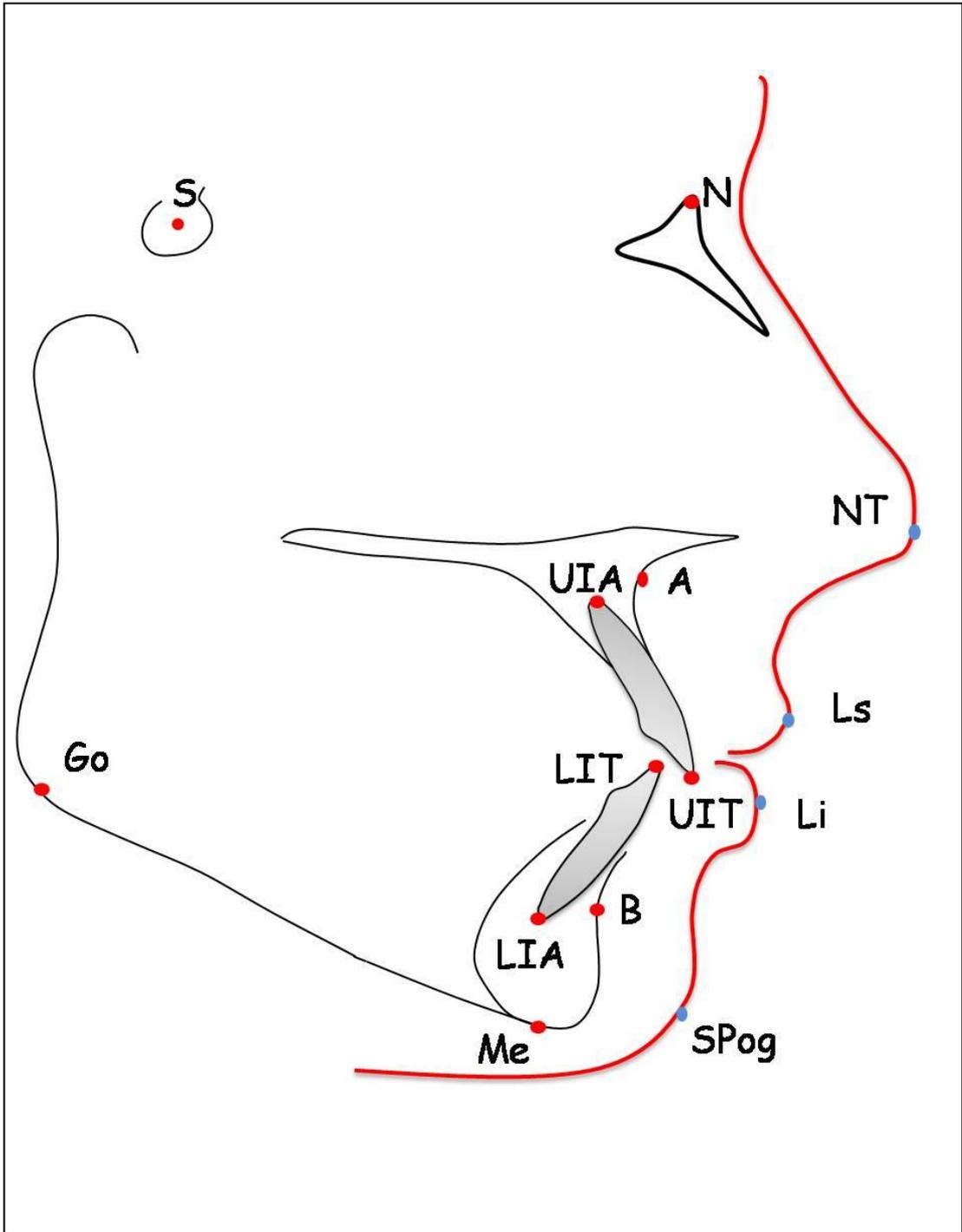
Figure 1: Landmarks used in lateral cephalometric x-rays.
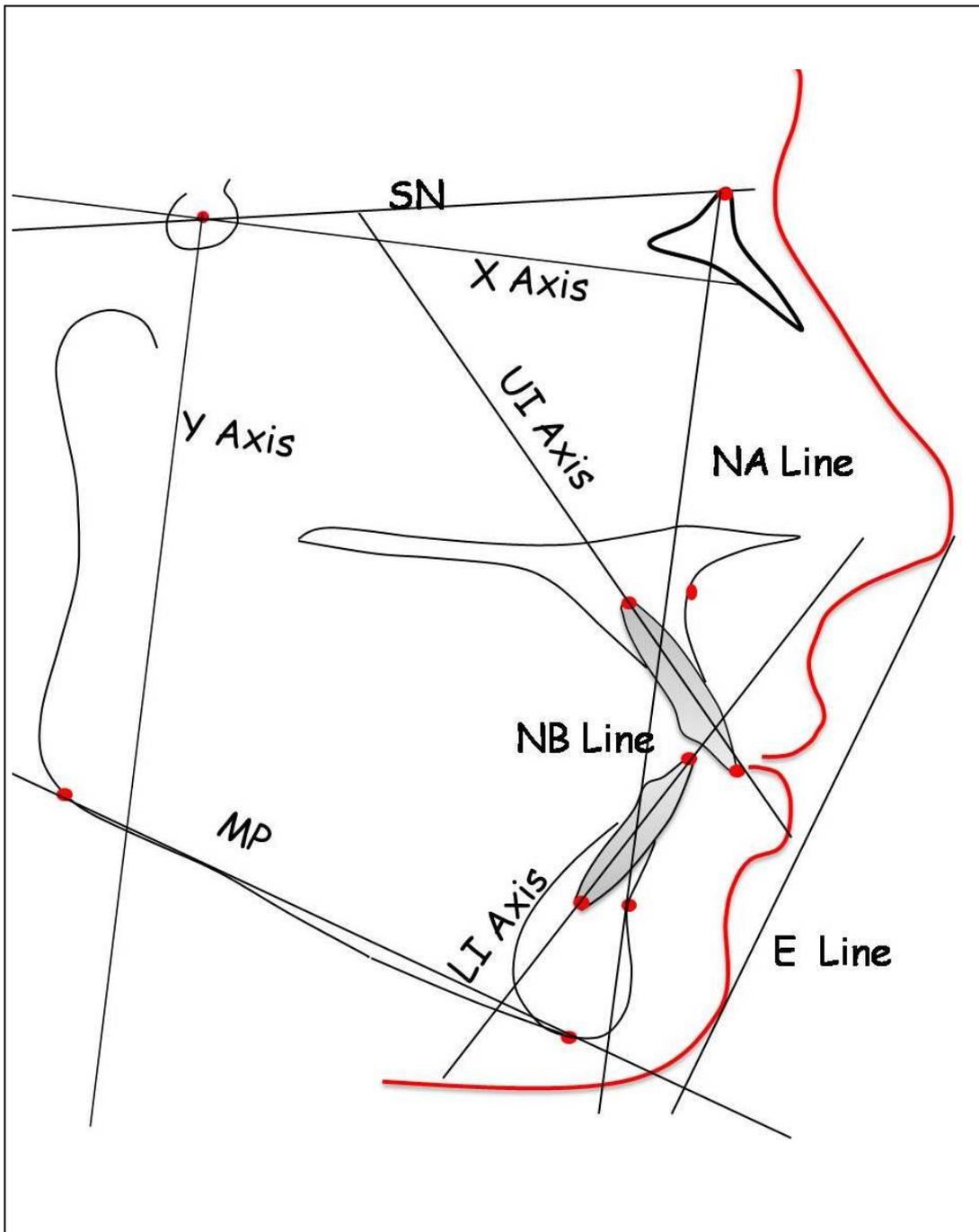
Figure 2: Planes used in lateral cephalometric x-rays.
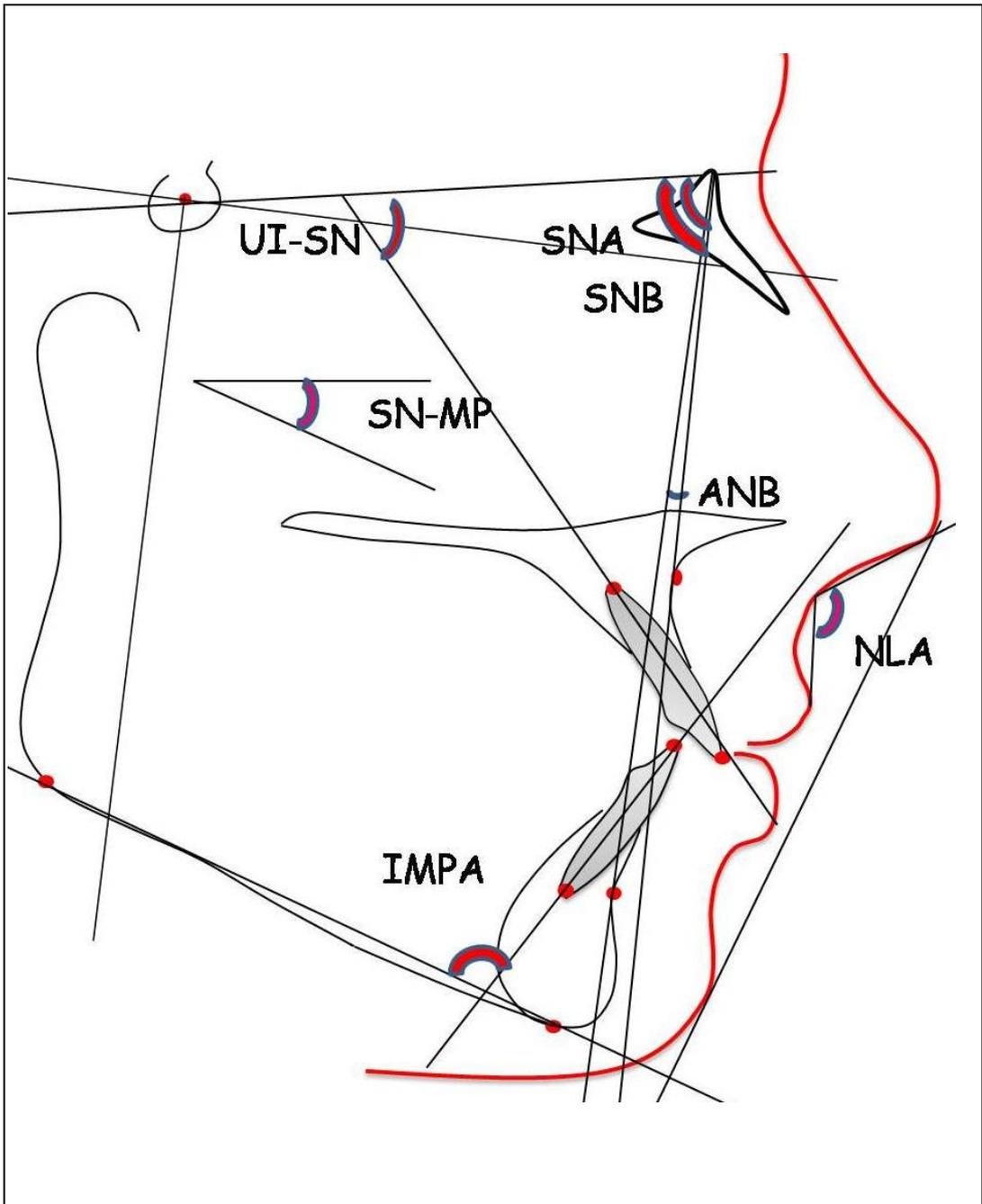
Figure 3: Angular measurements used in lateral cephalometric x-rays.
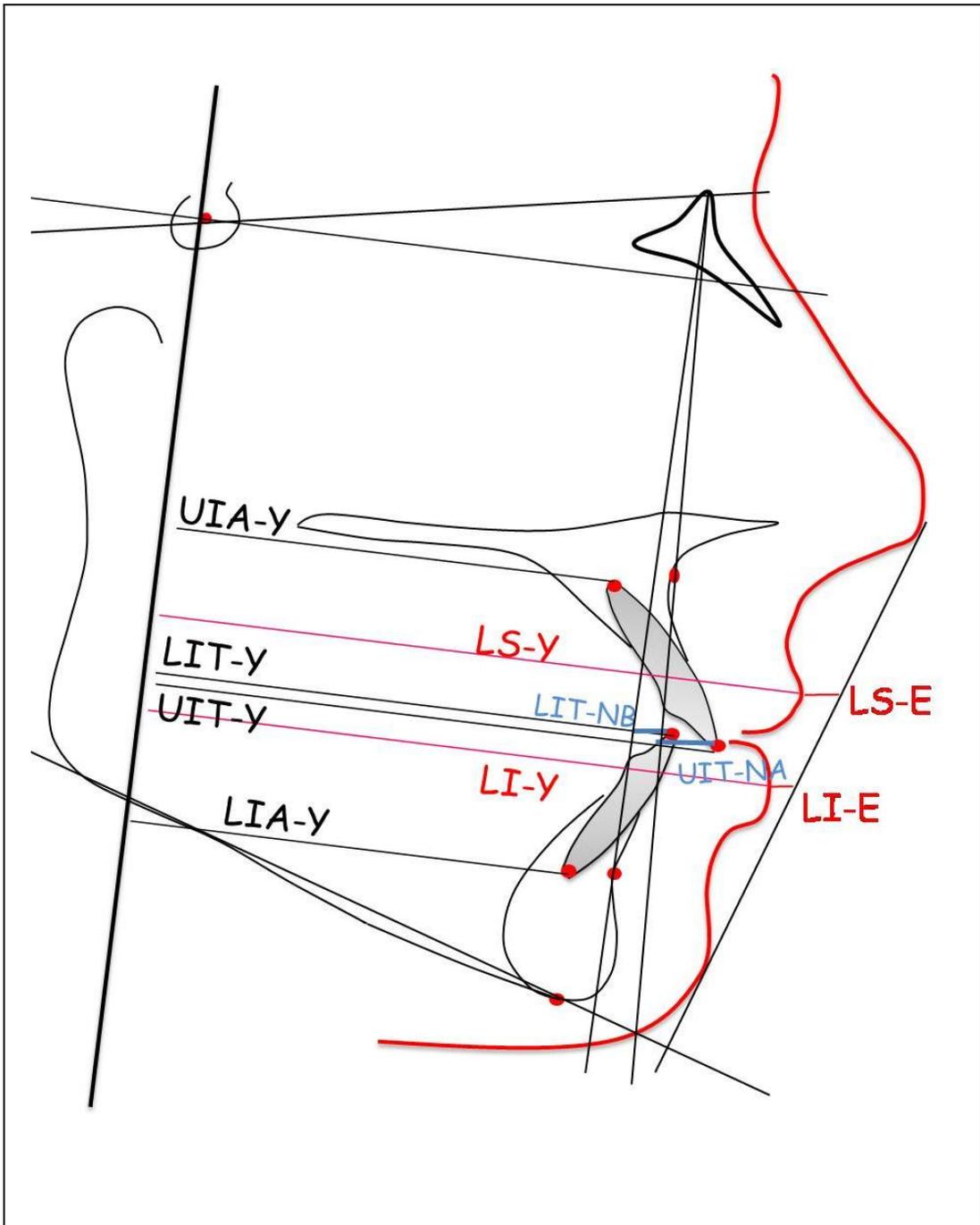
Figure 4: Linear measurements used in lateral cephalometrics x-rays.
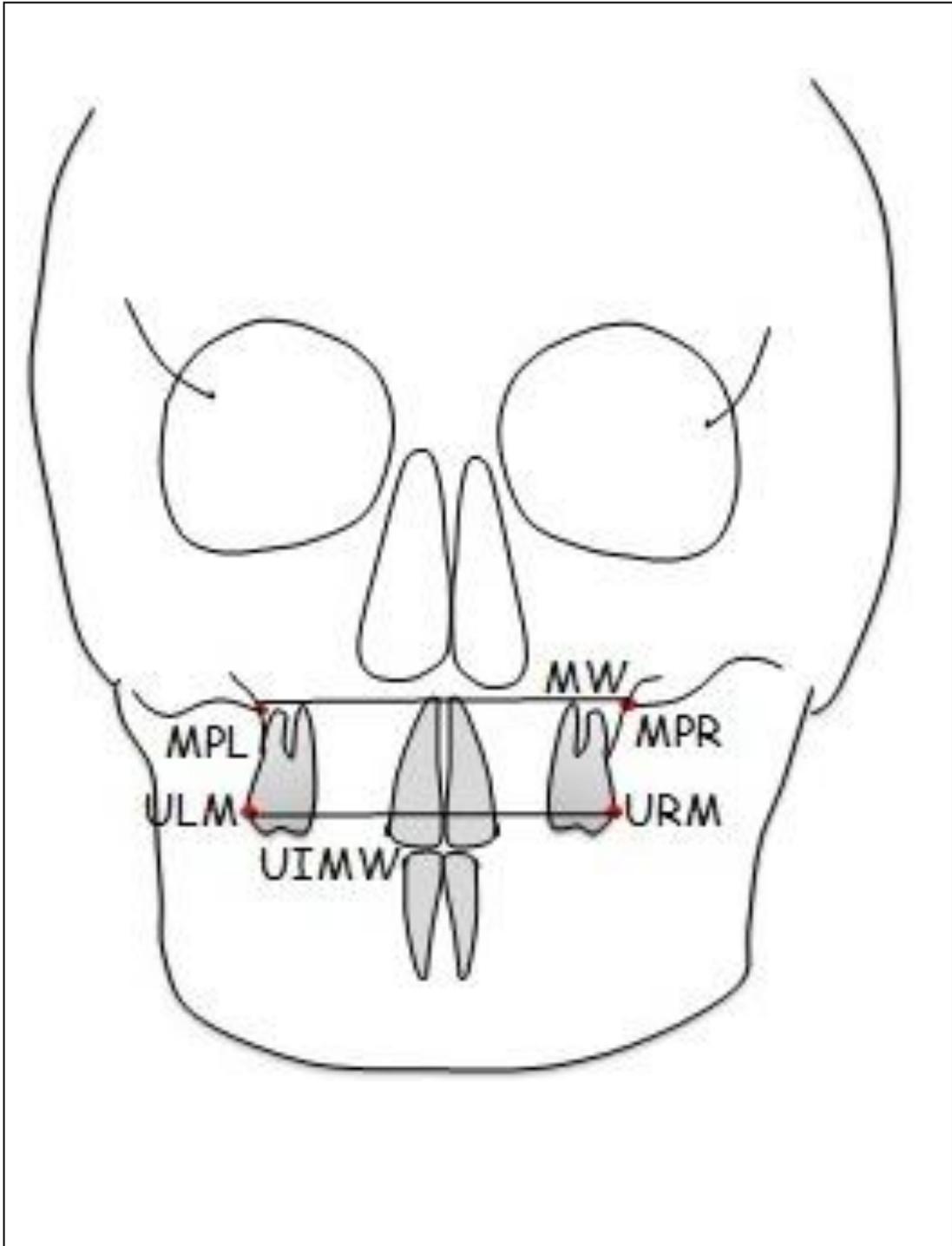
Figure 5: Landmarks and lines used in postero-anterior cephalometric x-rays.

5.5. Model Analyses

The impressions of patients were taken before and after treatment and at each session of archwire changes. Alginate impressions were sent to Orthomodel company in a sealed plastic bag at the same day they were taken. The impressions were poured at the day of delivery. Then the dental stone models were constructed. 3D model scanner (3Shape D250; 3Shape A/S) was used to convert dental models to digital models. The models were analyzed by 3Shape Orthoanalyzer Software (3Shape A/S). The digital models then were downloaded on internet 5 days following the delivery.

5.5.1. Landmarks used in model analyses

1- UCT: Upper right and left canine tubercule tip.

2- UCLP: The most lingual point at gingival junction of upper right and left canine.

3- U4BT: Upper right and left first premolar buccal tubercule tip.

4- U4LT: Upper right and left first premolar lingual tubercule tip.

5- U4LP: The most lingual point at gingival junction of upper right and left first premolar.

6- U5BT: Upper right and left second premolar buccal tubercule tip.

7- U5LT: Upper right and left second premolar lingual tubercule tip.

8- U5LP: The most lingual point at gingival junction of upper right and left second premolar.

9- U6BT: Upper right and left first molar mesiobuccal tubercule tip.

10- U6LT: Upper right and left first molar mesiolingual tubercule tip.

11- U6LP: The most lingual point at gingival junction of upper right and left first molar.

12- LCT: Lower right and left canine tubercule tip.

13- LCLP: The most lingual point at gingival junction of lower right and left canine.

14- L4BT: Lower right and left first premolar buccal tubercule tip.

15- L4LT: Lower right and left first premolar lingual tubercule tip.

16- L4LP: The most lingual point at gingival junction of lower right and left first premolar.

17- L5BT: Lower right and left second premolar buccal tubercule tip.

18- L5LT: Lower right and left second premolar lingual tubercule tip.

19- L5LP: The most lingual point at gingival junction of lower right and left second premolar.

20- L6BT: Lower right and left first molar mesiobuccal tubercule tip.

21- L6LT: Lower right and left first molar mesiolingual tubercule tip.

22- L6LP: The most lingual point at gingival junction of lower right and left first molar.

23- U1M: Mesial contact point of upper left first incisor.

24- L1M: Mesial contact point of lower first incisor.

25- U6MC: Mesial contact point of upper left and right first molar.

26- L6MC: Mesial contact point of lower left and right first molar.

5.5.2. Measurements for model analyses

27- The distance between left and right UCT.

28- The distance between left and right UCLP (Picture 24-1.).

29- The distance between left and right U4BT.

30- The distance between left and right U4LT.

31- The distance between left and right U4LP.

32- The distance between left and right U5BT.

33- The distance between left and right U5LT.

34- The distance between left and right U5LP (Picture 25-1.).

35- The distance between left and right U6BT.

36- The distance between left and right U6LT.

37- The distance between left and right U6LP (Picture 26-1.).

38- The distance between left and right LCT.

39- The distance between left and right LCLP (Picture 24-2.).

40- The distance between left and right L4BT.

41- The distance between left and right L4LT.

42- The distance between left and right L4LP.

43- The distance between left and right L5BT.

44- The distance between left and right L5LT.

45- The distance between left and right L5LP (Picture 25-2.).

46- The distance between left and right L6BT.

47- The distance between left and right L6LT.

48- The distance between left and right L6LP (Picture 26-2.).

49- Upper Available Arch Lenght: The curve between left and right U6MC (Picture 27-1).

50- Lower Available Arch Lenght: The curve between left and right U6MC (Picture 27-2).

51- Upper Arch Discrepancy: The discrepancy between upper available arch lenght and sum of upper tooth material (Picture 27-1.).

52- Lower Arch Discrepancy: The discrepancy between lower available arch lenght and sum of lower tooth material (Picture 27-2.).

53- Upper IR: Upper irregularity index; the discrepancy between contact points of upper incisors (Picture 28-1.).

54- Lower IR: Lower irregularity index; the discrepancy between contact points of lower incisors (Picture 28-2.).

55- Upper Constructed Arch Lenght: The sum of distance from U1MC to right U6MC and U1MC to left U6MC (Picture 29-1.).

