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EVALUATION OF MOLAR DISTALIZATION WITH ZYGOMATIC ANCHORAGE

NOR SHAHAB

MASTER THESIS

DEPARTMENT of ORTHODONTICS

SUPERVISOR

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II. CONTENTS

III. ABBREVIATIONS

1. °: Degrees
2. 2D: two-dimensional
3. 3D: three-dimensional
4. et al.: And others
5. fig: Figure
6. ANB: A point Nasion B point angle (at Nasion)
7. ANS: Anterior Nasal Spine
8. Ba: Basion
9. N: Nasion
10. Po: Porion
11. PP – SN: Palatal Plane – Sella/Nasion angle
12. SNA: Sella Nasion A point angle (at Nasion)
13. SNB: Sella Nasion B point angle (at Nasion)
14. FH: Frankfort Horizontal
15. CBCT: Cone-Beam Computed Tomography
16. CT: Computed Tomography
17. MIMICS: Materialize Interactive Medical Image Control Systems
18. SD: Standard Deviation
19. SPSS: Statistical Package for Social Sciences
20. ICC: Intraclass Correlation Coefficient
21. mm: millimetre

IV. Figure List:

I. Tables list:

1. **SUMMARY:**

Evaluation of Molar Distalization with Zygomatic Anchorage

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Aim:

The purpose of this study was to evaluate the treatment efficiency of miniplates and segmented archwires for upper molar distalization.

Materials and methods:

The records of 12 (5 males, 7 females, mean age 18 years) patients with Class II malocclusion, who had undergone maxillary molar distalization with zygomatic anchorage, were collected from the archives of the Department of Orthodontics, Faculty of Dentistry, Marmara University.

Plaster model casts prepared before and after molar distalization were scanned digitally and transferred to the Mimics 16.0 software for 3D analysis. Linear measurements were made on these digitized casts. Teeth movements were then measured on the maxillary arches superimposed on rugae area before and after distalization. Dental tipping movements were measured on cephalometric radiographies taken at the start and end of the distalization procedure.

Results and conclusion:

Skeletal anchorage protocol is an efficient treatment option for upper molar distalization with no side effects such as anchorage loss and excessive protrusion of anterior segment. The distal movements of the posterior teeth and the backward movements of the anterior teeth that were observed in varying amounts can contribute to the correction of anterior crowding; therefore, this is likely to shorten the treatment with fixed orthodontic appliances, the second stage of treatment. Moreover, it offers the patient a treatment alternative to extra-oral appliances and extractions.

Key words: Class II malocclusion, molar distalization, zygomatic anchorage.

2. ÖZET

Zigomatik Ankraj Sistemleri Kullanılarak Gerçekleştirilen Molar Distalizasyonunun Etkinliğinin Değerlendirilmesi

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Amaç:

Miniplak ve segmente ark telleri kullanılarak molar distalizasyonu gerçekleştirilmiş bireylerde miniplak ve segmente ark tellerinin molar distalizasyonu üzerindeki etkilerinin incelenmesi amaçlanmaktadır.

Materyal ve yöntemler:

Bu çalışmanın materyalini Marmara Üniversitesi Diş Hekimliği Fakültesi Ortodonti Anabilim Dalı arşivinden seçilen, Sınıf II maloklüzyonu olan, zigomatik ankraj kullanılarak maksiller molar distalizasyonu yapılmış 12 hastanın (5 erkek, 7 kadın) kayıtları oluşturmaktadır.

Molar distalizasyonu öncesi ve sonrası alınan alçı modeler dijital olarak taranmış ve Mimics 3B analiz programına aktarılmıştır. Doğrusal ölçümler sanal alçı modeller üzerinde yapılmıştır. Meydana gelen diş hareketleri diztalizasyon öncesi ve sonrası ruga bölgesinde çakıştırılan sanal maksiller arklar üzerinde ölçülmüştür. Dental tipping hareketi distalizasyon prosederünün başında ve sonunda alınan sefalometrik radyografiler üzerinde ölçülmüştür.

Bulgular ve sonuç: İskeletsel ankıraj protokolü, ankraj kaybı ve anteriyor bölge protrüzyonu gibi yan etkileri olmayan, üst molar distalizasyonunda kullanılan etkin bir tedavi seçeneğidir. Posteriyor dişlerin distal yönlü hareketi ve anteriyor dişlerin geri yönlü hareketi anteriyor çapraşıklığın düzeltilmesine katkı sağlar, bu da sabit ortodontik aygıtlarla tedavi süresinin kısalmasına sebep olur. Ayrıca bu yöntem ağız dışı apareylere ve çekimli tedavilere karşı hastaların başvurabileceği alternatif bir tedavi yöntemidir.

Anahtar Kelimeler: Sınıf II malokluzyon, molar distalizasyonu, zigoma ankraj sistemi.

3. INTRODUCTION AND AIMS

One of the treatment modalities of a Class II malocclusion is molar distalization, which requires distal movement of maxillary molars to achieve a Class I molar and canine relationship. The most conventional method to distalize maxillary molars is to use the cervical headgear, which can be used for either orthodontic or orthopedic corrections. However, the major disadvantage of an extra-oral method is lack of patient cooperation during treatment (Clemmer & Hayes, 1979; Egolf, BeGole, & Upshaw, 1990).

Headgears can be adjusted to provide a distalization force on the Class II side (Armstrong, 1971; Brosh, Portal, Sarne, & Vardimon, 2005; Wohl, Bamonte, & Pearson, 1998). Removable appliances designed to distalize molars have been advocated, but both approaches require much patient cooperation (Gumus & Arat, 2005; Maino, Alessandrini, & Mura, 2006).

Unilateral full-step Class II correction, with asymmetry in the maxillary arch, can pose a challenge for the orthodontist. Various treatment modalities have been developed and used successfully over the years, but many need intensive cooperation from the patient. Noncompliant mechanics can be complicated and inefficient. Unilateral premolar extraction is usually an available treatment option but can result in arch skewing or displacement of the midline.

Although it has been shown that a unilateral Class II malocclusion can be corrected by headgear with asymmetric face-bows (Baldini, 1980), the force delivery system unavoidably contains a lateral component that can result in a posterior crossbite (Yoshida, Jost-Brinkman, Miethke, König, & Yamada, 1998).

Appliances that are alternatives to the compliance-dependent headgear for maxillary molar distalization have been described. These are worn only intra-orally, are placed to remain fixed temporarily, and make treatment success independent of patient compliance. A major advantage for the patient, when comparing them with the extra-orally anchored headgear, is the lack of esthetic impairment.

Conventional noncompliance appliances rely exclusively on intraoral anchorage for molar distalization. One of these appliances is the distal jet (Bolla, Muratore, Carano, & Bowman, 2002; Carano & Testa, 1996).

As opposed to cervical headgear, which can achieve fractionated molar distalization only with combined coronal tipping and subsequent root uprighting, the biomechanics of the appliance should, in theory, enable it to perform almost translatory molar distalization (G. S. Kinzinger & Diedrich, 2008). The reciprocally acting forces are therapeutically undesired and must be absorbed by intraoral anchorage. Conventionally, the anchorage setup of a distal jet appliance includes periodontal anchorage combined with further intraoral anchorage support. Because of the temporary partial coverage of the palate, in particular, which restricts hygiene capacity, this anchorage design has been the subject of critical discussion (G. Kinzinger, Wehrbein, Byloff, Yildizhan, & Diedrich, 2005).

Pendulum appliances and distal jets have been advocated and proven successful for molar distalization. However, there are disadvantages, including laboratory time and expense. Whereas, these appliances incorporate design components to attempt to prevent anchorage loss, flaring of the anterior teeth and increased overjet usually take place to a significant extent. One negative sequela usually seen with these appliances as posterior teeth distalize is the increase of lower facial height due to clockwise mandibular autorotation (Bussick & McNamara, 2000; Carano & Testa, 1996; Chiu, McNamara, & Franchi, 2005; Ngantung, Nanda, & Bowman, 2001).