56- Lower Constructed Arch Lenght: The sum of distance from L1MC to right L6MC and L1MC to left L6MC (Picture 29-2.).
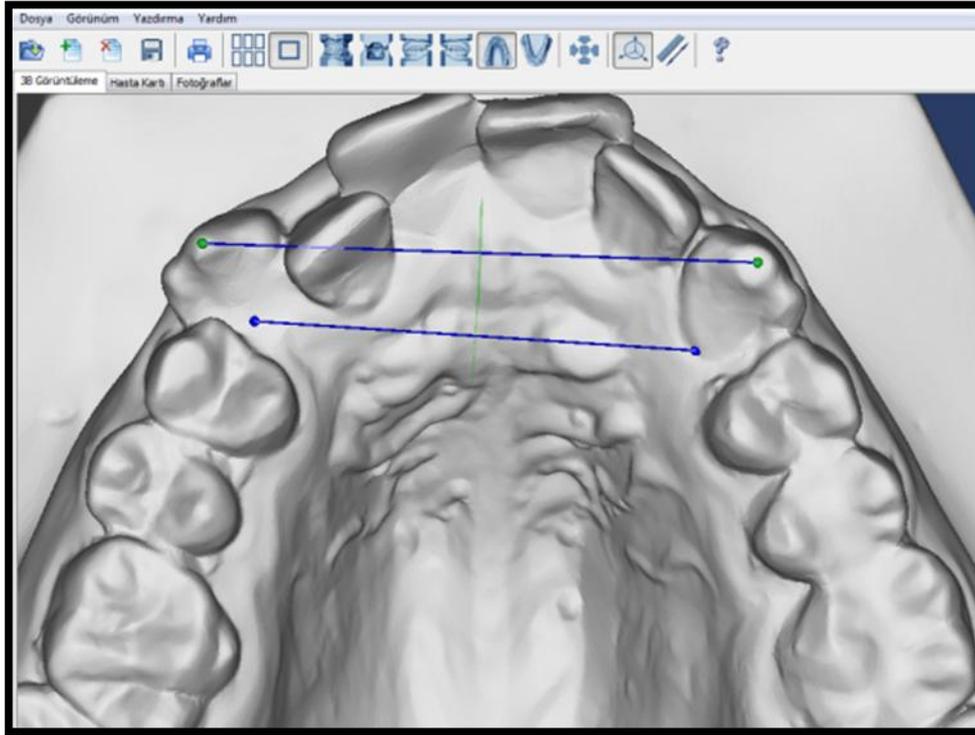
Picture 24-1: Model measurements for upper canine.
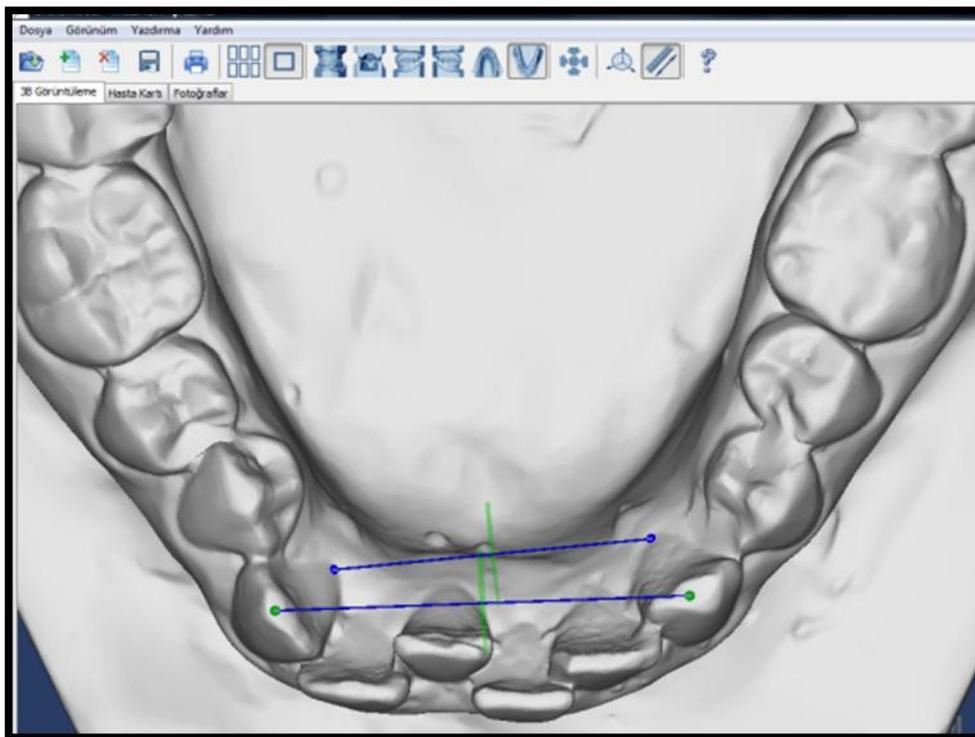
Picture 24-2: Model measurements for lower canine.
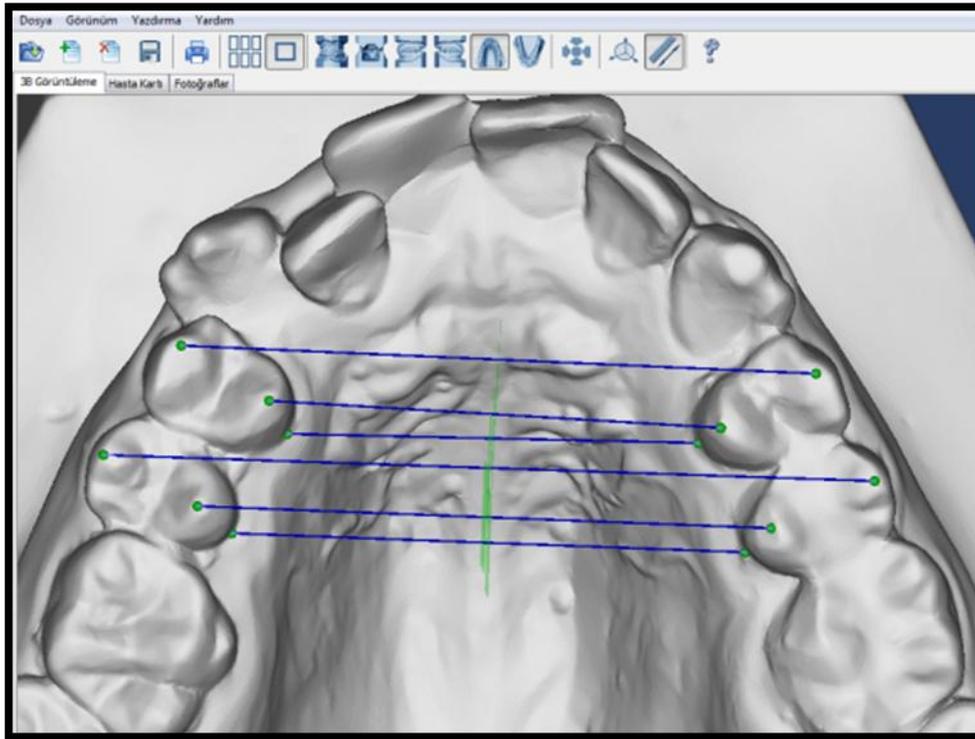
Picture 25-1: Model measurements for upper first and second premolars.
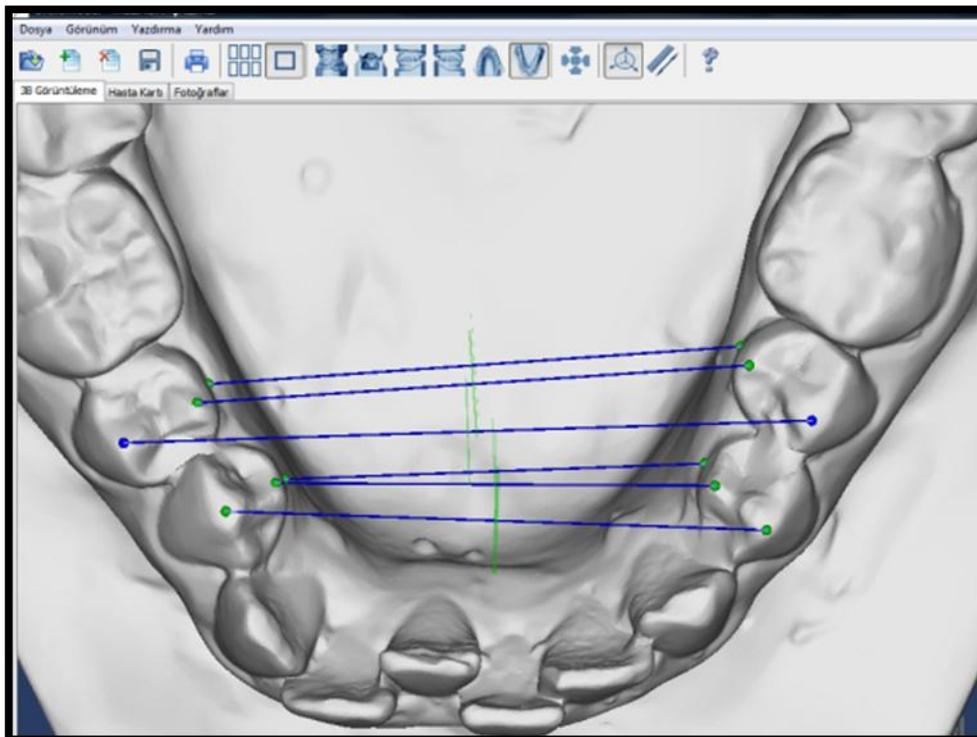
Picture 25-2: Model measurements for lower first and second premolars.
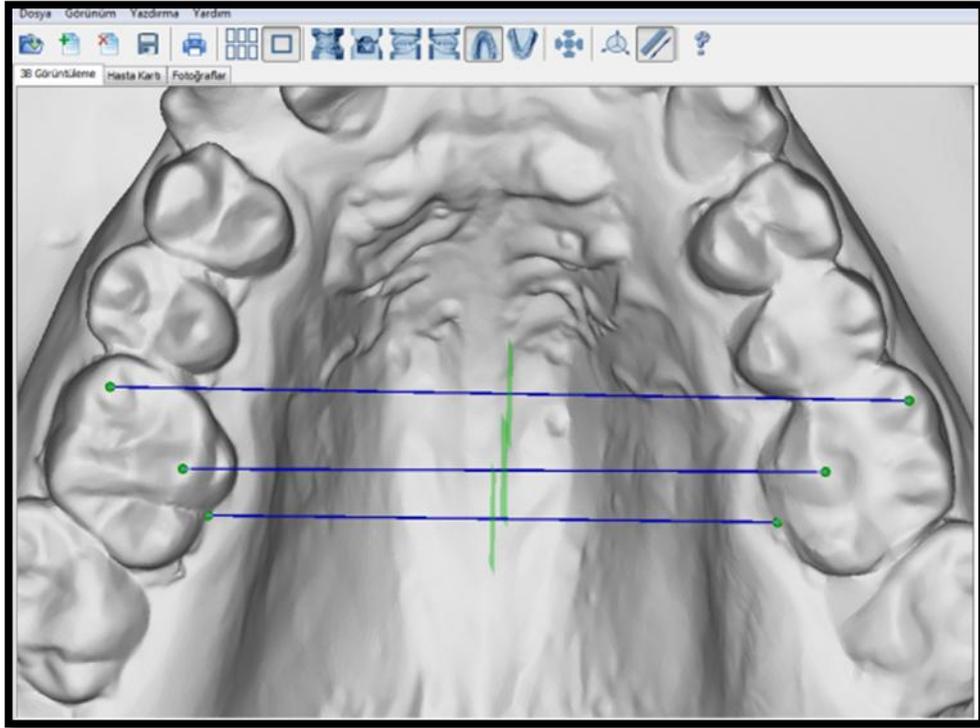
Picture 26-1: Model measurements for upper first molars.
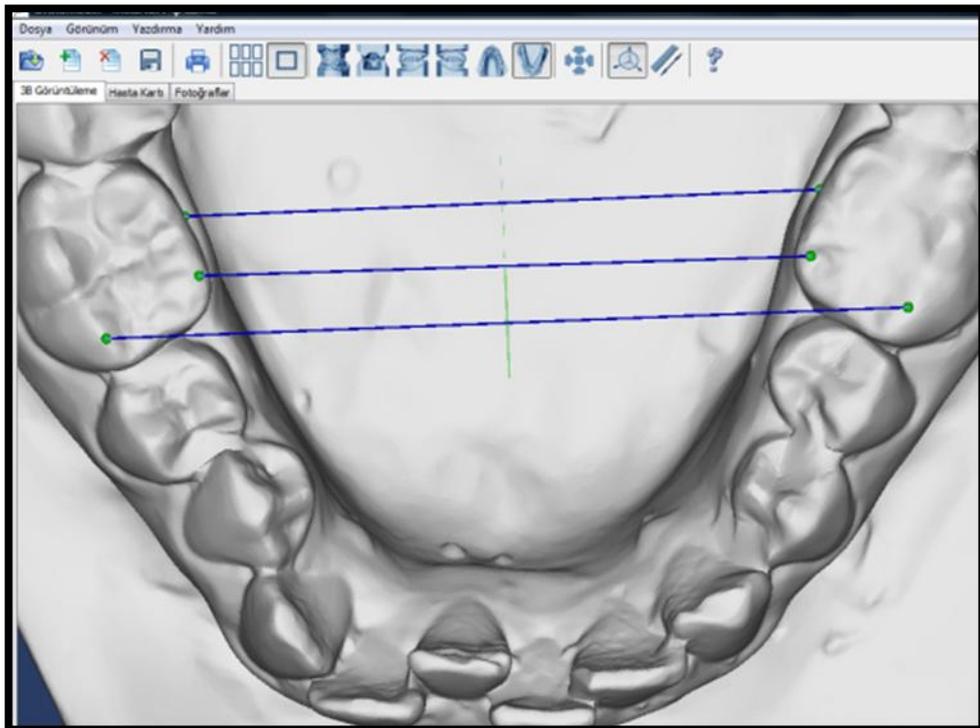
Picture 26-2: Model measurements for lower first molars.
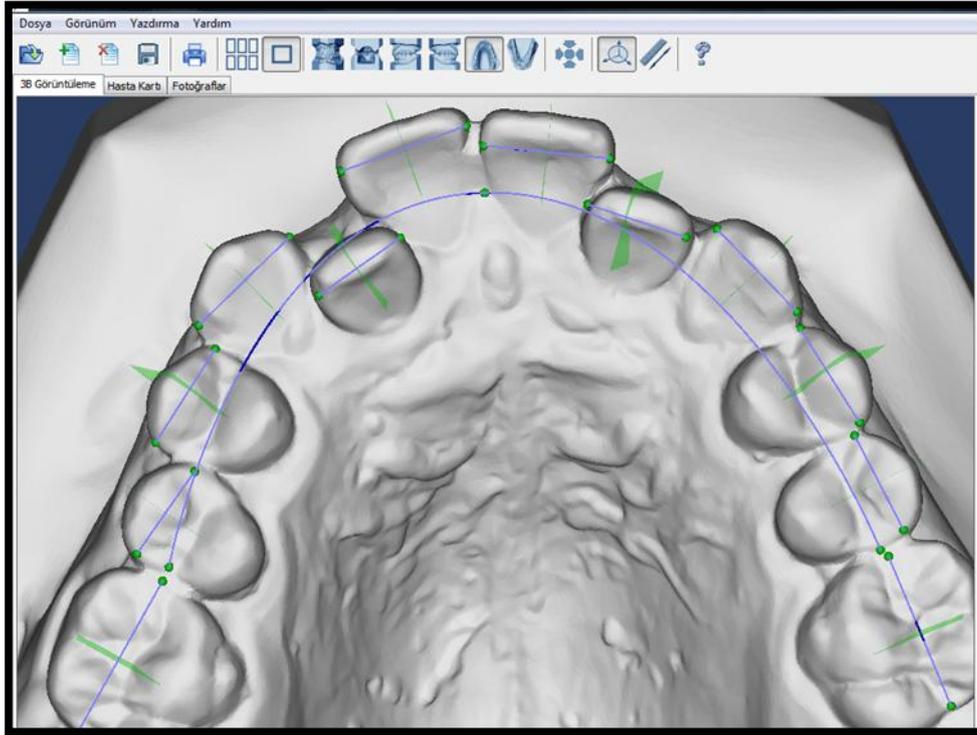
Picture 27-1: Upper arch discrepancy.
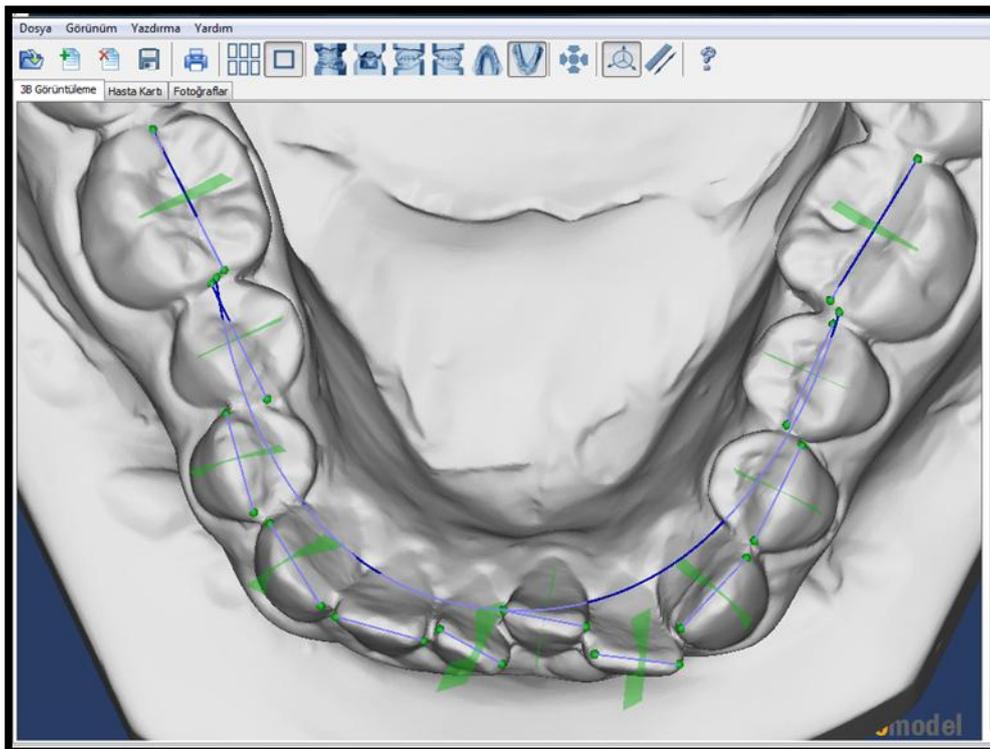
Picture 27-2: Lower arch discrepancy.
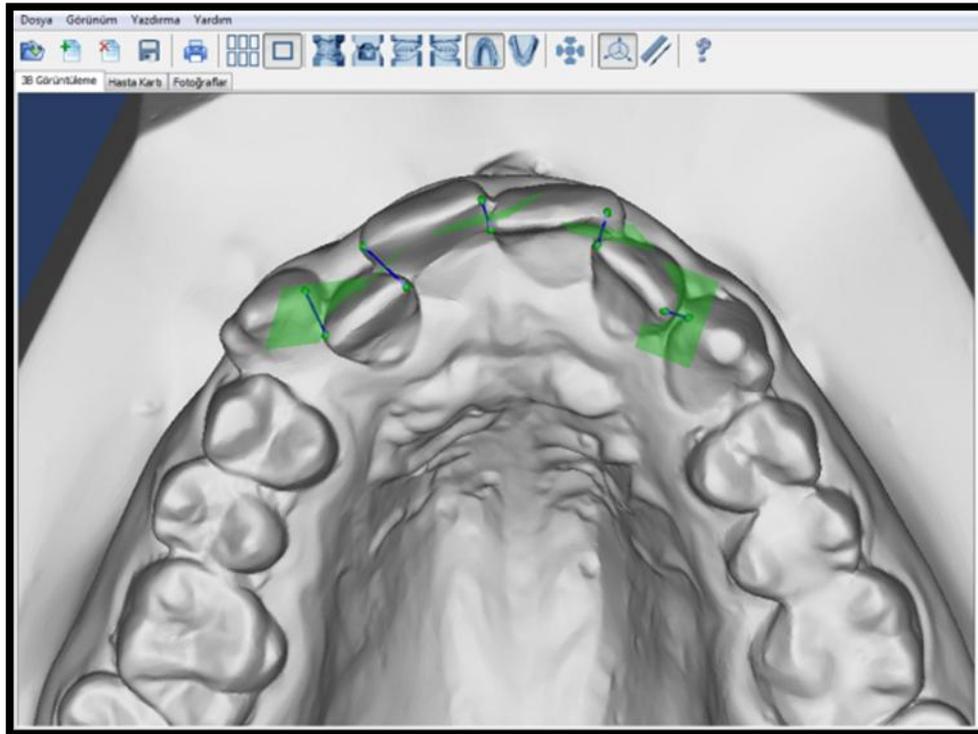
Picture 28-1: Upper irregularity index.
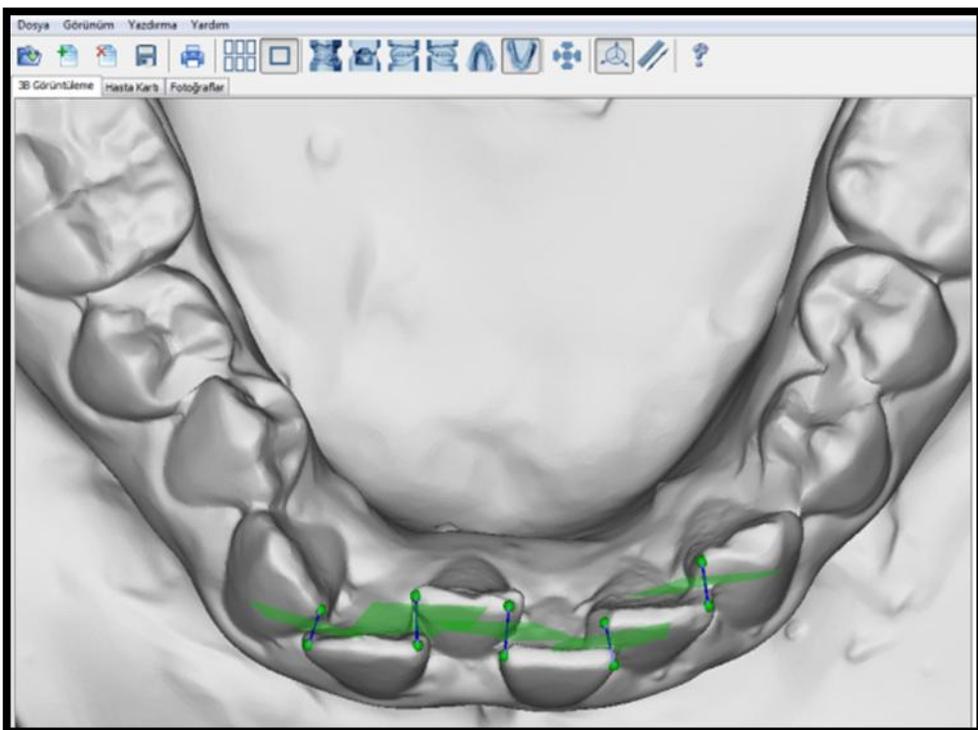
Picture 28-2: Lower irregularity index.
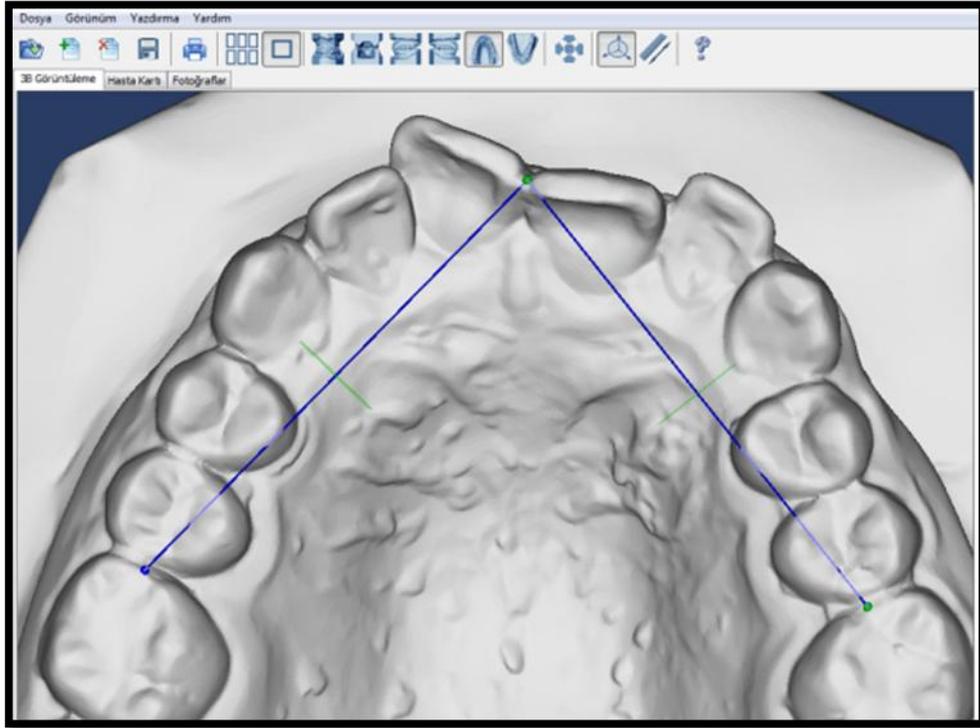
Picture 29-1: Upper constructed arch lenght.
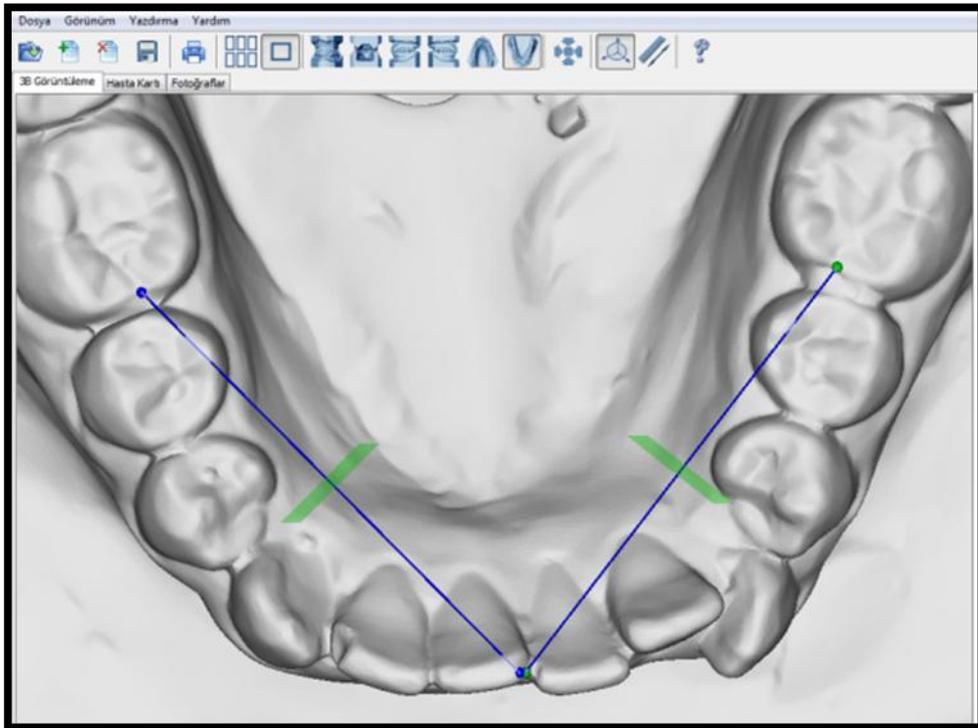
Picture 29-2: Lower constructed arch lenght.