Distal molar movement occurs mainly by tipping and rotation of the crowns, and anchorage loss does occur in the premolars and the incisors. The main problem with the pendulum appliance is its side effects on the anchorage unit, especially on the premolars and incisors. In addition, relapse of molar distalization is commonly seen because the molars are used as anchorage during distalization and retraction of the premolars and incisors.

To solve above-mentioned problems, various intra-oral distalizing mechanics combined with implants have been used, as it is possible to distalize the maxillary molars without anchorage loss by using absolute anchorage more efficiently than ever.

While it has been shown that dental implants placed in alveolar bone can withstand the forces required for orthodontic movements (Gelgör, Büyükyilmaz, Karaman, Dolanmaz, & Kalayci, 2004; Karaman, Basciftci, & Polat, 2002; Önçağ, Seçkin, Dinçer, & Arikan, 2007; Sugawara, Kanzaki, Takahashi, Nagasaka, & Nanda, 2006), many patients seeking orthodontic treatment have complete dentitions and, therefore, no available alveolar bone sites for implant placement. Consequently, several studies have looked at alternative sites, such as the hard palate, the mandibular retromolar area, the inferior border of the zygomatic buttress, the symphysis region and the labial or buccal inter-radicular bone areas (Everdi, Keles, & Nanda, 2005).

The inferior border of the zygomatico-maxillary buttress is suitable as direct access is easy and it is away from critical anatomical structures. Because it is close to the maxillary molars, the zygomatic buttress can be used for their anchorage either directly or indirectly (Kucukkeles, Ates, & Erverdi, 2014; Papadopoulos, 2014). Zygomatic miniplates are easily placed and removed under local anesthesia and can be used in various clinical situations.

The main objective of this retrospective archive study is to evaluate the treatment outcomes of zygomatic miniplates and segmented archwires for maxillary molar distalization. We intend to investigate the efficiency of this method and its application for further use.

4. LITTERATURE REVIEW

4.1. The Class II Malocclusion

Important goals that orthodontists aim to accomplish in their treatment include aesthetics, balance, function, and stability. A normal dental occlusion has been described for the human dentition and such serves as a goal of orthodontic treatment. Class II malocclusions stand for a major part of orthodontic anomalies, and are divided into two subgroups both skeletal and dentally (T. M. Graber & Swain, 1975). Angle (Edward Hartley Angle, 1907) considered the upper first molar´s sagittal relationship as reference when categorizing malocclusions into 3 groups and stating that Class II malocclusions made up 27% of these. In the following years epidemiologic studies from different populations by various researchers and institutions are to be found.

4.2. Epidemiology of Class II Malocclusion

The distribution of Class II malocclusion exhibits variation among different populations. According to the National Health and Nutrition Examination Survey, the Class II prevalence in American population was about 20%, 25-30% in the mixed dentition, 20-25% in the early permanent dentition phase while varying between 15-20% among the adult population (Brunelle, Bhat, & Lipton, 1996). The European and British populations seem to exhibit similar distributions (Laine & Hausen, 1983; Lavelle, 1976). The prevalence of Class II malocclusion in Arabic populations are reported to be around 10-15% (al-Emran, Wisth, & Böe, 1990). The prevalence in Oceania is reported to be as low as 0-5% (Baume, 1973). In Latin America the distribution is similar to the one in the Middle East, being around 10-15% (de Muñiz, 1986). In the Turkish population the prevalence is stated to be about 27.07% (Sari et al., 2003).

4.3. Etiology of Class II Malocclusion

Class II malocclusions have a multi-factorial etiology such as race, genetics and family related features (Samir E. Bishara, 2006). Acquired characteristics are likely to be repeated. Traits of one or both of the parents as a combination can be inherited in the same or in a modified manner (Samir E. Bishara, 2006).

4.3.1. Environmental Elements

Early loss of the maxillary primary second molar might lead to mesial migration or rotation of permanent molars thereof to developing to a Class II malocclusion (Samir E. Bishara, 2006). As molars mesialize, canines tend to end up in a more vestibular and premolars more in a palatal position, or remain impacted.