5.6. Evaluation of Clinical Efficiency

Clinnical efficiency involves many factors like treatment time, rate of levelling, chair time, incidence of bracket or ligature loss which may alter appointment numbers and cause an increase in chair time. Self-ligating brackets and conventional brackets used in this study have been compared for factors affecting clinical efficiency.

5.6.1. Total Treatment Time

Treatment time for ecah bracket system involved in the study has been evaluated in four seperate time periods.

1- T0: Before start of treatment.

2- T1: Time of arch wire change to rectangular Ni-Ti. Initial levelling.

3- T2: Time of arch wire change to rectangular stainless-steel. Final levelling.

4- T3: Finish of treatment.

5.6.2. Ligating Time of Wires

Ligating time for each archwire was recorded by a stop-watch. Time required to place elastomers or coil-springs were not included.

5.6.3. Incidence of Bracket Loss

Total number of brackets lost during treatment was recorded in both systems.

5.6.4. Incidence of Clip Deformation/breakage and Loss of Ligation

Total number of clips deformed or broken in study group and loss of ligation in control group during treatment was recorded.

5.10. Statistical Evaluation

For the evaluation of the results in this study, NCSS (Number Cruncher Statistical System) 2007 and PASS 2008 Statistical Software (Utah, USA) programme was used for statistical analyses. Besides standard descriptive statistical

calculations (mean and standard deviation), Student t test was performed during the evaluation of parametric data between groups. Mann Whitney U test was used in the non-parametric data comparision between groups. Paired sample t test was used for intragroup comparision of parametric data. Intragroup non-parametric data was evaluated by Wilcoxon sign test. Results were evaluated within 95% confidence interval. Statistical significance level was established at p<0.05. Correlations were calculated by Spearman's rho test. Correlation significance was set at the 0.05 level.

5.10.1. Error of the method

To evaluate the intraobserver measurement error in cephalometric tracings and model analyses, all parameters were repeated by the same observer for 15 patients chosen randomly. The reliability of the repeated measurements were statistically evaluated by calculating the intraobserver measurement correspondence.

6.RESULTS

6.1. Measurement Error

15 patients were randomly selected for measurement error calculation. All the model measurements and cephalometric tracings were repeated by the same observer. For model measurements and cephalometric tracings, intraclass correlation coefficients within the patients, 95% confidence intervals and intraobserver reliability were calculated. Findings suggest that measurements are reliable and within acceptable limits (Table 4,5.).

Table 4: Cephalometric tracing reliability.

	Intraclass Correlation Coefficient	95% Confidence Interval
SN-MP	0,997	0,992-0,999
SNA	0,983	0,949-0,994
SNB	0,991	0,974-0,997
ANB	0,975	0,927-0,991
UI-SN	0,997	0,991-0,999
UIT- NA	0,997	0,990-0,999
LIT-NB	1,000	1,000-1,000
IMPA	0,998	0,990-1,000
Nasolabial Angle	0,999	0,998-1,000
LS- E Line	0,996	0,988-0,999
LI- E Line	0,995	0,986-0,998
LS-Y axis	0,998	0,994-0,999
LI-Y axis	0,999	0,997-1,000
UIA-Y axis	0,997	0,991-0,999
UIT-Y axis	0,997	0,993-0,999
LIT-Y axis	0,998	0,994-0,999
LIA-Y axis	0,999	0,996-1,000
UIMW	0,994	0,982-0,998
MW	0,996	0,989-0,999

Table 5: Reliability of model measurements.

	Intraclass Correlation Coefficient	95% Confidence Interval
Distance between right and left UCT	0,987	0,960-0,995
Distance between right and left LCT	0,989	0,967-0,996
Distance between right and left UCLP	0,803	0,508-0,929
Distance between right and left LCLP	0,969	0,909-0,989
Distance between right and left U4BT	0,998	0,995-0,999
Distance between right and left L4BT	0,979	0,938-0,993
Distance between right and left U4LT	0,987	0,962-0,996
Distance between right and left L4LT	0,980	0,940-0,993
Distance between right and left U4LP	0,997	0,990-0,999
Distance between right and left L4LP	0,988	0,964-0,996
Distance between right and left U5BT	0,997	0,993-0,999
Distance between right and left L5BT	0,994	0,983-0,998
Distance between right and left U5LT	0,996	0,989-0,999
Distance between right and left L5LT	0,998	0,993-0,999
Distance between right and left U5LP	0,997	0,992-0,999
Distance between right and left L5LP	0,995	0,986-0,998
Distance between right and left U6BT	0,984	0,954-0,995
Distance between right and left L6BT	0,973	0,923-0,991
Distance between right and left U6LT	0,994	0,981-0,998
Distance between right and left L6LT	0,978	0,935-0,992
Distance between right and left U6LP	0,994	0,983-0,998
Distance between right and left L6LP	0,995	0,984-0,998
Upper available arch length	0,964	0,897-0,988
Lower available arch length	0,991	0,975-0,997
Upper Arch Discrepancy	0,962	0,891-0,987
Lower Arch Discrepancy	0,976	0,932-0,992
Upper Irregularity Index	1,000	1,000-1,000
Lower Irregularity Index	1,000	1,000-1,000
Upper Constructed Arch Length	1,000	1,000-1,000
Lower Constructed Arch Length	1,000	1,000-1,000

6.2 Study and Control Group Homogenity

In order to evaluate the differences in effects of self-ligating brackets and conventional brackets, initial model measurements, lateral and postero-anterior cephalometric tracings of both the study and control groups were performed. Medians and standart deviations of all perimeters were calculated and evaluated by Student t test.

There was no statistically significant difference (p>0.05) between groups for all measurements performed for lateral and postero-anterior cephalometric x-rays, indicating the homogenity between the two groups (Table 6.).

Initial model measurements performed, resulted in siginificant differences in distance between upper first premolar buccal tubercules, lingual tubercules and lingual points; upper molar lingual tubercules and lingual points in favour of control group (p<0.05) (Table 7.).

Table 6: Comparision of initial lateral and postero-anterior cephalometric measurements.

Pretreatment	Study Group	Control Group	^+p
SN-MP	37,07±4,68	34,50±4,40	*0,194*
SNA	76,84±2,94	78,65±2,31	*0,126*
SNB	74,38±2,60	76,30±2,31	*0,081*
ANB	2,77±1,64	2,35±1,33	*0,518*
Naso-labial Angle	105,13±10,62	100,80±7,84	*0,290*
UI-SN	101,61±6,21	106,10±4,56	*0,069*
UIT- NA	4,96±2,58	5,80±3,42	*0,510*
UIT-Y axis	68,69±6,02	69,30±3,33	*0,762*
UIA-Y axis	61,11±4,72	60,20±4,16	*0,633*
IMPA	92,30±6,48	92,50±6,40	*0,944*
LIT-NB	4,46±1,50	4,30±2,16	*0,835*
LIT-Y axis	64,07±5,83	64,80±4,35	*0,747*
LIA-Y axis	50,76±5,57	53,50±4,99	*0,237*
LS-Y axis	81,34±6,77	82,00±4,08	*0,790*
LS- E Line	-5,96±2,24	-5,00±3,82	*0,458*
LI-Y axis:	78,42±5,97	78,70±4,53	*0,904*
LI- E Line	-3,30±2,02	-2,45±3,67	*0,483*
UIMW	63,15±2,73	64,70±4,24	*0,300*
MW	62,81±3,06	64,60±2,83	*0,166*

Table 7: Comparision of initial model measurements.

Pretreatment	Study Group	Control Group	^+p
Distance between right and left UCT	32,92±1,86	33,48±2,22	*0,513*
Distance between right and left LCT	24,17±1,89	24,98±1,23	*0,252*
Distance between right and left UCLP	25,08±2,36	24,35±1,92	*0,434*
Distance between right and left LCLP	19,36±1,64	19,09±1,57	*0,696*
Distance between right and left U4BT	38,54±2,23	40,64±2,23	*0,036**
Distance between right and left L4BT	31,54±1,74	32,65±2,10	*0,178*
Distance between right and left U4LT	27,90±1,97	29,68±1,89	*0,040**
Distance between right and left L4LT	25,16±2,13	26,12±1,48	*0,240*
Distance between right and left U4LP	24,38±1,67	26,30±1,90	*0,018**
Distance between right and left L4LP	23,96±2,13	24,79±1,52	*0,306*
Distance between right and left U5BT	43,95±3,41	44,97±3,61	*0,498*
Distance between right and left L5BT	37,56±3,00	38,57±1,71	*0,352*
Distance between right and left U5LT	33,14±2,76	34,30±3,11	*0,356*
Distance between right and left L5LT	29,26±2,87	29,75±1,83	*0,646*
Distance between right and left U5LP	29,43±2,27	30,88±2,78	*0,185*
Distance between right and left L5LP	28,30±2,91	28,69±1,47	*0,707*
Distance between right and left U6BT	49,39±2,41	51,26±2,27	*0,073*
Distance between right and left L6BT	43,05±2,01	43,99±1,84	*0,260*
Distance between right and left U6LT	37,87±2,84	40,31±1,69	*0,026**
Distance between right and left L6LT	32,52±1,72	33,72±1,28	*0,080*
Distance between right and left U6LP	33,17±1,94	35,22±1,89	*0,019**
Distance between right and left L6LP	32,84±2,33	32,93±1,11	*0,912*
Upper available arch length	64,83±2,44	66,47±1,95	*0,098*

Table 7: Comparision of initial model measurements (Continued).

Pretreatment	Study Group	Control Group	^+p
Lower available arch length	54,91±2,85	56,44±1,66	*0,150*
Upper Arch Discrepancy	4,38±1,11	3,50±1,15	*0,107*
Lower Arch Discrepancy	5,67±2,05	4,90±1,64	*0,292*
Upper Irregularity Index	12,46±3,58	10,69±3,81	*0,292*
Lower Irregularity Index	9,16±3,77	9,02±2,44	*0,804*
Upper Constructed Arch Length	68,16±2,84	68,71±3,41	*0,677*
Lower Constructed Arch Length	57,38±3,35	58,27±3,39	*0,536*

6.3. Postero-anterior and Lateral Cephalometric Evaluation

Postero-anterior and lateral cephalometric x-rays of the study and control groups were taken before and after the orthodontic treatment. The angular and linear measurements at the begining and at the end were compared by Paired Sample t test separately for each group. The begining and end values within groups were compared by Student t test (Table 8,9.). The differences from begining to end of treatment for each group were compared by Mann-Whitney-U test (Table 10.).

6.3.1. Evaluation of Angular Measurements

According to the evaluations; the changes in SN-MP, SNA, SNB, ANB, UISN and NLA angles were not statistically significant (p>0.05). IMPA angle increased significantly in both study and control group (p<0.01) (Table 8.).

6.3.2. Evaluation of Linear Measurements

LIT-NB and LIT-Y axis increased significantly in both groups (p<0.01). LS-Y axis, LS-E line, LI-E line and LI-Y axis increased significantly in both groups (p<0.01).

UIMW increased significantly in both groups (p<0.01) (Table 9.).

Table 8: Average and standart deviation values for angular measurements in study and control group.

		Study Group Average±SD	**Control Group** Average±SD	[+]*p*
SN-MP	Initial	37,07±4,68	34,50±4,40	*0,194*
	End	37,77±5,58	34,90±3,93	*0,182*
	[++]*p*	*0,168*	*0,670*	
SNA	Initial	76,84±2,94	78,65±2,31	*0,126*
	End	77,38±2,87	79,80±2,09	*0,066*
	[++]*p*	*0,170*	*0,154*	
SNB	Initial	74,38±2,60	76,30±2,31	*0,081*
	End	74,23±2,86	77,50±1,84	*0,075*
	[++]*p*	*0,700*	*0,154*	
ANB	Initial	2,77±1,64	2,35±1,33	*0,518*
	End	3,15±1,57	2,30±1,42	*0,193*
	[++]*p*	*0,096*	*0,864*	
UI-SN	Initial	101,61±6,21	106,10±4,56	*0,069*
	End	105,85±6,79	111,20±6,19	*0,065*
	[++]*p*	*0,060*	*0,083*	
IMPA	Initial	92,30±6,48	92,50±6,40	*0,944*
	End	98,30±5,68	99,80±5,99	*0,548*
	[++]*p*	*0,001**	*0,009**	
NLA	Initial	105,13±10,62	100,80±7,84	*0,290*
	End	103,84±9,60	99,10±5,46	*0,061*
	[++]*p*	*0,162*	*0,649*	

Table 9: Average and standart deviation values of linear measurements in study and control group.

		Study Group Average±SD	Control Group Average±SD	^{+}p
UIT- NA	Initial	4,96±2,58	5,80±3,42	*0,510*
	End	6,70±2,56	7,05±2,06	*0,225*
	^{++}p	*0,065*	*0,263*	
LIT-NB	Initial	4,46±1,50	4,30±2,16	*0,835*
	End	7,00±1,40	7,40±1,64	*0,536*
	^{++}p	*0,001***	*0,001***	
LS- E Line	Initial	-5,96±2,24	-5,00±3,82	*0,458*
	End	-4,84±2,12	-3,80±2,86	*0,326*
	^{++}p	*0,004***	*0,046**	
LI- E Line	Initial	-3,30±2,02	-2,45±3,67	*0,483*
	End	-2,07±2,18	-0,15±2,97	*0,087*
	^{++}p	*0,002***	*0,008***	
LS-Y axis	Initial	81,34±6,77	82,00±4,08	*0,790*
	End	83,61±6,85	86,45±6,68	*0,331*
	^{++}p	*0,001***	*0,011**	
LI-Y axis	Initial	78,42±5,97	78,70±4,53	*0,904*
	End	80,46±6,84	83,85±6,37	*0,239*
	^{++}p	*0,008***	*0,006***	
UIA-Y axis	Initial	61,11±4,72	60,20±4,16	*0,633*
	End	61,96±4,46	62,00±5,25	*0,985*
	^{++}p	*0,158*	*0,177*	

Table 9: Average and standart deviation values of linear measurements in study and control group (Continued).

		Study Group Average±SD	**Control Group** Average±SD	[+]*p*
UIT-Y axis	Initial	68,69±6,02	69,30±3,33	*0,762*
	End	69,80±6,19	72,70±5,34	*0,630*
	[++]*p*	*0,122*	*0,055*	
LIT-Y axis	Initial	64,07±5,83	64,80±4,35	*0,747*
	End	67,30±5,95	69,90±5,54	*0,298*
	[++]*p*	*0,001***	*0,007***	
LIA-Y axis	Initial	50,76±5,57	53,50±4,99	*0,237*
	End	51,15±6,89	54,70±6,88	*0,234*
	[++]*p*	*0,689*	*0,502*	
MW	Initial	63,15±2,73	64,70±4,24	*0,300*
	End	63,23±2,78	64,75±4,02	*0,296*
	[++]*p*	*0,436*	*0,853*	
UIMW	Initial	62,81±3,06	64,60±2,83	*0,166*
	End	63,80±3,11	65,30±3,18	*0,272*
	[++]*p*	*0,018**	*0,015**	

6.3.3. Comparision of Changes

The changes of cephalometric measurements were not significant between groups (p>0.05) (Table 10.).

Table 10: Comparision of changes in lateral and postero-anterior cephalometric measurements in the study and control group.

	Study Group Average±SD (Med.)	**Control Group** Average±SD (Med.)	^+p
SN-MP	0,69±1,70 (0)	0,40±2,87 (0)	0,974
SNA	0,54±1,33 (0)	1,15±2,33 (0,5)	0,607
SNB	-0,15±1,40 (0)	1,20±2,44 (0,5)	0,160
ANB	0,38±0,77 (0)	-0,05±0,89 (0)	0,344
UI-SN	4,15±2,30 (4)	5,10±8,28 (7,5)	0,493
UIT- NA	1,85±1,46 (1,5)	1,25±3,31 (1,5)	0,572
UIT-Y axis	1,11±2,41 (1,5)	3,40±4,57 (3)	0,300
UIA-Y axis	0,84±2,02 (1)	1,80±3,88 (1,5)	0,707
NLA	-1,29±8,94 (-1)	-1,70±8,74 (-1,5)	0,436
LS- E Line	1,11±1,14 (1,5)	1,20±2,85 (0,3)	0,594
LS- Y axis	2,27±1,22 (2)	4,45±4,38 (3,5)	0,364
IMPA	6,00±3,53 (6)	7,30±6,98 (6)	0,755
LIT-NB	2,54±1,77 (2,5)	3,10±1,37 (3)	0,451
LIT-Y axis	3,23±2,35 (3)	5,10±4,67 (3,5)	0,409
LIA-Y axis	0,38±3,38 (1)	1,20±5,43 (1,5)	0,827
LI- E Line	1,23±1,09 (2)	2,30±2,12 (2)	0,130
LI-Y axis	2,04±2,30 (2)	5,15±4,50 (5)	0,127
MW	0,07±0,34 (0)	0,05±0,83 (0)	0,567
UIMW	1,00±1,32 (1)	0,70±0,59 (0,6)	0,682

6.4. Model Measurements

6.4.1. Measurements for Canine

All measurements for upper and lower canines were not statistically different between groups at all measurement times (p>0.05) (Table 11,12.).

The distance between right and left upper canine tubercules was 32,92±1,86 mm in study group and 33,48±2,22 mm in control group initially. In study group the distance increased to 33,73±1,68 mm at T1; 34,54±1,37 mm at T2 and 34,08±1,09 mm at T3. The increase was statistically significant for T1, T2 and T3 when compared to start of treatment (T0-T1 p<0.05, T0-T2 and T0-T3 p<0.01). In control group the results were 34,56±1,97 mm at T1, 34,54±1,53 mm at T2 and 34,10±1,44 mm at T3. The increase was again statistically significant for all measurement times (T0-T1 p<0.01, T0-T2 and T0-T3 p<0.05).

The distance between right and left upper canine lingual points was 25,08±2,36 mm in study group and 24,35±1,92 mm in control group initially. In study group the distance increased to 25,51±2,13 mm at T1; 25,87±1,94 mm at T2 and 26,05±1,97 mm at T3. The increase was statistically significant for T1, T2 and T3 when compared to start of treatment (p<0.01). In control group 24,98±1,32 mm at T1, 25,20±1,50 mm at T2 and 25,12±1,58 mm at T3. The increase was again statistically significant for all measurement times (T0-T1, T0-T3 p<0.05, T0-T2 p<0.01).

The distance between right and left lower canine tubercules was 24,17±1,89 mm in study group and 24,98±1,23 mm in control group at the start of the treatment. In study group the distance increased to 26,05±1,13 mm at T1. The increase was statistically significant (p<0.01). Then the measurement was stated as 25,82±1,23 mm at T2 and 25,49±1,16 mm at the end of the treatment. The change between T0-T2 and T0-T3 was again statistically significant (T0-T2 p<0.01, T0-T3 p<0.05). For the control group the distance between lower canine tubercules was 26,97±1,58 mm at T1, 26,35±1,29 mm at T2 and 25,49±1,16 mm at T3. The measurements were statististically siginificant when compared to initial results (T0-T1 p<0.01, T0-T2 and T0-T3 p<0.05).

For the lower arch, the distances between lingual points were 19,36±1,64 mm for study group and 19,09±1,57 mm for control group at the begining of the treatment. At T1 there was a significant increase: 20,25±1,09 mm for study group and 20,43±1,36 mm for control group (p<0.05). At T2 the distances measured were 20,22±0,99 mm in study group and 20,40±1,19 mm in control group. The increase was significant for both groups compared to initial measurements (p<0.01). At the end of the treatment the measurement was 20,04±0,94 mm for study group and 20,01±0,78 mm for control group. The increase was significant for both groups compared to initial measurements (p<0.05).

The increase resulted in distances between tubercule tips and lingual points were not correlated in upper and lower arches for both groups (p>0.05) (Table 13).

Table 11: Comparision of upper canine measurements.

		Study Group Average±SD	**Control Group** Average±SD	[+]**p**
Distance Between Right and Left UCT	**T0**	32,92±1,86	33,48±2,22	*0,513*
	T1	33,73±1,68	34,56±1,97	*0,289*
	T2	34,54±1,37	34,54±1,53	*0,996*
	T3	34,08±1,09	34,10±1,44	*0,976*
	T0-T1 [++]*p*	*0,027**	*0,006***	
	T0-T2 [++]*p*	*0,001***	*0,046**	
	T0-T3 [++]*p*	*0,006***	*0,036**	
Distance Between Right and Left UCLP	**T0**	25,08±2,36	24,35±1,92	*0,434*
	T1	25,51±2,13	24,98±1,82	*0,536*
	T2	25,87±1,94	25,20±1,50	*0,377*
	T3	26,05±1,87	25,12±1,58	*0,238*
	T0-T1 [++]*p*	*0,009***	*0,025**	
	T0-T2 [++]*p*	*0,001***	*0,007***	
	T0-T3 [++]*p*	*0,003***	*0,011**	

Table 12: Comparision of lower canine measurements.

		Study Group Average±SD	**Control Group** Average±SD	[+]*p*
Distance Between Right and Left LCT	**T0**	24,17±1,89	24,98±1,23	*0,252*
	T1	26,05±1,13	26,97±1,58	*0,120*
	T2	25,82±1,23	26,35±1,29	*0,331*
	T3	25,49±1,16	25,73±1,10	*0,624*
	T0-T1 [++]*p*	*0,002**	*0,004**	
	T0-T2 [++]*p*	*0,004**	*0,022*	
	T0-T3 [++]*p*	*0,041*	*0,050*	
Distance Between Right and Left LCLP	**T0**	19,36±1,64	19,09±1,57	*0,696*
	T1	20,25±1,09	20,43±1,36	*0,727*
	T2	20,22±0,99	20,40±1,19	*0,684*
	T3	20,04±0,94	20,01±0,78	*0,926*
	T0-T1 [++]*p*	*0,024*	*0,019*	
	T0-T2 [++]*p*	*0,038*	*0,008**	
	T0-T3 [++]*p*	*0,026*	*0,032*	

Table 13: Correlation between increase of distance between canine tubercule tips and lingual points.

			Study Group Average±SD	**Control Group** Average±SD
			Increase in distance between canine tubercule tips	
Upper Arch	Increase in distance between canine lingual points	**r**	0,187	0.491
		P	0,541	0,150
Lower Arch		**r**	0,357	0,455
		P	0,231	0,187

6.4.2. Measurements for First Premolar

Initially for all measurements performed, upper first premolar values showed a siginificant difference in favour of control group (p<0.01) but were comparable for lower first premolar (p>0.05). The average measurements for both upper and lower first premolar did not show significance between groups at T1, T2 and T3 (p>0.05); except the distances between upper lingual points at T1, lower lingual tubercules at T1 and T2 which were in favour of control group (p<0.01) (Table 14,15.).

The measured distance between right and left buccal tubercules of upper first premolar was 38,54±2,23 mm for study group initially and increased to 41,77±1,60 mm at T1, 43,00±1,34 mm at T2 and 42,48±1,16 mm at T3; where the increase was found statistically significant at all times (p<0.01). The distance between right and left buccal tubercules of upper first premolar was 40,64±2,23 mm initially for control group. The measurement was recorded as 43,30±2,02 mm at T1, 43,72±1,75 mm a T2 and 43,10±1,54 mm at T3. The increase was found statistically significant at all times (p<0.01).

The distance between right and left lingual tubercules of upper first premolar was 27,90±1,97 mm and 29,68±1,89 mm for study and control groups respectively. At T1 31,09±1,29 mm in study group and 32,42±2,08 mm in control group were recorded. The increase was significant for both groups (p<0.01). The distances were found as 32,46±1,02 mm in study and 32,90±1,45 mm in control groups respectively at T2; showing a statistically siginificant difference when compared to initial values (p<0.01). At the end of the treatment the values were recorded as 31,75±0,98 mm 32,23±1,26 mm and for study and control groups respectively; again significantly different from initial values (p<0.01).

The distance between right and left lingual points of upper first premolar was found to be 24,38±1,67 mm for study group and 26,30±1,90 mm for control group. The values for upper arch increased to 26,39±1,42 mm at T1, 27,34±1,42 mm at T2 and 27,16±1,28 mm at T3 for study group; displaying a significant difference compared to initial values (p<0.01). The increase compared to initial values were

significant also for control group; being 28,17±1,64 mm at T1, 28,30±1,24 mm at T2 and 27,95±1,33 mm at T3 (p<0.01).

The distance between right and left buccal tubercules first premolar in lower arch was stated to be 31,54±1,74 mm in study and 32,65±2,10 mm in control group. The value increased significantly for both groups at T1 reaching 34,62±0,83 mm in study and 35,47±2,12 mm in control group (p<0.01). At T2 the values were 34,69±1,13 mm and 35,38±1,95 mm in study and control groups respectively and were significantly different from initial values (p<0.01). At the end of the treatment the values recorded were 34,19±0,97 mm and 34,57±1,52 mm respectively and the increase was significant comparing initial values (p<0.01).

The measured distance between right and left lingual tubercules of lower first premolar was 25,16±2,13 mm for study group initially and increased to 27,31±1,04 mm at T1, 27,65±0,91 mm at T2 and 27,42±1,05 mm at T3; where the increase was found statistically significant at all times (p<0.01). The distance between right and left lingual tubercules of lower first premolar was 26,12±1,48 mm initially for control group. The measurement was recorded as 28,45±1,09 mm at T1, 28,65±1,28 mm a T2 and 28,16±1,18 mm at T3. The increase was found statistically significant at all times (p<0.01).

For the lower arch the distance between right and left lingual points of first premolar were 23,96±2,13 mm and 24,79±1,52 mm for study and control groups respectively. The measurements were recorded as 25,70±1,08 mm at T1, 25,86±1,06 mm at T2 and 25,86±1,17 mm at T3 for study group; stating a significant difference for all measurement times (p<0.01). In lower arch the control group values were 26,56±1,17 mm at T1, 26,68±1,34 mm at T2 and 26,34±1,37 mm at T3; displaying a significant difference (p<0.01).

The increases measured in distances between lingual tubercules and lingual points are highly correlated for both arches (p<0.01) (Table 16.).

Table 14: Comparision of upper first premolar measurements.

		Study Group Average±SD	Control Group Average±SD	[+]p
Distance Between Right and Left U4BT	T0	38,54±2,23	40,64±2,23	0,036*
	T1	41,77±1,60	43,30±2,02	0,056
	T2	43,00±1,34	43,72±1,75	0,278
	T3	42,48±1,16	43,10±1,54	0,285
	T0-T1 [++]p	0,001**	0,001**	
	T0-T2 [++]p	0,001**	0,001**	
	T0-T3 [++]p	0,001**	0,001**	
Distance Between Right and Left U4LT	T0	27,90±1,97	29,68±1,89	0,040*
	T1	31,09±1,29	32,42±2,08	0,073
	T2	32,46±1,02	32,90±1,45	0,409
	T3	31,75±0,98	32,23±1,26	0,307
	T0-T1 [++]p	0,001**	0,001**	
	T0-T2 [++]p	0,001**	0,001**	
	T0-T3 [++]p	0,001**	0,001**	
Distance Between Right and Left U4LP	T0	24,38±1,67	26,30±1,90	0,018*
	T1	26,39±1,42	28,17±1,64	0,011*
	T2	27,34±1,42	28,30±1,24	0,106
	T3	27,16±1,28	27,95±1,33	0,164
	T0-T1 [++]p	0,001**	0,001**	
	T0-T2 [++]p	0,001**	0,001**	
	T0-T3 [++]p	0,001**	0,002**	

Table 15: Comparision of lower first premolar measurements.

		Study Group Average±SD	Control Group Average±SD	[+]p
Distance Between Right and Left L4BT	T0	31,54±1,74	32,65±2,10	*0,178*
	T1	34,62±0,83	35,47±2,12	*0,204*
	T2	34,69±1,13	35,38±1,95	*0,298*
	T3	34,19±0,97	34,57±1,52	*0,476*
	T0-T1 [++]p	*0,001***	*0,001***	
	T0-T2 [++]p	*0,001***	*0,001***	
	T0-T3 [++]p	*0,001***	*0,001***	
Distance Between Right and Left L4LT	T0	25,16±2,13	26,12±1,48	*0,240*
	T1	27,31±1,04	28,45±1,09	*0,019**
	T2	27,65±0,91	28,65±1,28	*0,041**
	T3	27,42±1,05	28,16±1,18	*0,128*
	T0-T1 [++]p	*0,001***	*0,001***	
	T0-T2 [++]p	*0,001***	*0,001***	
	T0-T3 [++]p	*0,001***	*0,001***	
Distance Between Right and Left L4LP	T0	23,96±2,13	24,79±1,52	*0,306*
	T1	25,70±1,08	26,56±1,17	*0,082*
	T2	25,86±1,06	26,68±1,34	*0,115*
	T3	25,86±1,17	26,34±1,37	*0,371*
	T0-T1 [++]p	*0,001***	*0,001***	
	T0-T2 [++]p	*0,001***	*0,001***	
	T0-T3 [++]p	*0,001***	*0,001***	

Table 16: Correlation between increase of distances between first premolar palatal tubercules and palatal points.

			Study Group Average±SD	Control Group Average±SD
			Increase in distance between first premolar lingual points	
Upper Arch	Increase in distance between first premolar lingual tubercules	r	0,786**	0.855**
		p	0,001	0,002
Lower Arch		r	0,912**	0.806**
		p	0,001	0,005

6.4.3. Measurements for Second Premolar

The values recorded for second premolar present significant difference between groups for the distances between palatal tubercules of upper at T1 and lingual points of upper at T1 and T2 ($p<0.05$) (Table 17,18.).

The initial values of distance between right and left buccal tubercules were 43,95±3,41 mm for study group and 44,97±3,61 mm for control group in upper arch. The measurements increased to 46,69±1,88 mm and 48,48±2,74 mm at T1 respectively. The changes were statistically significant for both groups ($p<0.01$). At T2 and T3 the measurements were recorded as : 48,00±1,77 mm and 47,46±1,41 mm for study group and 48,92±2,27 mm and 48,60±2,38 mm for control group. The increase in measurements from T0-T2 and T0-T3 were statistically significant for both groups ($p<0.01$).

The increase of the distance between lingual tubercules of second premolars from 33,14±2,76 mm to 35,48±1,65 mm at T1, 36,85±1,59 mm at T2 and 36,26±1,28 mm at T3 was statistically significant for study group in upper arch ($p<0.01$). For the upper arch of control group the values were 34,30±3,11 mm, 37,65±2,56 mm, 38,07±2,31 mm and 37,66±2,25 mm for T0, T1, T2 and T3 respectively. The

increase was significant for all measurements when compared to initial values (p<0.01).

The initial values were 29,26±2,87 mm for study group and 29,75±1,83 mm for control group in lower arch for distance between right and left lingual tubercules. The measurements increased to 30,78±1,83 mm and 31,70±1,56 mm respectively. The changes were statistically significant for both groups (p<0.01). At T2 and T3 the measurements were recorded as : 31,12±1,67 mm and 30,89±1,53 mm for study group and 32,09±1,63 mm and 32,00±1,28 mm for control group. The increase in measurements from T0-T2 and T0-T3 were statistically significant for both groups (p<0.01).

The measured distance between right and left lingual points of upper second premolar was 29,43±2,27 mm for study group initially and increased to 30,86±1,46 mm at T1, 31,78±1,67 mm at T2 and 31,52±1,29 mm at T3; where the increase was found statistically significant at all times (p<0.01). The distance between right and left lingual points of upper second premolar was 30,88±2,78 mm initially for control group. The measurement was recorded as 33,08±2,10 mm at T1, 33,59±2,00 mm a T2 and 33,36±1,86 mm at T3. The increase was found statistically significant at all times (p<0.01).

In the lower arch the distance between right and left buccal tubercules of second premolar was 37,56±3,00 mm for study group initially and increased to 39,85±1,45 mm at T1, 40,25±1,41 mm at T2 and 40,06±1,58 mm at T3; where the increase was found statistically significant at all times (p<0.01). The same distance was 38,57±1,71 mm initially for control group. The measurement was recorded as 40,89±1,87 mm at T1, 41,19±1,92 mm a T2 and 40,60±1,72 mm at T3. The increase was found statistically significant at all times (p<0.01).

In the lower arch the measured distance between right and left lingual points of second premolar was 28,30±2,91 mm for study group initially and increased to 29,64±1,82 mm at T1, 30,02±1,64 mm at T2 and 29,63±1,76 mm at T3; where the increase was found statistically significant at all times (p<0.01). The value was 28,69±1,47 mm initially for control group. The measurement was recorded as

30,11±1,52 mm at T1, 30,51±1,49 mm a T2 and 30,23±1,23 mm at T3. The increase was found statistically significant at all times (p<0.01).

The increase in distances between lingual tubercules and lingual points of second premolar were found highly correlated (p<0.01) except the control group of lower arch where the correlation relation was smaller (p>0.05) (Table 19.).

Table 17: Comparision of upper second premolar measurements.

		Study Group Average±SD	Control Group Average±SD	[+]p
Distance Between Right and Left U5BT	T0	43,95±3,41	44,97±3,61	*0,498*
	T1	46,69±1,88	48,48±2,74	*0,077*
	T2	48,00±1,77	48,92±2,27	*0,289*
	T3	47,46±1,41	48,60±2,38	*0,167*
	T0-T1 [++]p	*0,001***	*0,001***	
	T0-T2 [++]p	*0,001***	*0,001***	
	T0-T3 [++]p	*0,001***	*0,001***	
Distance Between Right and Left U5LT	T0	33,14±2,76	34,30±3,11	*0,356*
	T1	35,48±1,65	37,65±2,56	*0,022**
	T2	36,85±1,59	38,07±2,31	*0,150*
	T3	36,26±1,28	37,66±2,25	*0,072*
	T0-T1 [++]p	*0,001***	*0,001***	
	T0-T2 [++]p	*0,001***	*0,001***	
	T0-T3 [++]p	*0,001***	*0,001***	
Distance Between Right and Left U5LP	T0	29,43±2,27	30,88±2,78	*0,185*
	T1	30,86±1,46	33,08±2,10	*0,007***
	T2	31,78±1,67	33,59±2,00	*0,028**
	T3	31,52±1,29	33,36±1,86	*0,011**
	T0-T1 [++]p	*0,003***	*0,002***	
	T0-T2 [++]p	*0,001***	*0,001***	
	T0-T3 [++]p	*0,001***	*0,002***	

Table 18: Comparision of lower second premolar measurements.

		Study Group Average±SD	Control Group Average±SD	[+]p
Distance Between Right and Left L5BT	T0	37,56±3,00	38,57±1,71	*0,352*
	T1	39,85±1,45	40,89±1,87	*0,148*
	T2	40,25±1,41	41,19±1,92	*0,192*
	T3	40,06±1,58	40,60±1,72	*0,442*
	T0-T1 [++]p	*0,003***	*0,001***	
	T0-T2 [++]p	*0,001***	*0,002***	
	T0-T3 [++]p	*0,001***	*0,002***	
Distance Between Right and Left L5LT	T0	29,26±2,87	29,75±1,83	*0,646*
	T1	30,78±1,83	31,70±1,56	*0,219*
	T2	31,12±1,67	32,09±1,63	*0,178*
	T3	30,89±1,53	32,00±1,28	*0,079*
	T0-T1 [++]p	*0,002***	*0,001***	
	T0-T2 [++]p	*0,001***	*0,001***	
	T0-T3 [++]p	*0,005***	*0,001***	
Distance Between Right and Left L5LP	T0	28,30±2,91	28,69±1,47	*0,707*
	T1	29,64±1,82	30,11±1,52	*0,522*
	T2	30,02±1,64	30,51±1,49	*0,467*
	T3	29,63±1,76	30,23±1,23	*0,368*
	T0-T1 [++]p	*0,005***	*0,002***	
	T0-T2 [++]p	*0,002***	*0,001***	
	T0-T3 [++]p	*0,006***	*0,002***	

Table 19: Correlation between increase of distances between second premolar palatal tubercules and palatal points.

			Study Group Average±SD	Control Group Average±SD
			Increase in distance between second premolar lingual points	
Upper Arch	Increase in distance between second premolar lingual tubercules	r	0,978**	0,576
		p	0,001	0,082
Lower Arch		r	0,940**	0,903**
		p	0,001	0,001

6.4.4. Measurements for First Molar

The distances between right and left lingual tubercules and lingual points of upper first molar displayed significant differences at all measurement times in fayour of control group (p<0.05) (Table 20,21.).

The measured distance between right and left buccal tubercules of upper first molar was 49,39±2,41 mm for study group initially and increased to 49,72±1,99 mm at T1, 50,60±2,04 mm at T2 and 50,38±1,78 mm at T3; where the increase was found statistically significant for T0-T2 and T0-T3 periods (T0-T2 p<0.01, T0-T3 p<0.05). The distance between right and left buccal tubercules of upper first molar was 51,26±2,27 mm initially for control group. The measurement was recorded as 51,86±2,80 mm at T1, 52,55±3,00 mm a T2 and 52,39±3,04 mm at T3. The increase was found statistically significant for T0-T2 and T0-T3 periods (T0-T2 p<0.01, T0-T3 p<0.05).

The distance between right and left lingual tubercules of upper first molar was 37,87±2,84 mm and 40,31±1,69 mm for study and control groups respectively. At T1 38,12±2,42 mm in study group and 40,97±2,55 mm in control group were recorded. The increase was significant for both groups (p<0.05). The distances were found as 38,50±2,71 mm in study and 41,18±2,21 mm in control groups respectively at T2;

showing a statistically siginificant difference when compared to initial values (p<0.05). At the end of the treatment the values were recorded as 38,46±2,28 mm 41,05±2,00 mm and for study and control groups respectively; again significantly different from initial values (p<0.05).

The distance between right and left lingual points of upper first molar did not present any significant difference in both groups (p>0.05).

The changes in lower first molar measurements were different between groups. The values resulted in significant difference in study group for distances between buccal and lingual tubercules (p<0.05), though no statistically significant change was observed for control group (p>0.05).

The measured distance between right and left buccal tubercules of lower first molar was 43,05±2,01 mm for study group initially and increased to 44,21±2,49 mm at T1, 44,44±1,55 mm at T2 and 44,41±1,79 mm at T3; where the increase was found statistically significant for T0-T1 (p<0.05), T0-T2 and T0-T3 periods (p<0.01). The distance between lingual tubercules was 32,52±1,72 mm initially and increased to 33,39±1,96 mm at T1, 33,82±1,42 mm at T2 and 33,28±1,27 mm at T3; where the increase was found statistically significant for T0-T1 (p<0.05), T0-T2 (p<0.01) and T0-T3 periods (p<0.05).

The distance between lingual points of lower first molar did not display a significant difference at any treatment period in both groups (p>0.05).

Table 20: Comparision of upper first molar measurements.

		Study Group Average±SD	Control Group Average±SD	[+]p
Distance Between Right and Left U6BT	T0	49,39±2,41	51,26±2,27	0,073
	T1	49,72±1,99	51,86±2,80	0,064
	T2	50,60±2,04	52,55±3,00	0,078
	T3	50,38±1,78	52,39±3,04	0,061
	T0-T1 [++]p	0,375	0,126	
	T0-T2 [++]p	0,007**	0,006**	
	T0-T3 [++]p	0,040*	0,029*	
Distance Between Right and Left U6LT	T0	37,87±2,84	40,31±1,69	0,026*
	T1	38,12±2,42	40,97±2,55	0,012*
	T2	38,50±2,71	41,18±2,21	0,019*
	T3	38,46±2,28	41,05±2,00	0,013*
	T0-T1 [++]p	0,474	0,160	
	T0-T2 [++]p	0,047*	0,019*	
	T0-T3 [++]p	0,038*	0,017*	
Distance Between Right and Left U6LP	T0	33,17±1,94	35,22±1,89	0,019*
	T1	33,27±1,93	35,14±2,66	0,013*
	T2	33,57±1,99	35,70±2,33	0,028*
	T3	33,47±1,70	35,53±2,34	0,028*
	T0-T1 [++]p	0,077	0,806	
	T0-T2 [++]p	0,230	0,270	
	T0-T3 [++]p	0,450	0,190	

Table 21: Comparision of lower first molar measurements.

		Study Group Average±SD	Control Group Average±SD	[+]p
Distance Between Right and Left L6BT	T0	43,05±2,01	43,99±1,84	*0,260*
	T1	44,21±2,49	44,34±2,26	*0,903*
	T2	44,44±1,55	44,13±2,78	*0,733*
	T3	44,41±1,79	44,79±2,06	*0,643*
	T0-T1 [++]p	*0,019**	*0,428*	
	T0-T2 [++]p	*0,002***	*0,773*	
	T0-T3 [++]p	*0,001***	*0,063*	
Distance Between Right and Left L6LT	T0	32,52±1,72	33,72±1,28	*0,080*
	T1	33,39±1,96	33,91±1,66	*0,513*
	T2	33,82±1,42	34,19±2,25	*0,635*
	T3	33,28±1,27	34,22±1,70	*0,143*
	T0-T1 [++]p	*0,012**	*0,658*	
	T0-T2 [++]p	*0,001***	*0,416*	
	T0-T3 [++]p	*0,049**	*0,297*	
Distance Between Right and Left L6LP	T0	32,84±2,33	32,93±1,11	*0,912*
	T1	32,93±1,95	32,65±1,91	*0,734*
	T2	32,86±1,62	32,44±1,99	*0,582*
	T3	32,95±1,75	32,97±1,54	*0,762*
	T0-T1 [++]p	*0,785*	*0,469*	
	T0-T2 [++]p	*0,946*	*0,230*	
	T0-T3 [++]p	*0,818*	*0,900*	

6.4.5. Comparision of Changes

The average of changes for performed model measurements displayed a significant difference only for upper first premolar. The increases were significantly higher for study group (p<0.05) (Table 22.).

Table 22: Comparision of average diffences of model measurements.

	Study Group Average±SD	Control Group Average±SD	^{+}p
Distance Between Right and Left UCT	1,16±1,27 (1,52)	0,61±1,52 (0,60)	*0,107*
Distance Between Right and Left UCLP	0,97±0,94 (0,47)	0,77±0,76 (0,50)	*0,852*
Distance Between Right and Left LCT	1,32±2,31 (1,08)	0,75±1,05 (0,72)	*0,457*
Distance Between Right and Left LCLP	0,68±0,97 (0,84)	0,91±1,14 (0,79)	*0,620*
Distance Between Right and Left U4BT	3,94±1,42 (4,14)	2,46±1,26 (2,27)	*0,035**
Distance Between Right and Left U4LT	3,85±1,59 (3,89)	2,55±1,40 (2,71)	*0,047**
Distance Between Right and Left U4LP	2,78±1,12 (3,02)	1,66±1,19 (1,95)	*0,041**
Distance Between Right and Left L4BT	2,65±1,62 (3,46)	1,91±1,29 (1,80)	*0,172*
Distance Between Right and Left L4LT	2,25±1,74 (2,93)	2,04±1,17 (2,09)	*0,495*
Distance Between Right and Left L4LP	1,89±1,32 (2,31)	1,54±0,71 (1,67)	*0,264*
Distance Between Right and Left U5BT	3,50±2,68 (2,64)	3,63±2,15 (3,55)	*0,710*
Distance Between Right and Left U5LT	3,12±2,18 (2,73)	3,36±2,18 (3,14)	*0,710*
Distance Between Right and Left U5LP	2,09±1,50 (2,02)	2,48±1,80 (2,32)	*0,756*
Distance Between Right and Left L5BT	2,50±1,77 (2,45)	2,02±1,51 (1,78)	*0,495*
Distance Between Right and Left L5LT	1,63±1,69 (1,53)	2,25±1,29 (2,18)	*0,535*
Distance Between Right and Left L5LP	1,33±1,42 (1,48)	1,55±1,06 (1,86)	*0,804*
Distance Between Right and Left U6BT	0,99±1,55 (1,08)	1,13±1,38 (1,39)	*0,901*
Distance Between Right and Left U6LT	0,69±1,57 (0,97)	0,74±0,79 (0,73)	*0,710*
Distance Between Right and Left U6LP	0,35±0,22 (0,30)	0,32±0,25 (0,31)	*0,905*
Distance Between Right and Left L6BT	1,36±1,15 (1,48)	0,79±1,18 (0,69)	*0,264*
Distance Between Right and Left L6LT	0,76±1,25 (0,66)	0,49±1,42 (1,14)	*0,804*
Distance Between Right and Left L6LP	0,08±1,29 (0,54)	0,04±0,99 (0,28)	*0,951*

6.4.6. Available Arch Lenght

Available arch lenght for upper were 64,83±2,44 mm for study group and 66,47±1,95 mm for control group initially; indicating no significant difference between groups (p>0.05). At T1 upper available arch lenght for study group increased up to 68,86±2,93 mm. This increase was significant when compared with pretreatment value (p<0.01). At following T2 and T3, the available arch lenghts for upper arch in study group became 69,39±2,65 mm and 69,32±2,57 mm respectively. The increase at both T2 and T3 were significant when compared to pretreatment values (p<0.01). The available arch lenght became 70,04±2,03 mm at T1, 70,42±2,16 mm at T2 and 70,26±2,33 mm at T3 for control group. Again the increase was significant for all stages of treatment when compared with initial measurements (p<0.01).

Available arch lenght for lower were 54,91±2,85 mm for study group and 56,44±1,66 mm for control group initially; indicating no significant difference between groups (p>0.05). At following T1, T2 and T3, the available arch lenghts for upper arch in study group became 59,76±3,12 mm, 60,66±1,97 mm and 60,70±1,89 mm respectively. The increases were significant when compared to pretreatment values (p<0.01). The available arch lenght became 61,06±2,70 mm at T1, 61,19±2,61 mm at T2 and 61,38±2,80 mm at T3 for control group. Again the increase was significant for all stages of treatment when compared with initial measurements (p<0.01).

The change in increase of available arch lenghts for both arches was not significant between groups (p>0.05).

The changes in available arch lenght for upper arch are listed in Table 23 and for lower arch in Table 24. The comparision of average in changes are shown in Table 25.

Table 23: Comparision of upper available arch lenght.

Upper Arch	Study Group Average±SD	Control Group Average±SD	^+p
T0	64,83±2,44	66,47±1,95	*0,098*
T1	68,86±2,93	70,04±2,03	*0,291*
T2	69,39±2,65	70,42±2,16	*0,328*
T3	69,32±2,57	70,26±2,33	*0,373*
T0-T1 ^{++}p	*0,001***	*0,001***	
T0-T2 ^{++}p	*0,001***	*0,001***	
T0-T3 ^{++}p	*0,001***	*0,001***	

Table 24: Comparision lower available arch lenght.

Lower Arch	Study Group Average±SD	Control Group Average±SD	^+p
T0	54,91±2,85	56,44±1,66	*0,150*
T1	59,76±3,12	61,06±2,70	*0,303*
T2	60,66±1,97	61,19±2,61	*0,588*
T3	60,70±1,89	61,38±2,80	*0,489*
T0-T1 ^{++}p	*0,001***	*0,001***	
T0-T2 ^{++}p	*0,001***	*0,001***	
T0-T3 ^{++}p	*0,001***	*0,001***	

Table 25: Comparision of changes in available arch lenghts.