4.4 Classification of Class II Malocclusions

Many studies that investigated the Class II malocclusion and its classifications found out that the source to this anomaly did not originate from a simple factor but that it was linked to multiple skeletal and dento-alveolar components (T. M. Graber, Vanarsdall Jr, & Vig, 2006).

McNamara (McNamara, 1981) stated that the Class II Malocclusion didn’t only develop due to vertical and sagittal problems, but that the transversal component also had a great influence on these malocclusions.

Angle defined the Class II anomaly as ´distal occlusion´ (Edward H Angle, 1899). According to the position of incisors the Class II anomaly can be divided into two groups:

-Division 1: characterized by increased overjet and incisor inclinations.

-Division 2: characterized by increased overbite and reduced incisor inclinations.

The Angle classification (Edward H Angle, 1899) being on a dental level and assessed only sagittally are considered as weaknesses of this method. Hence why there are researchers who think that this assessment method is non sufficient for all existing anomalies and their treatment plan (Du, Rinchuse, Zullo, & Rinchuse, 1998; Katz, 1992; Rinchuse & Rinchuse, 1989).

Graber and Vig were able to classify malocclusions as dental, skeletal and as a combination of both dental and skeletal anomalies (T. M. Graber et al., 2006). For dental problems the relationship between the jaws are described as normal while the teeth are malpositioned. While for skeletal problems the relationship between the jaws is altered. As standardized lateral cephalometric radiographs became widely used, dental and skeletal problems have become easy to identify and diagnose.

Jarabak and Fizzell stated that the Angle´s classification did not take into account the morphology and growth pattern of the face. They divided Class II anomalies into 5 groups consisting of dental, dentoalveolar, functional (or neuromuscular), skeletal and skeletal-dentoalveolar problems (Jarabak & Fizzell, 1972). They claimed that in dental Class II anomalies the jaws relationship to each other and the cranium are normal, while the relationship between the teeth seems to be the problem. Hence the maxilla is in its normal position when the upper centrals are in protruded position.

McNamara (McNamara, 1981) on the other hand, stated that when diagnosing Class II anomalies we need to take both maxilla and mandible´s skeletal and dental position into consideration and investigate. Based on this McNamara brought attention to the mandibular plane angle and lower facial height (McNamara, 1981). In a study done by Riedel (Riedel, 1952) it was concluded that the distance of maxillary centrals in Class II division l cases to the facial plane was twice as much compared with individuals with a normal occlusion.

Moyers et al. (Moyers, Riolo, Guire, Wainright, & Bookstein, 1980), divided Class II anomalies into 2 main groups; horizontal and vertical. The horizontal group was further divided in to 6 (A,B,C,D,E and F) and the vertical into 5 (1,2,3,4 and 5) groups. The investigators stated that 4 types of the horizontal group (B,C,D and E) carries skeletal characteristics of Class II malocclusions, the F type being the most prevalent one in the population happens to be the type with the least skeletal problems. The A type being described as the dental Class II malocclusion together with a normal profile; is where the jaws have an ideal relationship, the lower incisors have a normal position while the maxillary incisors are protruded, the overjet and overbite are increased.

Bishara (S E Bishara, Burkey, & Kharouf, 1994) stated that Class II malocclusions are mainly originating from underlying skeletal irregularities and deformities, but that individuals with normal skeletal relationships together with dental Class II malocclusions are also prevalent in a population. Bishara (S E Bishara et al., 1994), divided dental Class II malocclusions into 2 groups;

a) Maxillary dental protrusion:

When cephalometric radiographs are analyzed, no skeletal problems are found but due to maxilla´s dental position and the increased overjet, sometimes polydiastema are to be observed in the maxillary arch. In these cases the lower jaw and teeth are anterio-posteriorly in normal positions.

b) Mesial movement of maxillary permanent first molars:

When the contact between the permanent first molar and the primary second molar is lost due to a congenital missing tooth, early extraction or caries and the permanent molar moves mesially or erupts in an ectopic position. As a result of this mesial movement a Class II molar relationship arises (S E Bishara et al., 1994).

The treatment planning of skeletal and/or dental Class II anomalies is dependent on many factors. When treating skeletal Class II malocclusions elements as the patient´s growth pattern and potential, severity of the anomaly, the amount of crowding and soft tissue profile must be considered. Depending on these assessments a functional orthodontic treatment, extraction or orthognathic surgery treatment options are evaluated. 1,54 (S. J. Bowman, 2000)

4.5 Class II Treatment Strategies

Many methods and treatment approaches are available for Class II malocclusions. Orthodontists tend to focus on a treatment plan that targets the most affected dentoalveolar area. Treatment alternatives include extra-oral appliances, arch expanding appliances, functional appliances or an extraction protocol (McNamara, 1981).

Frankel (Fränkel, 1974) claimed that extractions impede the dentoalveolar development of the extraction area. Flattening of the soft-tissue profile (S. Bowman & Jr, 2000; Zierhut, Joondeph, Artun, & Little, 2000), occurrence of dark buccal corridors when smiling after extractions are seen as esthetically negative side effects post extractions.

Watson (Watson, 1980) suggested 6 factors that are important when considering extractions:

1. Hereditary potential versus environmental factors
2. Factors that can stimulate bone growth
3. Esthetic and facial harmony
4. Treatment method suitability
5. Economic factors
6. Treatment objectives

The latest development in treatment mechanics and changes in approach have decreased the need for extractions in cases with mild crowding (Kalra, 1995). The ratio of extraction cases has decreased from 60-80% to 30% (O'Connor, 1993). Non-extraction and non-compliance dependent treatment alternatives have become more preferable treating Class II malocclusions in the recent years.

Sinclair (Sinclair, 1994) states that new distalization mechanics are developed and 57% of orthodontists are preferring molar distalization mechanics now more than before.

Methods to gain space in non-extraction cases:

1. Proclining incisors
2. Molar distalization
3. Expanding the dental arch

4. Rapid Maxillary Expansion
5. Deeping the curve of Spee
6. Derotation
7. Stripping
8. Closing diastema

When the Class II problem lies in the upper arch/ upper molar position, molar distalization can be the solution. (Bishara, 2006; Brin, Kelley, Ackerman, & Green, 1982; T. M. Graber, Rakosi, & Petrovic, 1997; Luppanapornlarp & Johnston Jr, 1993; McNamara Jr, 1981; Sinclair, 1994; Vargervik & Harvold, 1985)

4.6 Indications and contraindications for molar distalization

When there is a maxillary skeletal and/or dental protrusion, no indication for maxillary tooth extraction, the mandibular tooth size/ arch perimeter does not allow mesial movement of the mandibular molar then molar distalization can be indicated. (Bussick & McNamara, 2000; İşeri, 2006; Papadopoulos, 2006)

Bowman (Bowman, 1998), listed these features below as contraindications to intra-oral molar distalization:

1. Protrusive profiles
2. High mandibular plane angle
3. Anterior openbite
4. Severe crowding

4.7 Extra-oral Molar Distalization

Extra-oral force systems were used in prognathic cases for the first time by Kingsley (Kingsley, 1981) and Angle (Ghosh & Nanda, 1996b). These extra-oral appliances were not used by any researchers for many years following. In 1935 Oppenheim (Oppenheim, 1936) and Kloehn (Kloehn, 1962) created a foundation for extra-oral appliances which became an essential part of orthodontic mechanics from the 1950s and on (Tezcan, Yigit, & Enacar, 1989). Researchers characterized these appliances as the most efficient for molar distalization in the following years. (Armstrong, 1971; Oosthuizen, Dijkman, & Evans, 1973)