		Study Group Average±SD (Med.)	Control Group Average±SD (Med.)	^+p
Upper Arch	**T0-T1**	4,03±1,15 (3,91)	3,57±1,57 (3,75)	*0,620*
	T0-T2	4,55±1,15 (4,11)	3,95±1,37 (4,45)	*0,352*
	T0-T3	4,49±1,05 (4,20)	3,80±1,55 (3,50)	*0,172*
Lower Arch	**T0-T1**	4,83±2,16 (5,19)	4,62±1,56 (4,40)	*0,620*
	T0-T2	5,74±1,79 (6,01)	4,75±1,65 (4,55)	*0,137*
	T0-T3	5,78±2,03 (6,01)	4,95±1,73 (3,50)	*0,239*

6.4.7. Arch Discrepancy

The arch discrepancies were 4,38±1,11 mm in upper and 5,67±2,05 mm in lower for study group; 3,50±1,15 mm in upper and 4,90±1,64 mm in lower for control group initially. There was no statistically significant difference between groups for both arches (p>0.05). After insertion of the preadjusted appliances, before switching to rectangular Ni-Ti wire, the discrepancies decreased and measured as 0,41±0,95 mm in upper and 0,96±1,76 mm in lower for study group and 0,38±0,80 mm in upper and 0,20±0,42 mm in lower for control group. At T2 and T3 arch discrepancies were 0 mm for both groups. The results are shown in Table 26 and 27.

Initial upper and lower arch discrepancy values were also compared for each group. The initial lower arch discrepancy displayed a significantly higher value than upper arch in both groups (p<0.05). The comparision is shown at Table 28.

Table 26: Comparision of upper arch discrepancy.

Upper Arch	Study Group Average±SD (Med.)	Control Group Average±SD	^+p
T0	4,38±1,11 (4,07)	3,50±1,15 (3,54)	*0,107*
T1	0,41±0,95 (0)	0,38±0,80 (0)	*0,797*

Table 27: Comparision of lower arch discrepancy.

Lower Arch	Study Group Average±SD (Med.)	Control Group Average±SD (Med.)	^+p
T0	5,67±2,05 (5,96)	4,90±1,64 (4,79)	*0,292*
T1	0,96±1,76 (0)	0,20±0,42 (0)	*0,254*

Table 28: Comparision of initial arch discrepancy between upper and lower arches.

	Study Group Average±SD (Med.)	Control Group Average±SD (Med.)
Upper	4,38±1,11 (4,07)	3,50±1,15 (3,54)
Lower	5,67±2,05 (5,96)	4,90±1,64 (4,79)
^+p	*0,029**	*0,031**

6.4.8. Irregularity Index

The irregularity index was measured at all four measurement times. The initial measurement of upper arch for study group was 12,46±3,58 mm and 10,69±3,81 mm for control group. For the lower arch the initial measurements were as follows: 9,16±3,77 mm in study group and 9,02±2,44 mm in control group. The difference between groups were not statistically significant at the start of the treatment (p>0.05). At the second phase of the treatment, before the start of rectangular Ni-Ti

wires the irregularity index measurements were as follows: for study group 2,27±3,22 mm in upper and 1,65±2,41 mm in lower; for control group 0,35±0,76 mm in upper and 0,43±0,75 mm in lower arches. Again the difference between groups were not statistically significant (p>0.05). The irregularity index dropped down to 0 mm for both groups before switching to rectangular stainless-steel wire. The irregularity index changes are shown in Table 29 and 30.

Table 29: Comparision of upper irregularity index.

Upper Arch	Study Group Average±SD (Med.)	Control Group Average±SD (Med.)	^{+}p
T0	12,46±3,58 (12,15)	10,69±3,81 (11,10)	*0,292*
T1	2,27±3,22 (0)	0,35±0,76 (0)	*0,109*

Table 30: Comparision of lower irregularity index.

Lower Arch	Study Group Average±SD (Med.)	Control Group Average±SD (Med.)	^{+}p
T0	9,16±3,77 (10,74)	9,02±2,44 (9,64)	*0,804*
T1	1,65±2,41 (0)	0,43±0,75 (0)	*0,193*

6.4.9. Constructed Arch Lenght

According to pretreatment measurements constructed arch lenghts were 68,16±2,84 mm (upper) and 57,38±3,35 mm (lower) for study group and 68,71±3,41 mm (upper) and 58,27±3,39 mm (lower) for control group; where the difference between groups was statistically insignificant (p>0.05). After the initial levelling with round wires, the constructed arch lenght measurements increased up to 70,40±3,03 mm and 71,65±2,60 mm for study group and control group in upper arch respectively and 60,07±3,41 mm for study group and 60,90±2,56 mm for control group in lower arch respectively. The increase of constructed arch lenght was statistically highly significant for both groups (p<0.01). After the insertion of

rectangular Ni-Ti wire 70,09±2,58 mm in upper and 60,50±3,08 mm in lower was measured in study group. 71,67±3,04 mm in upper and 60,55±2,59 mm in lower was measured for control group. At the end of the treatment the measurements were as follows: 70,19±2,89 mm in upper and 60,53±3,14 mm in lower for study group and 71,54±2,77 mm in upper and 60,60±2,59 mm in lower for control group. Comparision of constructed arch lenght for arches are shown in Table 31 and 32.

The average increases within measurement time peirods were not statistically significant between groups for both arches (p>0.05). The results are detailed for the average increases in Table 33.

Table 31: Comparision of constructed upper arch lenght.

Upper Arch	**Study Group** Average±SD	**Control Group** Average±SD	^+p
T0	68,16±2,84	68,71±3,41	*0,677*
T1	70,40±3,03	71,65±2,60	*0,311*
T2	70,09±2,58	71,67±3,04	*0,195*
T3	70,19±2,89	71,54±2,77	*0,273*
T0-T1 ^{++}p	*0,001****	*0,003****	
T0-T2 ^{++}p	*0,001****	*0,005****	
T0-T3 ^{++}p	*0,001****	*0,009****	

Table 32: Comparision of constructed lower arch lenght.

Lower Arch	Study Group Average±SD	Control Group Average±SD	^+p
T0	57,38±3,35	58,27±3,39	*0,536*
T1	60,07±3,41	60,90±2,56	*0,529*
T2	60,50±3,08	60,55±2,59	*0,967*
T3	60,53±3,14	60,60±2,59	*0,951*
T0-T1 ^{++}p	*0,005***	*0,003***	
T0-T2 ^{++}p	*0,001***	*0,006***	
T0-T3 ^{++}p	*0,001***	*0,003***	

Table 33: Comparision of average changes for constructed arch lenght.

		Study Group Average±SD (Med.)	Control Group Average±SD (Med.)	^+p
	T0-T1	2,24±1,80 (1,66)	2,93±2,31 (2,44)	*0,495*
Upper Arch	**T0-T2**	1,94±1,65 (1,81)	2,95±2,49 (2,65)	*0,352*
	T0-T3	2,03±1,65 (1,60)	2,83±2,82 (2,70)	*0,687*
	T0-T1	2,68±2,86 (3,16)	2,62±2,06 (3,45)	*0,951*
Lower Arch	**T0-T2**	3,11±2,39 (3,46)	2,27±1,98 (2,37)	*0,385*
	T0-T3	3,14±2,33 (3,29)	2,33±1,84 (2,45)	*0,828*

6.5. Evaluation of Clinical Efficiency

6.5.1. Treatment Time

Total treatment times were not statistically different between groups (p>0.05) except the difference at T0-T1 period which was shorter for study group in upper arch (p<0.05) (Table 34.). Total treatment time was similar between groups (p>0.05) (Table 35.).

Table 34: Comparision of treatment time for each period (Weeks).

		Study Group Average±SD (Med.)	Control Group Average±SD (Med.)	[+]p
Upper Arch	**T0-T1**	23,84±13,30 (18)	36,40±14,29 (37)	*0,041**
	T1-T2	18,92±10,67 (16)	20,70±12,86 (14)	*0,950*
	T2-T3	51,15±30,16 (58)	30,30±18,63 (23,5)	*0,145*
Lower Arch	**T0-T1**	32,69±18,44 (33)	35,10±10,75 (31)	*0,718*
	T1-T2	32,84±20,08 (27)	19,40±13,58 (14,5)	*0,114*
	T2-T3	24,92±18,11 (24)	26,20±15,23 (22,5)	*0,708*

Table 35: Comparision of total treatment time (Months).

	Study Group Average±SD	Control Group Average±SD	[+]p
Total treatment time	23,32±5,14	20,35±3,59	*0,134*

6.5.2. Ligating Time of Wires

Arch ligating times elapsed were significantly smaller for study group for all measurement times (p<0.01). In study group the average time elapsed for initial wire was 30,84±11,80 seconds for upper and 33,61±16,48 seconds for lower. For the same arch the average time elapsed was 218,50±31,09 seconds for upper and 202,00±41,37

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seconds for lower for control group. The average of arch ligating time decreased to 24,92±11,79 seconds for upper and 27,31±10,74 seconds for lower in the study group during ligation of 0.16 inch Ni-Ti, though the difference was not significant (p>0.05). The decrease in time for following arches were significant in study group for both upper and lower (p<0.05). In the control group 0,16 inch Ni-Ti, 16.22 inch rectangular Ni-Ti and 16.22 stainless steel arch ligation times decreased significantly for upper arch (p<0.05). Time elapsed for corresponding arches did not change significantly for lower (p>0.05) (Table 36,37.).

Table 36: Comparision of ligating time of upper wires (Seconds).

Upper Arch	Study Group Average±SD (Med.)	Control Group Average±SD (Med.)	[+]*p*
0.012 Biostarter	30,84±11,80 (28)	218,50±31,09 (230)	*0,001***
0.16 Ni-Ti	24,92±11,79 (20)	185,10±32,00 (195,5)	*0,001***
16.22 Ni-Ti	19,84±14,30 (15)	196,00±13,50 (195)	*0,001***
16.22 SS	14,30±7,06 (12)	193,00±13,98 (197,5)	*0,001***
T0-T1 [++]*p*	*0,100*	*0,020**	
T0-T2 [++]*p*	*0,012**	*0,042**	
T0-T3 [++]*p*	*0,002***	*0,050**	

Table 37: Comparision of ligating time of lower arch wires (Seconds).

Lower Arch	Study Group Average±SD (Med.)	Control Group Average±SD (Med.)	^+p
0.012 Biostarter	33,61±16,48 (35)	202,00±41,37 (197,5)	*0,001***
0.16 Ni-Ti	27,31±10,74 (26)	210,00±32,66 (200)	*0,001***
16.22 Ni-Ti	18,54±13,46 (15)	197,00±21,10 (200)	*0,001***
16.22 SS	15,54±11,80 (12)	190,50±16,74 (187,5)	*0,001***
T0-T1 ^{++}p	*0,074*	*0,952*	
T0-T2 ^{++}p	*0,002***	*0,574*	
T0-T3 ^{++}p	*0,002***	*0,332*	

6.5.3. Incidence of Bracket Loss

The average of bracket loss was 1,61±2,06 in study group and 1,80±1,81 in control group (Table 38.). There was no statistically significant difference between groups (p>0.05).

Table 38: Comparision of incidence of bracket loss.

	Study Group Average±SD (Med.)	Control Group Average±SD (Med.)	^+p
Total bracket loss	1,61±2,06 (2)	1,80±1,81 (2)	*0,644*

6.5.4. Incidence of Clip Deformation/breakage and Loss of Ligation

The number of clip deformation/breakage was between 0 and 13. The average was 4,15±3,43 (4).

No loss of ligation in control group was observed.

7. DISCUSSION

7.1 Discussion Of Aim

Self-ligating brackets have been proposed to replace with conventionally ligated brackets. They offered improvement for clinical deficiencies and difficulties of ligation with elastomers or stainless-steel ligatures.

Self-ligating brackets have also been thought as applying less ligation force and hence producing less friction than conventionally ligated brackets. It is suggested that due to increased intraslot wire play resulting in less friction and reduction in the magnitude of the generated forces, treatment time is shortened. Numerous literatures suggested that self-ligating mechanism also provide consistent archwire engagement and elimination of need for frequent visits for the replacement of ligatures. Self-ligating brackets are also promoted to require less chair time and less need of chair-side assistance because they are faster and easier for archwire removal and ligation (130, 50, 34, 46).

The idea of non-extraction protochol with mild crowded cases due to the ability of expansion of arches with self-ligating brackets was also another area of interest. Because the main starting point that self-ligating brackets accompolished less friction arouse conflicting results in literature.

There are numerous laboratary studies performed with straight line traction, all stating self-ligating brackets having less frictional resistance than conventionally tied brackets (125, 115, 23). These studies neglected second order angulations which resulted with binding and notching.

Studies with model designed to simulate first and second order corrections revealed self-ligating brackets outperformed conventional brackets when smaller diameter archwires were engaged. But when larger diameter arch-wires were engaged or second order angulations increased, the two bracket types were more comparable (55, 85, 100, 114).

Active and passive self-ligating brackets also differed in manner of friction. Studies noted that passive self-ligating brackets exhibited significantly lower friction than active ones (97, 113, 115). Using a buccal segment model, Taylor and Ison (124) reported similar findings with passive self-ligating brackets. The brackets had significantly less frictional resistance than self-ligating brackets with an active spring-clip and conventionally tied brackets.

In contrast, Bednar et al (14) testing self-ligating brackets with an active spring clip and Loftus et al (73) testing self-ligating brackets with a passive spring clip found these bracket types performed no better than conventional stainless steel brackets ligated by either elastomers or steel ties. They utilised friction tests using an approximated center of resistance that permitted free second order tipping.

The validity of laboratory friction studies conducted in the steady state has also been questioned. For example, comparision of clinical and laboratory measurements has shown that less force was needed when test jigs were used to measure resistance to tooth movement intraorally than in laboratory. It was suggested that this was due to the effect of occlusal forces on tooth movement in the mouth. This view is supported by the observation that simulated occlusal forces can temporarily abolish friction for some bracket/archwire combinations (74, 22).

The question of validity of laboratory studies stated that clinical results would be more valuable. And the number of laboratory studies exceeded the number of clinical studies. The clinical study results also opposed each other.

Harradine (50), Eberting et al (34), Gerber (46) all reported reduction in number of visits during active treatment and that overall treatment time was shorter.

In contrast with these studies; some authors concluded in randomised clinical trials that neither initial nor overall difference in rate of mandibular insicor alignment was present between conventional and self-ligating brackets (80, 111). Miles (81) also concluded that there was no difference in time and closure rate of extraction spaces among the two types of system of brackets tested.

Clinical studies agreed on the point that dramatically less chair time for arch wire removal and insertion compared with wire ligation of conventinonal brackets is required (18, 75, 113, 130).

Treatment of a crowded dental arch on a non-extraction basis, without tooth size reduction, requires an increase in arch perimeter to allow resolution of crowding and achievement of optimum arch levelling and allignment. Without active distal movement, changes typically involve both transverse expansion and proclination (139).

Self-ligating system proposes to resolve anterior crowding through expansion of the posterior width rather than expansion of inter-canine width. The posterior expansion is supported by Damon's philosophy that a self-ligating creates more stable tooth positions by incorporating the use of lighter forces in conjuction with the body's own physiolojic adaptations. Damon also presents that more expansion occurs in the inter-molar width than in the inter-canine width (30). This study evaluates if the transverse expansion of conventional and self-ligating brackets at canine, premolar and molar areas are the same.

This study deals with aspects of treatment efficiency of the self-ligating appliance, Quick bracket, as they compare with the conventional system. It is note-worthy that the especially clinic data available on self-ligation is limited and still there is no published research information for several bracket systems. Quick brackets have not been compared clinically before.

In present study the aim is to compare the clinical effects of self-ligating brackets and conventional brackets on dental arch and profile and clinical efficiency.

7.2. Discussion of Material and Method

Skeletally and dentally Class I patients with complete permanent dentition and with normal growth pattern and development were chosen. Patients with cleft lip and palate or missing/ectopic teeth were excluded because they were likely to represent unusual outliners in overall treatment time or time taken to manipulate archwires.

Patients who had previous orthodontic intervention were discluded as this might interfere with the results.

Ages of the subjects ranged from 10 to 24 years. The average age of the study group was 16,22±3,73 and that of control group was 14,57±2,20. The average ages of groups were comparable to previous studies (130, 111, 40). Sex distribution of this study was similar within groups: 10 females (76,9 %) and 3 males (23,1 %) in study group; 7 females (70,0 %) and 3 males (30,0 %) in control group. Gender was not found to be a factor in clinical outcomes of studies comparing two systems (34). Scott et al (111) also concluded that age and gender did not effect rate of tooth movement in both systems.

Attention was paid to the amount of initial crowding and irregularity index to be similar and not to be over limits of a non-extraction treatment protocol. In this study the treatment outcomes were discussed between two types of bracket systems on a non-extraction basis (40). Studies including extraction of premolars aim mainly to compare the rate of space closure with sliding mechanics (111, 81). The main focus then differs from studies investigating dental arch expansion amounts without extraction.

Patients who met the first selection criteria were randomly distributed among groups. The initial lateral and postero-anterior cephalometric measurements and model analyses showed that the groups were comparable.

The treatments of both groups were performed by the same researcher. Studies conducted by one researcher might reflect more trustable results than a study conducted by two or more researchers (80). Because the operator's ability and experience might distort the outcomes of the studies (40). Studies including patients treated by different orthodontic residents in clinics might even be more difficult to compare (111, 130, 34). Eberting et al (34) conducted a clinical study in three different university clinics and discussed if the residents' rush to complete their programme could have affected the results of the study.

The conventional and self-ligating brackets were clinically compared. The clinical comparision was based on clinical efficiency, post-treatment dental arch and profile changes.

The measurement of dental transverse expansion includes the expansion in inter-canine area, inter-premolar area and inter-molar area. In this study for the purpose of setting the reference points for the mesurements, tubercule tips and lingual tooth-gingiva junction points were used on the referral of previous studies (8, 40, 58). Some authors preferred the centric fossa of premolars (37) or centric fossa of molar (47, 88, 111).

Available arch lenght was mesured from mesial contact point of first molar to mesial contact of opposite side first molar. The degree of crowding, arch discrepancy, was assesed by substracting the sum of tooth material from available arch lenght (40).

Constructed arch lenght was measured from mesial contact point of first molar to midpoint between central insicors. This was also an accepted method of masurement used previously (111).

Irregularity index was used in a large number of clinical studies as a reference value for comparision of treatment efficiency (111, 88, 80, 82).

After bonding, 0,012 inch round 'BioStarter12' archwire (Forestadent Bernhard Forester GmbH, Westliche, Pforzheim, Germany) was ligated in both groups. The subjects were rewieved at approximately 6 weeks intervals and a sequence of 0,016 inch Ni-Ti, 0,016-0,022 inch Ni-Ti and 0,016-0,022 inch stainless steel archwires were used. Archwire progression occurred only if full engagement was possible. Dental impressions for recording purposes were taken at T0 –before starting treatment-, at T1 –the end of initial levelling signified by placement of 0,016-0,022 inch Ni-Ti, and at T2 –the end of final leveling stage signified by the placement of 0,016-0,022 inch stainless steel archwire. T3 represented the post treatment records. The data collection periods were similar to previous studies (88, 111, 44).

The study by Fleming et al (40) collected final data after 8 weeks of insertion of 0.019-0,025 stainless steel arch-wire. The difference of finishing wires can be attributed to difference of bracket slots which in discussed study is 0.22 slot.

'BioStarter12' archwire (Forestadent Bernhard Forester GmbH, Westliche, Pforzheim, Germany) was the initial archwire utilised in the study. In a recent report, it was stated to generate the lowest forces compared with leveling arches of different companies (36).

The archwires used through the levelling and allignment stage were not cinched in this study as the mechanism of cinching is difficult to standardize. This is in accordance with the study of Fleming et al (40). An effect of archwire cinching is a dramatic increase in moments around the center of resistance of included teeth. Therefore, not cinching the archwires might affect the pattern of insicor proclination by masking the third-order effects produced by the rectangular archwires.

In numerous literatures elastomeric ligatures were used for conventionally ligated brackets for the comparision within self-ligating and conventional brackets (80, 82, 88, 111). Stainless steel ligatures were preferred in this study as they are suggested to produce lesser friction compared to elastomers (14, 110, 113).

For recording purposes, Scott et al (111), Pandis et al (88), Fleming et al (40), Gilbert (47), Miles (80) got alginate impressions and obtained dental casts. Digital calipers were used in all studies to measure dental cast changes.

Franchi et al (37) used a different method of measuring dental arch changes. In their study the coordinates of all points were digitized by using a 3-dimensional electromagnetic digitizer (Microscribe-3DX, Immersion, San Jose, Calif.) interfaced with a computer. The data were stored, and measurements were made with software (Rhinoceros NURBS modelling for Windows, Robert McNeel and Assoc., Seattle, Washington).

In this study digital models have been used for evaluating the effects of treatment on the dental arch. Digital models have been subject to literature for validity.

The programmes used for the scanning of models to produce digital models have been tested for validitiy and these programmes all posses U.S.A. origin. In numerous studies comparing dental and digital models for tooth size, overbite and overjet, dental measurements, Bolton analyses, diagnosis and treatment planning, PAR index measurements E-model (U.S.A.) and Orto-Cad (U.S.A.) programmes have been used (45, 99, 117, 126, 144, 31). We have used Orthomodel (Turkiye) programme.

There is only one study performed on the validity of Orthomodel digital models which stated that digital models were as reliable as the dental stone models (1).

Digital model companies recommend that the alginate imppressions be sent to the company within a day sealed in a plastic bag or wrapped in humid towels. The impressions are then poured with dental stone and stone models are prepared. The dental models are scanned and digital models are prepared (60, 108).

Alcaniz et al (2) scanned the impression directly to construct the digital model. They stated that due to the blind points during scanning, servical points and contact points of the teeth were not as accurate as wished. The Orthocad company states that they can scan the impressions directly (60). But no study was found in literature performed on direct scan of impressions.

In our study, to decrease the probability of any dimensional deformation, alginate impressions were sent to the company in a sealed plastic bag and they were processed at the same day of delivery. 3Shape D250 scanner and 3 Shape Orthoanalyser programme was used in this study.

7.3. Discussion of Results   .

The aim of this study was to evaluate if there is significant difference between Quick self-ligating system and the traditionally ligated MIB brackets in manner of clinical efficiency, effect of mechanism on dental arch and soft tissue profile.

Clinical efficiency was measured in terms of levelling effectiveness, treatment period, chair time and any type of failure involving ligation. In addition, the mechanism of tooth allignment was studied in relation to changes in arch lenght, intercanine width, interpremolar width and intermolar width by using digital models.

Lateral cephalometrics were included for pre and post treatment dental and soft tissue profile changes. Postero-anterior cephalometrics contributed to expansion results. The data collected during this investigation has shown that in the sample investigated, the Quick self-ligating brackets was no more clinically effective than a conventionally ligated appliance except the chair time.

7.3.1. Discussion of Postero-anterior and Lateral Cephalometric Results

The initial values for lateral and postero-anterior cephalometric findings were comparable between groups (p>0.05).

SN-MP, SNA and SNB; together with the angle determining intermaxillary relation –ANB– remained nearly constant at the pre and post treatment comparision in both groups.

The average changes for SN-MP, SNA, SNB and ANB were comparable within groups. As the patients undergoing treatment were skeletally Class I at the begining, no procedure was involved to change skeletal relations. So the result of no significant change for these parameters is an expected finding.

In this study 4,15±2,30 (4) degrees of change in study group and 5,10±8,28 (7,5) degrees of change in control group was measured for UI-SN angle. UIT-NA measurement increased slightly in both groups: 1,85±1,46 (1,5) mm in self-ligating group and 1,25±3,31 (1,5) mm in conventional group. UIT-Y axis measurement increased similarly: 1,11±2,41 (1,5) mm and 3,40±4,57 (3) mm in study and control groups respectively. The values for UIA-Y axis were 0,84±2,02 (1) mm and 1,80±3,88 (1,5) mm. The parameters mentioned increased but did not present a significant change (p>0.05). The results were also comparable within groups indicating similar results for torque delivery.

Similarly, Pandis et al (89) stated that change in UI-SN angle was 4.3±0.9 degrees for self-ligating group and 6.7±0.9 degrees for conventional system. The study also revealed no difference within groups. They concluded that self-ligating Damon2 brackets seem to be equally efficient in delivering torque to maxillary incisors relative to conventional brackets in extraction and non-extraction cases.

An in-vitro study confirmed these findings that no significant difference in terms of their levelling effectiveness and torque expression was observed (36).

Yu et al (143), in their study comparing RPE and Damon bracket effects, stated the upper incisors in Damon group were tipped forward by 9.2 degrees, while the change in RPE group was not significant (p<0.05). The increase in upper incisor inclination was higher than our results for self-ligating brackets.

The lips became more protrusive compared to pretreatment in both groups. LS-E line and LS-Y axis presented similar, significant differences from begining to end of the study in both groups (p<0.05). The upper lip approximated the E line by 1,11±1,14 (1,5) mm in study group and 1,20±2,85 (0,3) mm in control group. The changes were insignificant between groups. The naso-labial angle decreased by -1,29±8,94 (-1) degrees and -1,70±8,74 (-1,5) degrees in study and control groups respectively. This is in accordance with the increase in upper insicor inclination.

In the present study IMPA ended up with a siginificant increase for both groups discussed: 6±3,53 (6) degrees in self-ligating group and 7±6,98 (6) degrees in conventional group. The changes were similar between groups. Supporting this finding, the increase for LIT-NB, LIT-Y axis were significant for both of the groups. LIT-NB, LIT-Y axis and LIA-Y axis increased by 2,54±1,77 (2,5) mm, 3,23±2,35 (3) mm and 0,38±3,38 (1) mm respectively in study group. The changes for control group were 3,10±1,37 (3) mm, 5,10±4,67 (3,5) mm and 1,20±5,43 (1,5) mm in the same order. The changes similar between groups. It was concluded that lower insicors protruded in both groups.

Similarly, the study by Scott et al (111) stated proclination of mandibular incisors: 2.34±3,72 degrees for control group and 1,73±4,06 degrees for self-ligating Damon3 group at T2 period. The result was insignificant between groups. These changes are smaller when compared with our study, but extraction was involved in the study of Scott et al (111). This might explain the lesser proclination of mandibular incisors.

Fleming et al (40) stated an increase in IMPA value by 4.41 degree in Smart Clip self-ligating bracket and 4.32 degree in conventional brackets. The differences

were insignificant. These changes were also lower from our study which could be attributed to less initial amount of crowding in lower arch.

Weinberg and Sadowsky (139) stated 6 degrees of mandibular insicor proclination in non-extraction treatment protocol with conventional brackets. Initial irregularity index was 2.3 mm. The results were comparable to our study, altough the initial irregularity index was higher in our group.

Similarly, the study by Pandis et al (88) stated an increase in IMPA insignificant within groups: In self-ligating group from 93.70±7,88 degrees to 101.11±8,78 degrees and in control group from 95.66±5,95 degrees to 101.88±7,51 degrees. This data was collected at T2 period.

Again similar to our results, Yu et al (143) in their study comparing RPE followed by straightwire conventional appliances and Damon bracket effects, stated the lower incisors in Damon group were tipped forward by 7.5 degrees, while the change in RPE group was not significant (p<0.05).

The lower lip followed the changes of lower incisor. The lower lip also became more protrusive compared to pretreatment. LI-E line and LI-Y axis presented significant changes compared to pretreatment (p<0.05). The average changes for LI-E line were 1,23±1,09 (2) mm and 2,30±2,12 (2) mm for study and control groups respectively. The distance to Y axis changed in average by 2,04±2,30 (2) mm and 5,15±4,50 (5) mm in the same order. The average changes did not present a significant difference between groups (p>0.05).

The postero-anterior cephalometric findings stated no expansion in alveolar area of maxilla. The MW remained almost constant from begining to end of treatment for both groups. This is in accordance with a longitidunal growth study investigating the maxillary transverse growth from ages 6 to 18 (138). This study stated that this measurement remained nearly steady after 14 years of age. On the other hand UIMW showed a significant increase, indicating the buccal tipping of molars in both groups (p<0.05). The average changes were similar between groups, pointing a similar tipping (p>0.05).

7.3.2. Discussion of Model Measurement Results

Arch development is a therapeutic effect of fixed appliances in non-extraction treatment protocols. Dentoalveolar expansion leading to changes in archform and size has been documented in studies on the effectiveness of fixed appliances in orthodontic patients (58). Changes in transverse measures of the maxillary arch include increases in intercanine width from 0.55 mm (64) to 2.13 mm (16), interpremolar width (at second premolars) from 2.10 mm (64) to 4.94 mm (16) and intermolar width from 1.53 mm (64) to 2.96 mm (16). These modifications have an impact on arch perimeter with consequent production of space to accomodate teeth. The reported increase in arch perimeter or arch lenght range from 0.22 mm (20) to 1.8 mm (91).

Arch form development and posterior expansion of the dental arches have been indicated as effects of low-friction mechanics with self-ligating brackets during the initial phases of treatment with super-elastic nickel-titanium 0.014 inch wires (30).

In the present study the distance between right and left upper and lower canine tubercules and lingual points showed significant but similar increases comparing initial values. The low correlation between two measurements involving canine states that canines were tipped buccally in both groups.

The distance between right and left upper canine tubercules was 32,92±1,86 mm in study group initially. The distance increased to 33,73±1,68 mm at T1; 34,54±1,37 mm at T2 and then slightly decrased to 34,08±1,09 mm at T3; indicating significant differences (T0-T1 $p<0.05$, T0-T2 and T0-T3 $p<0.01$). The distance between lingual points was 25,08±2,36 mm initially, then increased to 25,51±2,13 mm at T1; 25,87±1,94 mm at T2 and 26,05±1,97 mm at T3; with statistically significant changes ($p<0.01$).

The distance between right and left upper canine tubercules was 33,48±2,22 mm in control group initially. The results were 34,56±1,97 mm at T1, 34,54±1,53 mm at T2 and 34,10±1,44 mm at T3. The difference was again statistically significant for all measurement times (T0-T1 $p<0.01$, T0-T2 and T0-T3 $p<0.05$). The distance between lingual points was 24,35±1,92 mm initially and 24,98±1,32 mm at T1,

25,20±1,50 mm at T2 and 25,12±1,58 mm at T3. The differences were again statistically significant for all measurement times (T0-T1, T0-T3 p<0.05, T0-T2 p<0.01).

The distance between right and left lower canine tubercules was 24,17±1,89 mm in study group at the start of the treatment. Then the distance increased to 26,05±1,13 mm at T1 and slightly decreased to 25,82±1,23 mm at T2 and 25,49±1,16 mm at the end of the treatment. The changes were again statistically significant (T0-T1, T0-T2 p<0.01, T0-T3 p<0.05). The distance between lingual points were 19,36±1,64 mm for study group at the begining of the treatment. The values were recorded as 20,25±1,09 mm at T1, 20,22±0,99 mm at T2 and 20,04±0,94 mm at T3 for study group; indicating statistically significant changes (p<0.05).

The distance between right and left lower canine tubercules was 24,98±1,23 mm in control group at the start of the treatment. The distance increased to 26,97±1,58 mm at T1, then slighly dropped to 26,35±1,29 mm at T2 and 25,49±1,16 mm at T3. The measurements were statististically siginificant when compared to initial results (T0-T1 p<0.01, T0-T2 and T0-T3 p<0.05). The distance between lingual points was 19,09±1,57 mm for control group at the begining of the treatment. The results were 20,43±1,36 mm at T1, 20,40±1,19 mm at T2 and 20,01±0,78 mm at T3. The changes were significant compared to initial measurements (p<0.05).

The average changes of canine measurements from T0-T3 in study group were slightly higher but not enough to represent a significant difference.

Similarly Gilbert (47) found no difference for inter-canine measurement (tips), pre and posttreatment, between two types of brackets, Damon2 brackets and conventionally ligated MBT brackets, at the treatment of both mild and moderate crowding Class I cases.

A study by Franchi et al (37), using low-friction ligatures rather than self-ligating brackets, found increases of 2.30 mm in upper intercanine width (cusps), 1.96 mm in intercanine width (lingual points). This study evaluated the first leveling and alignment stage of orthodontic treatment using 0.014 inch and 0.016 inch round wires with an average duration of 6 months. Findings of this study are higher

compared to our results involving upper canine. In this study distance between upper canine tubercules increased from 32,92±1,86 mm to 33,73±1,68 mm and lingual points increased from 25,08±2,36 mm to 25,51±2,13 mm. The results of both studies actually can not be compared exactly as the previous one involves low-friction ligatures. The common point is the increase in measurements of canine.

The study by Scott et al (111) also stated that the increase in mandibular intercanine width (cusp tips) from T0 to T2 was comparable between groups of self-ligating Damon3 brackets and conventionally ligated brackets. The increase was 2,66±2,33 mm in conventional group, whereas 2,55±2,27 was measured for Damon group. The study of Scott et al, different from the method of this study, included extraction cases and elastomeric ligatures. Approximately 1,08 mm increase in study group and 0,72 mm in control group was found in this study. The associated distal movement of canines into the wider section of the mandible might be explained by extractions. This statement could also explain higher results.

A clinical study, with initial amount of crowding 2,65 mm, stated a change of lower arch in inter-canine width (cusp tips), at 8 weeks after the ligation of rectangular stainless (40). No significant change within groups were observed. The results were comparable with this study.

Another clinical study by Pandis et al (88) compared Damon2 brackets with conventionally ligated brackets. They stated that mandibular inter-canine distance (cusp tips) increased: from 25.01±1,49 mm to 26.59±1,30 mm at T1 in control group and from 25.78±1,92 mm to 26.78±1,36 mm at T2 in study group. The differences were insignificant within groups, similar to results of this study, in spite of the difference in arch wire utilization.

Yu et al (143), in their study comparing RPE and Damon bracket effects, stated that upper and lower inter-canine width increased significantly 2.9 mm and 1.3 mm respectively in RPE group, while there was no significant change in Damon group.

In the present study, for the upper arch, the distances between buccal tubercules, lingual tubercules and lingual points of first and second premolars displayed a significant difference (p<0.01).

The measured distance between right and left buccal tubercules of upper first premolar was 38,54±2,23 mm for study group initially and increased to 41,77±1,60 mm at T1, 43,00±1,34 mm at T2 and the slightly decreased to 42,48±1,16 mm at T3. The distance between lingual tubercules was 27,90±1,97 mm initially. Then increased to 31,09±1,29 mm at T1 and 32,46±1,02 mm at T2. Presenting a slight decrease, ended as 31,75±0,98 mm at T3. The distance between lingual points was found to be 24,38±1,67 mm initially. The value then increased to 26,39±1,42 mm at T1, 27,34±1,42 mm at T2 and 27,16±1,28 mm at T3. The changes were all significantly different from initial values (p<0.01).

The distance between right and left buccal tubercules of upper first premolar was 40,64±2,23 mm initially for control group. The measurement was recorded as 43,30±2,02 mm at T1, 43,72±1,75 mm a T2 and 43,10±1,54 mm at T3. The distance between lingual tubercules was 29,68±1,89 initally, then increased to 32,42±2,08 mm at T1, to 32,90±1,45 mm at T2 and again with slight decrease resulted as 32,23±1,26 mm at T3. The distance between lingual points was found to be 26,30±1,90 mm initially, 28,17±1,64 mm at T1, 28,30±1,24 mm at T2 and 27,95±1,33 mm at T3. All changes compared to initial values were significant (p<0.01).

The initial value of distance between right and left buccal tubercules of second upper premolar was 43,95±3,41 mm for study group. The measurements increased to 46,69±1,88 mm at T1, 48,00±1,77 mm at T2 and then slightly decreased to 47,46±1,41 mm at T3. The change in the distance between lingual tubercules of second premolars from 33,14±2,76 mm to 35,48±1,65 mm at T1, 36,85±1,59 mm at T2 and 36,26±1,28 mm at T3 was reported. The measured distance between right and left lingual points of upper second premolar was 29,43±2,27 mm for study group initially and increased to 30,86±1,46 mm at T1, 31,78±1,67 mm at T2 and 31,52±1,29 mm at T3. The changes were found statistically significant at all times (p<0.01).

The initial value of distance between right and left buccal tubercules of second upper premolar was 44,97±3,61 mm for control group. The measurements increased to 48,48±2,74 mm at T1, 48,92±2,27 mm at T2 and then again slightly decreased to

48,60±2,38 mm at T3. For the distance between lingual tubercules the values were 34,30±3,11 mm, 37,65±2,56 mm, 38,07±2,31 mm and 37,66±2,25 mm for T0, T1, T2 and T3 respectively. The distance between right and left lingual points of upper second premolar was 30,88±2,78 mm initially. The measurement was recorded as 33,08±2,10 mm at T1, 33,59±2,00 mm a T2 and 33,36±1,86 mm at T3. The changes were found statistically significant at all times (p<0.01).

The average changes for upper first premolar were recorded as 3,94±1,42 (4,14) mm in study group, 2,46±1,26 (2,27) mm in control group for buccal tubercules; 3,85±1,59 (3,89) mm in study group and 2,55±1,40 (2,71) mm in control group for lingual tubercules; 2,78±1,12 (3,02) mm in study group, and 1,66±1,19 (1,95) mm in control group for lingual points.

The average changes for upper second premolar were recorded as 3,50±2,68 (2,64) mm in study group, 3,63±2,15 (3,55) mm in control group for buccal tubercules; 3,12±2,18 (2,73) mm in study group and 3,36±2,18 (3,14) mm in control group for lingual tubercules; 2,09±1,50 (2,02) mm in study group, and 2,48±1,80 (2,32) mm in control group for lingual points.

The changes were comparable within groups for upper second premolar but for upper first premolar there was a significant difference which was higher for study group (p<0.05). This stated that the dental arch expansion was greater in upper first premolar area for study group. No study was found in literature comparing changes in upper first and second premolar area.

The increases measured in distances between lingual tubercules and lingual points were highly correlated for both premolars. The exception was the second premolar of control group where the correlation was smaller. This statement shows that there was both buccal tipping and dentoalveolar expansion in the upper premolar area.

Tao et al (123) also concluded that self-ligating system can successfully increase the arch width and correct moderate dental crowding with non-extraction approach by expanding the dental arch by buccal tipping of bicuspids and molars.

In the present study, for the lower arch, the distances between buccal tubercules, lingual tubercules and lingual points of first and second premolars also displayed a significant difference (p<0.01).

The distance between right and left buccal tubercules first premolar in lower arch was stated to be 31,54±1,74 mm in study group. The value increased significantly reaching 34,62±0,83 mm at T1, 34,69±1,13 mm at T2 and then with a slight decrease ended up 34,19±0,97 mm at T3. The distance between lingual tubercules was 25,16±2,13 mm initially and increased to 27,31±1,04 mm at T1, 27,65±0,91 mm at T2 and ended up at 27,42±1,05 mm at T3. The distance between lingual points was 23,96±2,13 mm. The measurements were recorded as 25,70±1,08 mm at T1, 25,86±1,06 mm at T2 and 25,86±1,17 mm at T3. The changes all displayed significant differences for all measurement times (p<0.01).

The distance between right and left buccal tubercules first premolar in lower arch was stated to be 32,65±2,10 mm in control group. The value increased significantly reaching 35,47±2,12 mm at T1, 35,38±1,95 mm at T2 and decreasing to 34,57±1,52 mm at T3. The distance between lingual tubercules was 26,12±1,48 mm initially. The measurement was recorded as 28,45±1,09 mm at T1, 28,65±1,28 mm a T2 and 28,16±1,18 mm at T3. The distance between lingual points was 24,79±1,52 mm. The measured values were 26,56±1,17 mm at T1, 26,68±1,34 mm at T2 and 26,34±1,37 mm at T3. The changes all displayed significant differences for all measurement times (p<0.01).

In the lower arch the distance between right and left buccal tubercules of second premolar was 37,56±3,00 mm for study group initially and increased to 39,85±1,45 mm at T1, 40,25±1,41 mm at T2 and slightly decreased to 40,06±1,58 mm at T3. The initial value for distance between right and left lingual tubercules were 29,26±2,87 mm for study group. The measurements increased to 30,78±1,83 mm at T1, 31,12±1,67 mm at T2 and decreased to 30,89±1,53 mm at T3. The distance between lingual points of second premolar was 28,30±2,91 mm initially and increased to 29,64±1,82 mm at T1, 30,02±1,64 mm at T2 and decreased to 29,63±1,76 mm at T3. The changes were found statistically significant at all times (p<0.01).

The distance between right and left buccal tubercules of lower second premolars was 38,57±1,71 mm initially for control group. The measurement was recorded as 40,89±1,87 mm at T1, 41,19±1,92 mm a T2 and 40,60±1,72 mm at T3. The distance between right and left lingual tubercules was 29,75±1,83 mm initially and increased to 31,70±1,56 mm at T1. At T2 and T3 the measurements were recorded as 32,09±1,63 mm and 32,00±1,28 mm. The value for distance between lingual points was 28,69±1,47 mm initially. The measurement was recorded as 30,11±1,52 mm at T1, 30,51±1,49 mm a T2 and 30,23±1,23 mm at T3. The changes were found statistically significant at all times ($p < 0.01$).

The average changes for lower first premolar were recorded as 2,65±1,62 (3,46) mm in study group, 1,91±1,29 (1,80) mm in control group for buccal tubercules; 2,25±1,74 (2,93) mm in study group and 2,04±1,17 (2,09) mm in control group for lingual tubercules; 1,89±1,32 (2,31) mm in study group, and 1,54±0,71 (1,67) mm in control group for lingual points.

The average changes for lower second premolar were recorded as 2,50±1,77 (2,45) mm in study group, 2,02±1,51 (1,78) mm in control group for buccal tubercules; 1,63±1,69 (1,53) mm in study group and 2,25±1,29 (2,18) mm in control group for lingual tubercules; 1,33±1,42 (1,48) mm in study group, and 1,55±1,06 (1,86) mm in control group for lingual points.

The changes were comparable within groups for lower first and second premolar ($p > 0.05$).

Similarly, Fleming et al (40) stated no statistically significant change within groups of Smart Clip and Victory twin brackets for lower arch inter-premolar width of both first and second premolars at 8 weeks after the ligation of rectangular stainless steel wire.

The increases measured in distances between lingual tubercules and lingual points were highly correlated for both arches and for both premolars. This statement again presents that there was both buccal tipping and dentoalveolar expansion in premolar area of lower arch, similar between groups.

Tao et al (123) also agreed that Damon system expands the dental arch by buccal tipping of bicuspids.

For the molar area, the conclusions slightly differed in upper and lower arches. The measured distance between right and left buccal tubercules of upper first molar was 49,39±2,41 mm for study group initially and increased to 49,72±1,99 mm at T1, 50,60±2,04 mm at T2 and 50,38±1,78 mm at T3. Changes were significant for both periods (p<0.05). The distance between right and left lingual tubercules of upper first molar was 37,87±2,84 mm initially. The following measurements were 38,12±2,42 mm at T1, 38,50±2,71 mm at T2 and 38,46±2,28 mm at the end of the treatment. Changes were significant for T0-T2 (p<0.01) and T0-T3 (p<0.05) periods. Distance between lingual points remained almost the same from begining to end of treatment.

The distance between right and left buccal tubercules of upper first molar was 51,26±2,27 mm initially for control group. The measurement was recorded as 51,86±2,80 mm at T1, 52,55±3,00 mm T2 and 52,39±3,04 mm at T3. The distance between lingual tubercules of upper first molar was 40,31±1,69 mm initially. At T1 40,97±2,55 mm, at T2 41,18±2,21 mm and at T3 41,05±2,00 mm was recorded. Changes were significant for T0-T2 and T0-T3 periods (p<0.05). The distance between right and left lingual points of upper first molar did not present any significant difference (p>0.05).

The distance between buccal and lingual tubercules of upper first molar was steady at T1, then increased significantly for both groups at T2 and T3 periods (p<0.01); but not representing a difference between groups. Controversely, the distance between lingual points of upper first molar did not present any significant difference in both groups (p>0.05). This states a buccal tipping of upper first molar similar in both groups.

Postero-anterior cephalometric findings also supports this result. The UIMW increased significantly in both groups (p<0.01), although MW remained almost the same (p>0.05). The UIMW resulted in similar change between groups.

Yu et al (143) in their study comparing RPE and Damon bracket effects, stated that both groups showed buccal tipping of bicuspids and molars, with more extend of

bicuspid tipping in Damon group. The maxillary base width increased 2.1 mm in RPE group, which was significantly larger than that of 0.6 mm in Damon group. They concluded that Damon appliance expands the dental arch by buccal tipping of bicuspids and molars. Although differing from our methadology by comparing RPE and self-ligating brackets, it is still comparable to our results stating a buccal tipping observed.

The Damon appliance utilizes a broad Damon archform, typically producing significant expansion in the premolar and molar regions. Particularly in the upper arch the expansion can be up to 10 mm but more commonly 6 mm. Mikulencak (79) conducted a retrospective study to compare tipping produced by rapid maxillary expansion with the tipping produced by the Damon sytem appliance and found no difference in the amount of molar tipping associated with the increase in arch width between the two methadologies. An inverse relationship was found between pre-treatment molar arch-width and change in molar angulation with the Damon system.

Tao et al (123) also concluded that self-ligating system can successfully increase the arch width by expanding the dental arch by buccal tipping of molars.

A study by Franchi et al (37), using low-friction ligatures rather than self-ligating brackets reported 1.7 mm (central fossa) increase and 0.04 mm decrease (lingual points) in inter-molar width. This study also demonstrated that molars tipped buccally 4 degrees. This supports the possibility that molar expansion observed is related to rolling or tipping of the molars rather than bodily movement or basal maxillary expansion. The study of Franchi et al (37) evaluated the leveling and alignment stage of orthodontic treatment using 0.014 inch and 0.016 inch round wires with an average duration of 6 months. These results differ from findings of present study from the point that the inter-molar width remained nearly constant until we switched to rectangular wires. The difference might arise from low-friction ligatures included.

For the lower arch, the molars resulted in a different scenario. The changes in lower first molar measurements were different between groups.

The measured distance between right and left buccal tubercules of lower first molar was 43,05±2,01 mm for study group initially and increased to 44,21±2,49 mm at T1, 44,44±1,55 mm at T2 and 44,41±1,79 mm at T3. Changes were significant for all periods (T0-T1 p<0.05, T0-T2 and T0-T3 p<0.01). The distance between lingual tubercules was 32,52±1,72 mm initially and increased to 33,39±1,96 mm at T1, 33,82±1,42 mm at T2 and 33,28±1,27 mm at T3. The changes were found statistically significant for all periods (To-T1 and T0-T3 p<0.01, T0-T2 p<0.019). The distance between lingual points of lower first molar did not display a significant difference at any treatment period (p>0.05).

The values between buccal and lingual tubercules resulted in significant difference in study group (p<0.05), though no statistically significant change was observed for control group (p>0.05). The distance between lingual points still remained nearly unchanged.

In spite of this difference, the average changes were still similar between groups. These results overall stated a similar buccal tipping of lower molars in both groups without any alveolar expansion.

Similarly, a thesis study comparing difference in the expansion of inter-molar area with Damon2 brackets and conventionally ligated MBT brackets, found no difference between two brackets at the the treatment of both mild and moderate crowding Class I cases (47).

On the other hand, Fleming et al (40) reported a significant difference in mandibular inter-molar width in favour of the Smart Clip self-ligating group although this was minimal (0.9 mm). Such small changes in molar expansion of 1-2 mm will only result in an additional 0.27-0.58 mm in arch perimeter which is also clinically insignificant.

A clinical study by Pandis et al (88) compared Damon2 brackets with conventionally ligated brackets. The inter-molar width changed from 44.21±2,53 mm to 44.64±2,74 mm at T2 in control group but increased from 44.21±2,60 mm to 46.25±1,72 mm at T2 in study group. The change was significant for study group. Although the overall expansion of the mandibular arch of the population treated in

that trial was found to be relatively small, the inter-molar width gained in the Damon2 bracket group reached 1.5 mm above the value observed for conventional appliances. In this study it should be noted that wires used were not of the same shape for the two bracket systems. The Damon arch has a broader arch form compared to Sentalloy archwire used in conventional appliances. Also with Damon system rectangular arch wire was utilised where round wire was used for control group. The difference in posterior expansion may be solely attributed to the differences in the archwire forms.

Self-ligating system proposes to resolve anterior crowding through expansion of the posterior width rather than expansion of inter-canine width. The posterior expansion is supported by Damon's philosophy that a self-ligating creates more stable tooth positions by incorporating the use of lighter forces in conjuction with the body's own physiolojic adaptations. Damon also presents that more expansion occurs in the inter-molar width than in the inter-canine width (30).

On the contary, a recent study comparing the pre- and post-treatment CBCT scans, treated with either active or passive self-ligating brackets stated that for both systems, expansion of the dental arches occurred increasingly from the canine to the 2nd premolar, and mainly occurred as a result of tipping. No transverse augmentation of basal bone could be detected (28).

The reported dental effects of our study agree that dentoalveolar expansion was not due to pure bodily movement and tippings were observed for all upper and lower teeth. Evaluated changes in dental arch dimensions of non-extraction patients treated with conventional and self-ligating brackets are similar except for upper first premolar area. The results showed that postreatment maxillary and mandibular arch widths increased significantly.

The significant increases in the transverse widths of both arches led to a statistically significant increase in available arch lenght from T0 to T3 (p<0,01): 4,49±1,05 (4,20) mm in study group for upper arch and 3,80±1,55 (3,50) mm in control group also for upper; 5,78±2,03 (6,01) mm and 4,95±1,73 (3,50) mm respectively for lower arch.

Available arch lenght for upper was 64,83±2,44 mm for study group initially, increasing to 68,86±2,93 mm at T1, 69,39±2,65 mm at T2 and 69,32±2,57 mm at T3. That for lower arch was 54,91±2,85 mm initially. It became 59,76±3,12 mm, 60,66±1,97 mm and 60,70±1,89 mm at T1, T2 and T3 respectively. The increases were significant when compared to pretreatment values for both arches (p<0.01).

Available arch lenght for upper was 66,47±1,95 mm for control group initially; and became 70,04±2,03 mm at T1, 70,42±2,16 mm at T2 and 70,26±2,33 mm at T3. The measurement for lower was 56,44±1,66 mm for control group initially. The value increased to 61,06±2,70 mm at T1, 61,19±2,61 mm at T2 and 61,38±2,80 mm at T3. Again the increase was significant for all stages of treatment when compared with initial measurements for both arches (p<0.01).

The increases in available arch lenght was similar between groups; in accordance with the similarity in proclination of incisors and dentoalveolar expansion of arches.

Tao et al (123) concluded that self-ligating system can successfully increase the arch width and correct moderate dental crowding with non-extraction approach by expanding the dental arch by buccal tipping of bicuspids and molars. During the correction of upper arch crowding with non-extraction Damon technique, they stated that arch perimeter is gained by the increase in both arch length and inter-bicuspid arch width, in addition to the labial movement of incisors. This statement corresponds to present study in overall mechanism. But this mechanism holds true for both types of mechanisms.

In accordance with these results, constructed arch lenghts also increased significantly in both groups.

According to pretreatment measurements constructed arch lenghts were 68,16±2,84 mm (upper) and 57,38±3,35 mm (lower) for study group and 68,71±3,41 mm (upper) and 58,27±3,39 mm (lower) for control group. After the initial levelling with round wires, the constructed arch lenght measurements increased up to 70,40±3,03 mm and 71,65±2,60 mm for study group and control group in upper arch respectively and 60,07±3,41 mm for study group and 60,90±2,56 mm for control

group in lower arch respectively. After the insertion of rectangular Ni-Ti wire 70,09±2,58 mm in upper and 60,50±3,08 mm in lower was measured in study group. 71,67±3,04 mm in upper and 60,55±2,59 mm in lower was measured for control group. At the end of the treatment the measurements were as follows: 70,19±2,89 mm in upper and 60,53±3,14 mm in lower for study group and 71,54±2,77 mm in upper and 60,60±2,59 mm in lower for control group. The changes were significant in both groups (p<0.01). The average increases within measurement time peirods were not statistically significant between groups for both arches (p>0.05).

The constructed arch lenght incrased by 2,03±1,65 (1,60) mm and 2,83±2,82 (2,70) mm for upper arch in study and control groups respectively on average (T0-T3). For the lower arch the average measurements were as follows: 3,14±2,33 (3,29) mm for study group and 2,33±1,84 (2,45) mm for control group (T0-T3). The constructed arch lenght increase can be attributed to both buccal tipping of molars and proclination of incisors. In the present study 4,15±2,30 degrees of change in study group and 5,10±8,28 degrees of change in control group for UI-SN angle was measured. IMPA increased by 6±3,53 degrees in self-ligating group and 7±6,98 degrees in conventional group. The results were comparable for both measurements. It has been shown that for every 5 degrees of anterior inclination, about 1 mm of arch lenght is generated (98).

Most of the significant transverse changes occured mainly between T0-T1 period. This may be the reason why most of the clinical studies comparing two different bracket systems included only initial levelling stage.

There were aspects of expansion created by orthodontic appliances not analyzed in this study that may be of interest in future investigations. The post-treatment results were recorded just at the end. Therefore no data was collected to record the long term stability. Although this study demonstrated nearly no siginificant difference between the two systems in regard to dentoalveolar expansion, that does not evaluate the self-ligating system's ability to create better post-treatment results for the periodontium. If the periodontium is more physiologically stable by using the self-ligating system for treatment, the dentition may be more stable.

Still the debate whether the anticipated true-expansion and buccal bone modeling using self-ligating brackets actually occurs or not is not confirmed. Due to the large inter-individual variation, a 3D patient-specific analysis seems to be mandatory to identify individual factors influencing the final treatment outcome. In order to fully exploit the possibility of CBCT technology in analysing treatment outcomes, clinicians have to be able to localize absolute changes in pre- and post-treatment 3D-models registered on stable cranium structures. 3D approach may be the most valuable assessment of changes in the dento-alveolar structures to compare conventional and self-ligating system.

7.3.2. Discussion of Results for Clinical Efficiency

Overall treatment time was similar between groups being 23,32±5,14 months for study group and 20,35±3,59 months for control group.

In this study the treatment time elapsed until initial levelling (T0-T1) of mandibular arch was 36,40±14,29 weeks for study group and 35,10±10,75 weeks for control group. Treatment durations for final levelling (T1-T2) and period for utilisation of rectangular stainless steel wire (T2-T3) were also comparable between groups.

The similarity between groups in treatment time was in accordance with a randomised clinical trial that revealed neither initial nor overall difference in rate of mandibular insicor alignment (111).

Miles (81) studied the difference in time required to close the extraction space during en-masse retraction with self-ligating and conventional brackets. He concluded that there was no difference in time and closure rate among the brackets tested. This study, although differing from method of present study by involving extraction procedure, resulted in similar results.

In this present study, the initial irregularity index values were 9,16±3,77 mm and 9,02±2,44 mm for study and control groups respectively in lower arch. Both the initial irregularity index value and time until initial levelling (T1) were similar between groups. At T1 self-ligating brackets a had greater but insignificant

irregularity. The results were 1,65±2,41 mm in self-ligating group and 0,43±0,75 mm in control group. This can be attributed to the lack of engagement of the 0.012 inch and 0.016 inch wires by the Quick bracket compared with a theoretically fully engaged MIB bracket.

On a similar basis, the study of Scott et al (111) compared the allignment efficiency of Damon3 and Synthesis brackets. The Synthesis group had a slightly higher mean irregularity at initial (12.44±3,72 mm) compared with the Damon group (11,3±3,18 mm). For the rate of of initial incisor alignment from initial to end of levelling stage (T1), the Synthesis group had a slightly higher mean rate of initial incisor alignment of 0.135 mm per day compared to Damon3 group 0.119 mm per day. It was concluded that only initial incisor irregularity had an effect on incisor allignment; appliance type did not.

The study by Miles (80) compared the decrease in mandibular irregularity index between Smart-Clip MBT prescription brackets and conventionally ligated MBT brackets. The irregularity index measurements were comparable initially but the conventional group had a significantly lower irregularity index compared to self-ligating group at the end of 10 weeks (T1) of first arch wire change (p<0,05). By the second arch wire change (T2) at end of 20 weeks, there was no difference between groups (p>0,05). These results support findings of this study.

In another clinical study with a split-mouth design, Miles et al (82) compared the levelling effectiveness of Damon2 and conventional twin brackets on mandibular arch. Similar to present study, at both arch wire changes at 10 and 20th weeks, the conventional bracket had achieved a lower irregularity index value by 0.2 mm; which is clinically insignificant.

Pandis et al (88) stated that when aligning stage of treatment was considered solely; for moderate crowding with an irregularity index of smaller than 5 mm, there is evidence that the Damon2 brackets can produce faster correction although this becomes more insignificant for more severe crowding. In this study the mean irregularity index was more than 5 mm which implies a more severe crowding. This statement of insignificant treatment time difference corresponds with our sudy.

Additionally, another study revealed a positive effect of the severity of crowding on treatment duration, which accounted for about 20 % additional treatment time for each additonal irregularity index added. Regarding the speed of tooth movement, low or no friction is one factor, whilsth the behaviour of the periodontal tissues and their limiting effect on the free movement of the teeth is another part of the equation. Furthermore, retrieved nickel-titanium archwires provided proof of the presence of calcified protein integuments which constitute a variable not intercorporated into in vitro studies and possibly affect free-sliding and friction (34).

Fleming et al (40) compared the efficiency of mandibular arch alignment in three dimensions with SmartClip self-ligating bracket system and a conventional Victory twin in non-extraction cases. They stated that the mean duration of alignment and levelling was 250.1±37,7 days overall: 247.2±36,8 in the self-ligating group and 253±39 days in conventional group. This duration involves the period 8 weeks after stainless-steel wire is passively engaged. The authors concluded that overall bracket type had little influence on alignment efficiency, and it was highly correlated to pretreatment irregularity. This holds true also for the bracket systems used in the present study.

The proposed advantages of reduced force levels and friction associated with self-ligating bracket do not appear to result in more rapid tooth alignment. Teeth only seem to allign faster when they are more displaced to start with, irrespective of appliance type.

For maxillary arch the results slightly differed from mandibular arch in this study. The first levelling stage period (T0-T1) elapsed 23,84±13,30 weeks for study group and 36,40±14,29 weeks for control group; indicating a significant shorter treatment time for self-ligating group until final levelling stage ($p<0.05$). T1-T2 period lasted for 18,92±10,67(16) weeks in study group and 20,70±12,86(14) weeks for control group. The time between T2-T3 was 51,15±30,16 (58) weeks for study group and 30,30±18,63 (23,5) weeks for control group. This difference in last period correlated overall treatment times with each other.

Arch discrepancy medians were 4,07 mm in upper and 5,96 mm in lower for study group. The significantly shorter levelling time for self-ligating brackets may be attributed to significantly smaller arch dicrepancy (p<0.05) and greater inter-bracket distance compared to mandibular arch. Although the values were also smaller for upper arch in control group (3,54 mm in upper, 4,79 mm in lower), it did not seem to be effective.

This difference may be assigned to the substentionally higher 'free play' of the self-ligating appliances, an effect which faciliates an undisturbed labial movement of the crown. In contrast, elastomeric modules or steel ligatures act as obstacles because of the stress they exert on the wire adjacent to the bracket sides, precluding the free sliding of the wire into the slot walls, thus adversely effecting the movement rate. This advantage of self-ligation over conventional ligation is eliminated when crowding exceeds a certain extent and the availability of space within the arch is restricted, as in mandibular arch in this study. In the latter case, the relative efficiency of the bracket system seems to be of limited use because of difficulties that are beyond the capabilities of mechanotheropatical configurations (88). Interestingly, Henao and Kusy (55) in an in vitro study, where active and passive self-ligating brackets were evaluated concluded that when clearance was substantial, the passive self-ligating brackets with slides performed better than those with clips. However, as malocclusion became more severe and archwire size reduced overall clearance, the two self-ligating designs of slides (passive) and clips (active) performed in a similar manner. Although extrapolation from laboratory experiments to the clinical settings should be done with caution, due to unknown variables, it appears that Henao and Kusy's (55) findings are in aggrement with findings of the study by Pandis et al (88) as discussed above.

Opposing the overall treatment time similarity in this study, the shortening of treatment time was stated in the literatures by numerous studies (3, 13, 34, 46, 47, 50,72, 104)

The study by Gerber (46) confirmed that overall treatment time was 10 months shorter with Damon2 brackets compared with mini-twin brackets in Class I non-extraction cases.

Beceti (13) also presented 6 months less treatment time with Damon2 self-ligating brackets in Class I cases.

A further clinical study in three practices found an average reduction in treatment time of six months (31 versus 25 months) and seven visits (28 to 21) for Damon self-ligating cases compared with conventional ligation (34).

One case report stated a treatment duration of 10 months for a premolar extraction case using Damon brackets (72). It was argued that such an extraction treatment would take approximately 24 months with conventional bracket systems.

Alpern (3) reported that treatment times were on average 5.7 months sooner with In-Ovation R self-ligating brackets. But the literature only presented a few clinical case reports.

Gilbert (47) stated that treatment with Damon2 system was approximately 2 months less than MBT cases for Class I non-extraction cases. No exact comparision between treatment times were made due to the fact that treatments were handled by different operators. Therefore they stated that a true assesment of actual treatment time could not be attained.

Harradine (50) retrospectively compared the overall treatment duration of 30 cases treated with Damon SL brackets to 30 matched cases treated by the same operator with conventional brackets. The Damon SL cases required an average of four fewer months (19.4 months versus 23.5 months) and four fewer visits (12.7 versus 16.5) to be treated to an equivalent standart based on the Peer Assesment Rating Scores. This study was retrospective, with the author conceding that the selection of cases for inclusion may have reflected a 'tendency to include only the more successful and pleasing'.

However retrospective studies of this nature are potentially biased due to uncontrolled factors including operator experience and preference, differing archwires and archwire sequences, and modified appointment intervals (41). Miles et al (82), commenting on these retrospective studies, reported that the reduction in treatment times described may merely reflect a transition to more efficient treatment

systems rather than being related purely to the use of self-ligating appliances. He also suggests that with the advent of more efficient treatment approaches, the use of self-ligating brackets is likely to be less influential. Also, data collection relies on the accuracy of treatment records, whilst studies employing more than one practioner to collect larger number of patients, present the additional complicating factors of inter-operative variability in materials handling and clinical management.

The fact that time elapsed for the ligation of wires is significantly lower for the study group is in accordance with similar clinical studies (18, 50, 113, 75, 130).

The medians of average ligating times of maxillary arches were 28 sec., 20 sec., 15 sec. and 12 seconds for wires from initial to finishing arch. 35 sec., 26 sec., 15 sec., 12 seconds were recorded for mandibular arches. The slight difference in first levelling wires may be attributed to more crowding present at mandibular arch initially. Overall, there was a decreasing tendency in ligating time for both arches from inital leveling arches to finishing arches. This corresponds with previous study, also displaying gradually decreasing times for Damon2 brackets (130).

For the conventional group, the medians of average ligating times of maxillary arches were 230 sec, 195,5 sec., 195 sec. and 197,5 seconds from initial to finishing arch. The results of mandibular arch was similar: 197,5 sec., 200 sec., 200 sec. and 187.5 seconds in the same order. The time remained nearly unchanged in average for conventional group.

Turnbull and Birnie (130) assesed the relative speed of archwire changes, comparing the Damon2 self-ligating brackets with conventional elastomeric ligation methods. They found that Damon2 brackets had a significantly shorter mean archwire ligation time for both placing and removing wires. This difference in ligation time became more marked for larger archwire sizes used in later stages of treatment. This corresponds with the present study also for the fact that average time for larger wires is smaller than initial wires. Therefore, time-saving efficiencies appear to be relatively greater at later stages of treatment. This may be explained by the relatively more time to fully engage light nickel-titanium wires in all teeth when crowding is present.

Similarly, a study by Berger and Byloff (18) stated that self-ligating brackets are faster to tie and untie, saving up to 2-3 minutes compared with modules and 6 or 7 minutes compared with stainless steel ligatures per arch. They found a mean ligation time with stainless steel ligature for maxillary arch as 280 seconds in one office and 328 seconds in the second one. For the mandibular arch the times measured was 292 seconds and 355 seconds respectively. For Damon1 bracket 26 seconds and 28 seconds were recorded in upper and 27 seconds and 28 seconds in lower arches.

The study by Shivapuja and Berger (113) also displayed a significantly less chair time for arch wire removal and insertion. An article by Maijer and Smith (75) demonstrated a four-fold reduction in ligation time compared with wire ligation of conventional brackets.

In particular, the use of self-ligating appliance systems results in a dramatic improvement in chair-side efficiency when compared to insertion of archwires using stainless-stell wires. This saving of time can be used to schedule more patients, increase efficiency, improve patient relationships or allow oral hygiene reinforcement (75).

On the contrary Harrine (50) stated that time savings with Damon SL brackets were not clinically significant. However this could be due to slide problems mostly encountered with Damon SL brackets. This problem was then dveloped by Damon2 and Damon3 brackets.

Treatment efficiency involves several factors including breakages. A higher bracket failure rate results in extra visits for the patient and additional chair time required for repairs. The present study ended up similar bracket failures in both groups. The findings were 1,61±2,06 (2) for study group and 1,80±1,81 (2) for control group.

Similarly, Pandis et al (87), Harradine (50) and Yu and Qian (142) stated no difference in failure rate between self-ligating and edgewise brackets.

On the contrary, studies by Miles et al (82), Harradine and Birnie (53) reported greater failure rate by self-ligating brackets over conventional twin brackets. This

higher failure rate could be attributed to operator inexperience with the slide mechanism and also due to the bracket design because a shear force can be inadvertently applied when operating the slide.

The number of clip deformation/breakage was between 0 and 13 in this study. The average was 4,15±3,43 (4). Besides, no ligation was lost in conventional group.

Yu and Qian (142) found no significant difference between ligating loss rate of self-ligating bracket and conventional bracket. This differs from the present study because the comparision was between self-ligating brackets and elastomers.

This retrospective analysis of Damon SL brackets stated that 50 percent of patients had slide breakages, which occurred almost always during slide opening or closure (50). This study including 25 consecutive cases in treatment for more than 1 year with Damon SL brackets reported 31 broken and 11 inadvertently opened slides between visits. This compared with 15 lost elastomeric ligatures in 25 consecutively treated cases with conventional brackets, could be regarded to effect the clinical effiency. Inadvertant slide openings or loss of elastomers could have detrimental effects on the control of the tooth, which in turn may result in prolonged treatment times.

The overall evaluation of clinical efficiency factors compared concludes that two bracket systems are similar to each other in manner of treatment time for severely crowded cases and bracket failure. Chair time is significantly shorter for self-ligating brackets which may in turn be evaluated for the greater cost.

The significant difference of initial levelling phase in upper arch may indicate that self ligating brackets might help shortening treatment time for moderate crowded cases.

Clip deformation observed for Quick brackets may be attributed as a clinical problem; both for treatment time and expense. Quick2 brackets with improved clip properties may be a solution to this problem.

8. CONCLUSION

In this thesis study the clinical effects of self-ligating Quick brackets (Forestadent Bernhard Forester GmbH, Westliche, Pforzheim, Germany) and conventionally ligated MIB (MIB, France) brackets were compared using lateral and postero-anterior cephalograms and digital models and factors effective in clinical efficiency.

The results of the present study state that the dentoalveolar expansion in treatment of severely crowded Class I cases with conventional brackets ligated with stainless steel ligatures and self-ligating brackets are similar except for upper first premolar area. Both the buccal tipping of posterior teeth and protrusion of incisors contribute the dentoalveolar expansion.

This study concludes that clinical efficiency is similar with self ligating and conventional brackets but ligating time is shorter with self ligating system. These results confirm that self-ligating brackets increase clinical efficiency by decreasing the chair time.

9. REFERENCES

1. Alcan T, Ceylanoğlu C, Baysal B. (2009). The relationship between digital model accuracy and time-dependent deformation of alginate impressions. *Angle Orthod.*, 79:30-35.

2. Alcaniz M, Montserrat C, Grau V, Chinesta F, Ramon A, Albalat S. (1998). An advanced sytem for the simulation planning of orthodontic treatment. *Med. Image. Anal.*, 2:61-77.

3. Alpern MC. (2008). Gaining control with self-ligation. *Semin Orthod,* 14:73-86.

4. Andreasen GF, Quevedo FR. (1970). Evaluation of frictional forces in the 0.022-0.028 edgewise bracket in vitro. *J Biomech,* 98:117-126.

5. Articolo LC, Kusy RP. (1999). Influence of angulation on the resistance to sliding in fixed appliances. *Am J Orthod Dentofacial Orthop*, 115:39-51.

6. Ash JL, Nikolai RJ. (1978). Relaxation of orthodontic elastomeric chains and modules in vitro and in vivo. *Journal of Dental Research*, 57:685-690.

7. Ateş M. (2008). Hızlı Üst Çene Genişletmesi Sonrası Boyutsal Değişikliklerin Ölçümünde Kullanılan Yöntemlerin Tartışılması. M. U. Sağlık Bilimleri Enstitüsü, Doktora Tezi, Istanbul, (Danışman: Prof. Dr. N Küçükkeleş).

8. Azizi M, Shrout MK, Haas AJ, Russell CM, Hamilton EH. (1999). A retrospective study of Angle Class I malocclusions treated orthodontically without extractions using two palatal expansion methods. *Am J Orthod Dentofacial Orthop*, 116(1):101-107.

9. Badawi HM, Toogood RW, Carey JPR, Heo G, Major PW. (2008). Torque expression of self-ligating brackets. *Am J Orthod Dentofacial Orthop,*133:721-728.

10. Bagramian RA, McNamara JA. (1998). A prospective survey of percutenous injuries in orthodontists. *Am J Orthod Dentofacial Orthop,* 114:654-658.

11. Bayrı R. (2008). Evaluation of frictional resistance of conventional brackets with different ligating methods and different self-ligating brackets. M. U. Sağlık Bilimleri Enstitüsü, Doktora Tezi, Istanbul, (Danışman: Prof. Dr. N Küçükkeleş).

12. Bazakidou E, Nanda RS, Duncanson MG, Sinha P. (1997). Evaluation of frictional resistance in esthetic brackets. *Am J Orthod Dentofacial Orthop,*112:138–144.

13. Beceti M. (2007). Sınıf I çapraşıklıklarda Damon II braketlerinin klinik etkinliğinin incelenmesi. M. U. Sağlık Bilimleri Enstitüsü, Doktora Tezi, Istanbul, (Danışman: Prof. Dr. S Biren).

14. Bednar JR, Gruendeman GW, Sandrik JL. (1991). A comparative study of frictional forces between orthodontic bracket and arch wires. *Am J Orthod Dentofacial Orthop,*100:513-522.

15. Begg PR. (1977). Orthodontic Theory and Technique, 3 rd ed. Philadelphia: W.B. Saunders Co.

16. BeGole EA, Fox DL, Sadowsky C. (1998). Analysis of arch changes in arch form with premolar expansion. *Am J Orthod Dentofacial Orthop,* 113:307-315.

17. Berger J. (2008). The Speed System: An overwiev of the appliance and clinical performance. *Semin Orthod,* 14:54-63.

18. Berger J, Byloff FK. (2001). The clinical efficiency of self-ligated brackets. *J Clin Orthod,* 35:304-308.

19. Birnie D. (2008). The Damon Passive self ligating system. *Semin Orthod,* 14:19-35.

20. Bishara SE, Cummins DM, Zahner AR. (1997). Treatment and posttreatment changes in patients with Class II Div I malocclusion after extraction and non-extraction treatment. *Am J Orthod Dentofacial Orthop,* 111:18-27.

21. Blake M, Woodside DJ, Pharoah MJ. (1995). A radiographic comparision of apical root resorption atfer orthodontic treatment with the edgewise and speed appliances. *Am J Orthod Dentofacial Orthop*, 118:262-273.

22. Braun S, Bluestein M, Moore BK, Benson G. (1999). Friction in perspective. *Am J Orthod Dentofacial Orthop,*115:629-627.

23. Cacciafesta V, Sfondrini MF, Ricciardi A, Scribante A, Klersy C, Auricchio F. (2003). Evaluation of friction of stainless steel and esthetic self-ligating brackets in various bracket-archwire combinations. *Am J Orthod Dentofacial Orthop,* 124:395-402.

24.   Cash AC, Good Sa, Curtis RV, McDonald F. (2004). An evaluation slot size in orthodontic brackets-are standards as expected?. *Angle Orthod,*74:450-453.

25.   Chia-tze K, Shinn-Jyh D, Chich-Kang W, Hong H, Ming-Yung C, Tsui-Hsien H. (2006). Comparision of frictional resistance after immersion of metal brackets and orthodontic wires in a fluoride-containing prophylactic agent. *Am J Orthod Dentofacial Orthop,*130:568-568.

26.   Coley-Smith A, Rock WP (1997). Orthodontic products update: Bracket recycling-Who does what? *British Orthodontic society,* 24:172-174.

27.   Costalos PA, Sarraf K, Cangialosi TJ, Efstratiadis S. (2005). Evaluation of the accuracy of digital model analysis for American Board of Orthodontics objective grading system for dental casts. *Am J Orthod Dentofacial Orthop*, 128:624-629.

28.   Cattaneo P, Cevidanes L, Treccani M, Myrda A, Melsen B. (2009)**.** Transversal Expansion and Self-Ligating Brackets: A CBCT Study. *AAOM*, 109 [th] Annual Session, Boston, USA.

29.   Damon DH. (2005). Treatment of face with biocompatible orthodontics. In: *Orthodontics: Current Principles and Techniques*. Eds: Graber TM, Vanarsdall Rl, Vig KWL, 4th ed., St Louis, Elsevier Mosby, p. 753-831.

30.   Damon DH. (1998). The Damon low-friction bracket:A biologically compatible straight wire system. *J Clin Orthod,* 32(11):670-680.

31.   DeLong R, Heinzen M, Hodges JS, Douglas WH. (2003). Accuracy of a system for creating 3-D computer models of dental arches. *J Dent Res*, 82:438-442.

32.   Downing A, McGabe J, Gordon P. (1994). A study of frictional forces between orthodontic bracket and arch wire. *Br J Orthod,* 21:349-357.

33.   Drescher D, Bourael C, Schumaer HA. (1989). Frictional forces between bracket and arch wire. *Am J Orthod Dentofacial Orthop,* 96:397-404.

34.   Eberting JJ, Straja Sr, Tuncay OC. (2001). Treatment time, outcome and patient satisfaction comparisions of damon and conventional brackets. *Clin Orthod Res* 4:228-234.

35. Eliades T, Pandis N. (2009). Self-ligation in Orthodontics. Blackwell Publishing, UK, p.13-14.

36. Fansa M, Keilig L, Reimann S, Jager A, Bourael C. (2009). The leveling effectiveness of self-ligating and conventional brackets for complex tooth malalignments. *J Orofac Orthop,* 70(4):285-296.

37. Franchi L, Baccetti T, Camporesi M, Lupoli M. (2006). Maxillary arch changes during leveling and aligning with fixed appliances and low-friction ligatures. *Am J Orthod Dentofacial Orthop*, 130:88-91.

38. Frank CA, Nikolai RJ. (1980). A comparative study of frictional resistance between orthodontic bracket and archwire. *Am J Orthod Dentofacial Orthop*, 78(6):593-609.

39. Fleming PS, DiBiase AT, Sarri G, Lee RT. (2009). Pain experience with a Self-ligating and conventional fixed orthodontic appliance. *Angle Orthod,* 79:46-50.

40. Fleming PS, DiBiase AT, Sarri G, Lee RT. (2009). Comparision of mandibular arch changes during alignment and levelling with 2 preadjusted edgewise appliances. *Am J Orthod Dentofacial Orthop*, 136:340-347.

41. Fleming PS, DiBiase AT, Lee RT. (2008). Self-ligating appliances: Evolution or revolution. *Aust Ortod J*, 24:41-49.

42. Forsberg C, Brattström V, Malmberg E, Nord CE. (1991). Ligature wires and elastomeric rings: two methods of ligation, and their association with microbial colonization of Streptococcus mutans and lactobacilli. *Eur J Orthod,* 13:416-420.

43. Fortini A, Lupoli ML, Cacciafesta V. (2005). A new low-friction ligation system. *J Clin Orthod*, 39(8):464-470.

44. Garino F, Favero L. (2003). Control of tooth movements with the Speed system. *Prog Orthod,* 4:23-30.

45. Garino F, Garino B. (2002). Comparision of dental arch measurements between stone and digital casts. *World J Orthod*, 3:250-254.

46. Gerber AL. (2002). A comparision of root resorption with mini-twin versus Damon2 brackets. Master Thesis study. WestVirginia University.

47. Gilbert B. (2003). Comparsion of inter-canine and inter-molar expansion between the Damon2 passive self-ligating bracket system and a conventional .022 MBT bracket in the treatment of Class I non-extraction orthodontic cases. Master Thesis study. University of Lousville School of Dentistry.

48. Gioka C, Eliades T. (2004). Materials induced variation in the torque expression of the preadjusted appliances. *Am J Orthod Dentofacial Orthop,* 125:323-328.

49. Hain M, Dhopatkar A, Rock P. (2006). A comparision of different ligation methods on friction. *Am J Orthod Dentofacial Orthop,* 130:666-670.

50. Harradine NWT. (2001). Self-ligating brackets and treatment efficiency. *Clin Orthod Res*, 4:220-227.

51. Harradine NWT. (2003). Self-ligating brackets: Where are we now. *J of Orthod*, 30:262-273.

52. Harradine NWT. (2008). The history and development of self-ligating brackets. *Semin Orthod,* 14:5-18.

53. Harradine NWT, Birnie DJ. (1996). The clinical use of Activa self-ligating brackets. *Am J Orthod Dentofacial Orthop,* 109:319-328.

54. Harrel WE Jr, Hatcher DC, Bolt RL. (2002). In search of anatomic truth: 3-dimensional digital modeling and the future of orthodontics. *Am J Orthod Dentofacial Orthop*, 12:325-330.

55. Henao SP, Kusy RP. (2004). Evaluation of the frictional resistance of conventional and self-ligating bracket designs using standardized arc-wires and dental typodonts. *Angle Orthod*, 74:202-211.

56. Huang Y, Keiling L, Rahimi A, reimann S, Eliades T, Jager A, Bourael C. (2009). Numeric modelling of torque capabilities of self-ligating and conventional brackets. *Am J Orthod Dentofacial Orthop*, 136(5):638-643.

57. Ireland AJ, Sheriff M, McDonald F. (1991). Effect of bracket and wire composition on frictional forces. *Eur J Orthod,* 13:322-328.

58. Işık F, Sayınsu K, Nalbantgil D, Arun T. (2005). A comparative study of dental arch widths:extraction and non-extraction treatment. *Eur J Orthod,* 27:585-589.

59. Iwasaki LR, Beatty MW, Randall CJ, Nickel JC. (2003). Clinical ligation forces and intraoral friction during sliding on a stainless steel archwire. *Am J Orthod Dentofacial Orthop,* 123:408-415.

60. Joffre L. (2004). Current products and practices Orthocad: digital model for digital era. *J of Orthod*, 31:1-4.

61. Kapila S, Angolar PV, Duncanson M, Nanda RS. (1990). Evaluation of friction between edgewise stainless-steel brackets and orthodontic wires of four alloys. *Am J Orthod Dentofacial Orthop,* 98:117-126.

62. Keith O, Jones SP, Davies EH. (1993). The influence of bracket material, ligation force and and wear on frictional resistance of orthodontic brackets. *Br J Orthod,* 20:109-115.

63. Khambay B, Millett D, Mc Hugh S. (1990). Evaluation of methods of arch wire ligation on frictional resistance. *Eur J Orthod ,* 26:327-332.

64. Kim E, Gianelly AA. (2003). Extraction versus nonextraction: Archwidths and smile esthetics. *Angle orthod,* 73:354-358.

65. Kuroe K, Tariri T, Nakayama T, Nagakubo C, Kubota S, Matsuda S, Gakuji I. (1994). Frictional forces with friction-free edgewise brackets. *J Clin Orthod,* 28(6):347-351.

66. Kusy RP, Whitley JQ. (1989). Effects of sliding velocity on the co-efficients of friction in a model orthodontic system. *Dent Mater*, 5:235-240.

67. Kusy RP, Whitley JQ. (1990). Coefficients of friction for arch wires in stainless-steel and polycrystalline alumina bracket slots: the dry state. *Am J Orthod Dentofacial Orthop*, 112:34-40.

68. Kusy RP, Whitley JQ. (1997). Friction between different wire-bracket configurations and materials. *Semin Orthod,* 3:166-177.

69. Kusy RP, Whitley JQ. (1999). Influence of arch wire and bracket dimensions on sliding mechanics: derivations and determinations of the critical contact angles for binding. *Eur J Orthod,* 21:199-208.

70.   Kusy RP, J.Whitley (2003). Influence of fluid media on the frictional coefficients in orthodontic sliding. *Seminars in Orthodontics*, 9(4): 281-289.

71.   Kusy RP, Whitley JQ, Mayhew MJ, Buckthal JE. (1988). Surface roughness of orthodontic arch wires via laser spectroscopy. *Angle Orthod*, January:33-45.

72.   Loh Kaı-Woh (2007). Rapid tooth movement with a low-force, low-friction bracket system. *J of Clinical Orthod,* 41:451-457.

73.   Loftus BP, Artun J, Nicholls JI, Alonzo TA, Stoner JA. (1999). Evaluation of friction during sliding tooth movement in various bracket-arch wire combinations. *Am J Orthod Dentofacial Orthop*, 116:336-345.

74.   Loftus BP, Artun J. (2001). A model for evaluating friction during orthodontic movement. *Eur J Orthod,* 23:253-261.

75.   Maijer R, Smith DC. (1990). Time savings with self-ligating brackets. *J Clin Orthod,* 24:29-31.

76.   Marcel TJ. (2001). Three-dimensional on-screen virtual models. *Am J Orthod Dentofacial Orthop,*119:666-668.

77.   Mayers M, Firestone AR, Rashid R, Vig KWL. (2005). Comparision of peer assessment rating (PAR) index scores of plaster and computer-based digital models. *Am J Orthod Dentofacial Orthop*, 128:431-434.

78.   Michelberger DJ. (1999). An investigation of the friction, wear and and corrosion properties of orthodontic appliances. University of Alberta. Master thesis.

79.   Mikulencak DM. (2007). A comparision of maxillary arch width and molar tipping changes between rapid maxillary expansion and fixed appliance vs the Damon system. *Am J Orthod Dentofacial Orthop,* 132:562-568.

80.   Miles PG. (2005). SmartClip versus conventional twin brackets for initial alignment: Is there a difference? *Aust Orthod J,* 21:123-127.

81.   Miles PG. (2007). Self-ligating vs conventional twin brackets during en-masse space closure with sliding mechanics. *Am J Orthod Dentofacial Orthop*, 132:223-225.

82.   Miles PG, Weyant R, Rustveld L. (2006). A clinical trial of Damon2 vs conventional Twin brackets during initial alignment. *Angle Orthod*, 76:480-485.

83. Mullen SR, Martin CA, Ngan P, Gladwin M. (2007). Accuracy of space analysis with emodels and plaster models. *Am J Orthod Dentofacial Orthop*, 132:346-352.

84. Ogata RH, Nanda RS, Duncanson MG Jr, Sinha PK, Currier Gh. (1996). Frictional resistance in stainless steel bracket-wire combinations with effects of vertical deflections. *Am J Orthod Dentofacial Orthop,* 109:535-542.

85. Pandis N, Eliades T, Partowi S, Bourauel C. (2008). Forces exerted by conventional and self-ligating brackets during simulated first and second order corrections. *Am J Orthod Dentofacial Orthop,* 133:738-742.

86. Pandis N, Nasika M, Polychronopoulou A, Eliades T. (2008). External apical root resorption in patients treated with conventional and self-ligating brackets. *Am J Orthod Dentofacial Orthop,*134:646-651.

87. Pandis N, Polychronopoulou A, Eliades T. (2006). Failure rate of self-ligating and edgewise brackets bonded with conventional acid etching and a self-etching primer. *Angle Orthod*, 76:119-122.

88. Pandis N, Polychronopoulou A, Eliades T. (2007). Self-ligating vs conventional brackets in the treatment of mandibular crowding:a prospective clinical trial of treatment duration and dental effects. *Am J Orthod Dentofacial Orthop*, 132:208-215.

89. Pandis N, Strigou S, Eliades T. (2006). Maxillary incisor torque with conventional and self-ligating brackets: a prospective clinical trial. *Orthod Craniofac Res,* 9(4):193-198.

90. Pandis N, Vlachopoulos K, Polychronopoulou A, Madianaos P, Eliades T. (2008). Periodontal condition of the mandibular anterior dentition in patients with conventional and self-ligating brackets. *Orthod Craniofac Res*, 11(4):211-215.

91. Paquette DE, Beattie JR, Johnston LE Jr. (1992). A long term comparision of nonextraction and premolar extraction edgewise therapy in borderline Class II patients. *Am J Orthod Dentofacial Orthop*, 102:1-14.

92. Park HY, Shearer TR. (1983). In vitro release of nickel and chrornium from simulated orthodontic appliances. *Am J Orthod Dentofac Orthop,* 84: 156- 159.

93. Parkin N. (2005) Clinical pearl- Clinical tips with System-R. *J of Orthod*, 32:244-246.

94. Paventy AM. (2009). Nonextraction treatment using the Damon system: A CBCT evaluation. *AAOM*, 109 th Annual Session, Boston, USA.

95. Peluso MJ, Josell SD, Levine SW, Lorei BJ. (2004). Digital models: An introduction. *Semin Orthod,* 10:226-238.

96. Peterson L, Spencer R, Andreasen G. (1982). A comparision of friction resistance for Nitinol and stainless steel wire in edgewise brackets. *Quintessence Int,* 5:563-571.

97. Pizzoni L, Ravnholt G, Melsen B. (1998). Frictional forces related to self-ligating brackets. Eur J Orthod, 20:283-291.

98. Proffitt W, Fields HW. (1986). Contemporary Orthodontics. Mosby Publications, St Louis, Mosby, p.421-445.

99. Quimbly ML, Vig KW, Rashid RG, Firestone AR. (2004). The accuracy and reliability of measurements made on computer-based digital models. *Angle Orthod,* 74:298-303.

100. Read-Ward GE, Jones SP, Davies EH. (1997). A comparision of self-ligating and conventional orthodontic bracket systems. *Br J of Orthod,* 24:309-317.

101. Redlich M, Mayer Y, Harari D, Lewinstein I. (2003). In vitro study of frictional forces during sliding mechanics of 'reduced-friction' brackets. *Am J Orthod Dentofacial Orthop,* 124:69-73.

102. Redmond WR. (2001). Digital models: A new diagnostic tool. *J Clin Orthod,* 35:386-387.

103. Redmond WR, Redmond WJ, Redmond JR. (2000). Ortho-bytes. *Am J Orthod Dentofacial Orthop*, 117:240-241.

104. Richause DJ, Miles P. (2007). Self-ligating brackets: Present and future. *Am J Orthod Dentofacial Orthop,*132:216-222.

105. Riley JL, Garret Sg, Moon PC. (1979). Frictional forces of ligated plastic and metal edgewise brackets. *J Dent Res,* 58:91-98.

106. Rheude B, Sadowsky PL, Ferriera A, Jacbson A. (2005). An evaluation of the use of digital study models in orthodontics diagnosis and treatment planning. *Angle Orthod.,* 75(3):300-304.

107. Rock WP, Wilson HJ. (1989). The effect of bracket type and ligation method upon forces exerted by orthodontic archwires. *Br J Orthod,* 16:213-217.

108. Santaro M, Galkin S, Teredesai M, Nicolay OF, Cangialosi TJ. (2003). Comparision of mesasurements made on digital and plaster models. *Am J Orthod Dentofacial Orthop,* 124:101-105.

109. Saunders CR, Kusy RP. (1994) Surface topography and frictional characteristics of ceramic brackets. *Am J Orthod Dentofacial Orthop,* 30(2):78-84.

110. Schumacher HA, Bourauel C, Drescher D. (1999). The influence of bracket design on frictional losses in the bracket/archwire system. *J Orofac Orthop,* 60:335-347.

111. Scott P, DiBiase AT, Sheriff M, Cobourne MT. (2008). Alignment efficiency of Damon3 self-ligating and conventional orthodontic bracket systems: A randomized clinical trial. *Am J Orthod Dentofacial Orthop,* 134:471-478.

112. Scott P, Sheriff M, Dibiase AT, Cobourne MT. (2008). Perception of discomfort during initial orthodontic tooth alignment using a self-ligating or conventional bracket system: a randomized clinical trial. *Eur J Orthod*, 30(3):227-232.

113. Shivapuja PK, Berger J. (1994). A comparative study of conventional ligation and self-ligation bracket systems. *Am J Orthod Dentofacial Orthop,*106:472-480.

114. Sims APT, Waters NE, Birnie DJ. (1994). A comparison of the forces required to produce tooth movement ex vivo through 3 types of pre-adjusted brackets when subjected to determined tip or torque values. *Br J Orthod*, 21;367-373.

115. Sims APT, Waters NE, Birnie DJ, Pethybridge RJ. (1993). A comparision of the forces required to produce tooth movement in vitro using two self-ligating brackets and a preadjusted bracket employing two types of ligation. *Eur J Orthod*, 15:377-385.

116. Stannard JG, Gau JM, Hanna MA. (1986). Comparative friction of friction wires under dry and wet conditions. *Am J Orthod Dentofacial Orthop*, 89:485-491.

117.   Stevens DR, Flores-Mir C, Nebbe B, Raboud DW, Heo G, Major PW. (2006). Validity, reliability, and reproducibility of plaster vs digital study models:Comparision of peer assesment rating and Bolton analysis and thier constituent measurements. *Am J Orthod Dentofacial Orthop,* 129:794-803.

118.   Stewart MB. (2001). Dental models in 3D. Orthodontic Products. February: 21-24.

119.   Stolzenberg J. (1935). The Russell attachment and its improved advantages. *Int J Orthod Dent Children,* 21;837-840.

120.   Sukontapatipark W, El-Agroudi MA, Selliseth NJ, Thunold K, Selvig KA. (2001). Bacterial colonisation associated with fixed orthodontic appliances. A scanning electron microscopy study. *Eur J Orthod*, 23:475-484.

121.   Taloumis LJ, Smith TM, Hondrum SO. (1997). Force decay and deformation of elastomeric ligatures. *Am J Orthod Dentofacial Orthop,* 111:1-11.

122.   Tang GH, Zhang L, Xu XC, Li X, Chu FT. (2008). Indications for non-extraction treatment of dental crowding with Damon appliance. *Shanghai Kou Qiang Yi Xue,* 17(3):364-371.

123.   Tao L, Yao R, Tang GH, Xu XC, Yu YL. (2008). Arch perimeter changes on non-extraction correction of dental crowding with Damon appliance. *Shanghai Kou Qiang Yi Xue,* 17(3):243-9.

124.   Taylor NG, Ison K. (1996) Frictional resistance between orthodontic brackets and archwires in the buccal segments. *Angle Orthod*, 66:215-222.

125.   Thomas S, Sheriff M, Birnie D. (1998). A comparative study of the frictional characteristics of two types of self-ligating brackets and two types of pre-adjusted edgewise brackets tied with elastomeric ligatures. Eur J Orthod, 20:589-596.

126.   Thomassetti JJ, Taloumis LJ, Denny JM, Fischer JR. (2001). A comparision of 3 computerized Bolton tooth-size analyses with a commonly used method. *Angle Orthod*, 71:351-357.

127.   Thorstenson GA, Kusy RP. (2001). Resistance to sliding of self-ligating brackets versus conventional stainless steel twin brackets with second-order angulation in the dry and wet (saliva) states. *Am J Orthod Dentofacial Orthop,* 120:361-370.

128. Tidy DC. (1991). Frictional forces in fixed appliances. *Am J Orthod Dentofacial Orthop*, 96:249-254.

129. Turfaner U. (2008). Eststik kapaklı braketlerde (Self-ligating) farklı braket tel kombinasyonları ile ortaya çıkan sürtünme kuvvetlerinin incelenmesi. I. U. Sağlık Bilimleri Enstitüsü, Doktora Tezi, Istanbul, (Danışman: Prof. Dr. S Fıratlı).

130. Turnbull NR, Birnie DJ. (2007). Treatment efficiency of conventional vs self-ligating brackets:effects of archwire size and material. *Am J Orthod Dentofacial Orthop*, 131:395-399.

131. Türkkahraman H, Özgür SM, Yesim BF, Yetkin Z, Kaya S, Önal S. (2005). Archwire ligation techniques, microbial colonization, and periodontal status in orthodontically treated patients. *Angle Orthod,* 75:231-236.

132. Tselepsis M, Brockhurst P, West VC. (1994). Frictional resistance between brackets and archwires. *Am J Orthod Dentofacial Orthop,*106:131-138.

133. Valant J. (2008). Time:A Self-Ligating Interactive Bracket. *Semin Orthod,* 14:46-53.

134. Van Gastel J, Quireynen M, Teughels W, Pauwels M, coucke W, Carels C. (2009). Microbial adheison on different bracket types in vitro. *Angle Orthod,* 79(5):915-21.

135. Vaughan JL, Duncanson MG, Nanda RS, Currier GF. (1995). Relative kinetic frictional forces between between sintered stainless steel brackets and orthodontic arch wires. *Am J Orthod Dentofacial Orthop,* 107:20-27.

136. Veenema AC, Katsaros C, Boxum SC, Bronkhurst EM, Kuijpers-Jagtman AM. (2009). Index of complexity, Outcome and Need scored on plaster and digital models. *Europ J of Orthod,* 31:281-286.

137. Voudoris JC, Schismenos C, Lackovic K, Kuftinec MM. (2009). Self-ligation esthetic brackets with low frictional resistance. *Angle Othod,* 80(1): 188-194.

138. Wagner DM, Chung C. (2005). Transverse growth of the maxilla and mandible in untreated girls with low, average and high MP-SN angles: A longitidunal study. *Am J Orthod Dentofacial Orthop,* 128:716-23.

139.   Weinberg M, Sadowsky C. (1996). Resolution of mandibular arch crowding in growing patients with Class I malocclusions treated non-extraction. *Am J Orthod Dentofacial Orthop,* 110:359-364.

140.   Wildmann AJ. (1972). Round table- the Edgelock bracket. *J Clin Orthod,* 6:613-623.

141.   Yamagutchi K, Nanda RS, Morimoto N, Oda Y. (1996). A study of force application, amount of retarding force and bracket width in sliding mechanics. *Am J Orthod Dentofacial Orthop*, 109:50-56.

142.   Yu YL, Qian YF. (2007). The clinical implication of self-ligating brackets. *Shanghai Kou Qiang Yi Xue,* 16(4):431-435.

143.   Yu YL, Tang GH, Gong FF, Chen LL, Qian YF. (2008). A comparison of rapid palatal expansion and Damon appliance on non-extraction correction of dental crowding. *Shanghai Kou Qiang Yi Xue,* 17(3):237-242.

144.   Zilberman O, Huggare JAV, Parikakais K. (2003). Evaluation of the validity of tooth size and arch width measurements using conventional and three-dimensional virtual orthodontic models. *Angle Orthod, 73*:301-306.

10. BIOGRAPHY

Kişisel Bilgiler

Adı	BURCU	Soyadı	USTA SELAMET
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Eğitim Düzeyi

	Mezun Olduğu Kurumun Adı	Mezuniyet Yılı
Doktora/Uzmanlık	MARMARA ÜNİVERSİTESİ SAĞLIK BİL. ENST.	2009
Yüksek Lisans	MARMARA ÜNİVERSİTESİ DİŞ HEKİMLİĞİ FAKÜLTESİ	2001
Lisans		
Lise	ÖZEL ŞENER LİSESİ	1995

İş Deneyimi (Sondan geçmişe doğru sıralayın)

	Görevi	Kurum	Süre (Yıl - Yıl)
1.	DİŞ HEKİMİ	ÇAMLICA MEDİCANA HAST.	2002-2003
2.			
3.			

Yabancı Dilleri	Okuduğunu Anlama*	Konuşma*	Yazma*
İNGİLİZCE	ÇOK İYİ	ÇOK İYİ	ÇOK İYİ

* Çok iyi, iyi, orta, zayıf olarak değerlendirin

Yabancı Dil Sınav Notu [#]

KPDS	ÜDS	IELTS	TOEFL IBT	TOEFL PBT	TOEFL CBT	FCE	CAE	CPE
87					240			

[#] Başarılmış birden fazla sınav varsa, tüm sonuçlar yazılmalıdır

[#] KPDS: Kamu Personeli Yabancı Dil Sınavı; ÜDS: Üniversitelerarası Kurul Yabancı Dil Sınavı; IELTS: International English Language Testing System; TOEFL IBT: Test of English as a Foreign Language-Internet-Based Test TOEFL PBT: Test of English as a Foreign Language-Paper-Based Test; TOEFL CBT: Test of English as a Foreign Language-Computer-Based Test; FCE: First Certificate in English; CAE: Certificate in Advanced English; CPE: Certificate of Proficiency in English

	Sayısal	Eşit Ağırlık	Sözel
LES Puanı	57.722	61.045	59.384
(Diğer) Puanı			

Bilgisayar Bilgisi

Program	Kullanma becerisi

MARMARA ÜNİVERSİTESİ TIP FAKÜLTESİ
ARAŞTIRMA ETİK KURULU

Sayı : B.30.2.MAR.0.01.02/AEK/ 1202
Konu :

14.09.2007

Sayın Doç.Dr. Sibel BİREN

MAR-YÇ-2007-0197 protokol nolu " Self-ligating Braketlerin konvansiyonel braketlerle klinik olarak karşılaştırılması " isimli projeniz Fakültemiz Araştırma Etik Kurulu tarafından incelenerek onaylanmıştır.

Prof. Dr. Haner DİRESKENELİ
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Araştırma Etik Kurul Başkanı