Extra-oral appliances used for molar distalization are divided into 3 groups based on their support point such as cervical, high pull or as a combination of both (Tezcan et al., 1989). Among these cervical headgears are most common type in use and are also known as ´the Kloehn type headgear´ in reference to its developer. Molar distalization achieved by these appliances result in tipping (Altug-Atac & Erdem, 2007; Badell, 1976; Baumrind, Korn, Isaacson, West, & Molthen, 1983; Iscan, Dincer, & Gultan, 1989; T. T. Üçem & Yükselb, 1998) and extrusion (Altug-Atac & Erdem, 2007; Badell, 1976; Baumrind et al., 1983; Cangialosi, Melstrell, Leung, & Ko, 1988; Iscan et al., 1989; T. T. Üçem & Yükselb, 1998; Wieslander & Tandläkare, 1963) which in return causes a posterior rotation of the mandible (Barton, 1972; Elder & Tuenge, 1974; Iscan et al., 1989; T. T. Üçem & Yükselb, 1998; Watson, 1972; Wieslander & Tandläkare, 1963). In relation to this the mandible exhibits structural compensation areas as an increase in ramus inclination (Iscan et al., 1989), a change in condyle growth pattern (Iscan & Dincer, 1988; Iscan et al., 1989), an increase in gonial angle (Iscan et al., 1989) and lower face height (Armstrong, 1971; Baumrind et al., 1983; Iscan et al., 1989; Odom, 1983; Triftshauser & Walters, 1976; Wieslander & Tandläkare, 1963). These kind of extra-oral appliances in general cause an anterior rotation of the lower jaw hence they are suitable for use in skeletal deep bite cases (Kucukkeles, Cakirer, & Mowafi, 2006).

As a result of tipping occurring during molar distalization by cervical headgears, second molars might not be able to erupt and stay impacted. To facilitate a parallel movement of molar distalization, Graber (T. Graber, 1955) suggested combined headgears for the first time. Combined headgears take anchorage from occipital and cervical areas. These appliances are successfully used in molar distalization cases without any change in vertical dimensions (Tezcan et al., 1989).

Cervical and combined headgears are not recommended in cases where the mandible has a posterior rotation; instead high-pull headgears are the appliances of choice (Tezcan et al., 1989). Since this type of appliance takes anchorage in the parietal area of the head, molar intrusion (Baumrind et al., 1983; Brown, 1978; Fotis, Melsen, Williams, & Droschl, 1984; T. T. Üçem & Yükselb, 1998) and anterior rotation (Tezcan et al., 1989; T. T. Üçem & Yükselb, 1998) of the mandible is to be expected in the contrary to cervical headgears that cause molar extrusion.

Although headgears are proven to give results in an efficient and short time, patients that are of target for these appliances are usually in their teen years and concerned with esthetics hence arising compliance problems.

In a study conducted by Cureton et el. (Cureton, Regennitter, & Yancey, 1993), it was shown that patients in the age group 14-16 were the least compliant patients for headgear use and that there was no difference between genders regarding duration of use.

Weiss et al. (Weiss & Eiser, 1977) claimed in their study that patients of age 12 and below were more compliant in orthodontic treatments compared to elder patients and adults. Clemmer (Clemmer & Hayes, 1979) on the other hand contraindicated this statement claiming that younger patients were not any more complaint and that girls conscious of their esthetics/looks paid also more attention to their orthodontic treatment.

In order for headgears to be efficient in molar distalization their use time need to be minimum 14 hours (Armstrong, 1971; Poulton, 1967). Daily application of 4-6 hours does not produce an orthodontic tooth movement. To be able to achieve growth modification in the maxilla, extra-oral appliances need to be worn at least 12 hours per day for 12-18 months. Hence patient cooperation is the main challenge that faces an orthodontist in treatments with headgears.

Doruk et al. (Doruk, Agar, & Babacan, 2004) added a timer to the back part of the headgear to asses wear time and patient cooperation. Starting 46 patients wore headgears for 2 months, later they were to be divided into 2 groups; wear time more than 16 hours versus those wear time less than 16 hours. The group who wore it for less than 16 hours was later informed about the timer and continued using the appliance for another 4 months. This resulted in an increase in wear time by 4.5-6 hours daily.

Guray and Orhan (Güray & Orhan, 1997) conducted a similar study by placing a timer on headgears and achieving molar distalization in 4 months. Patients used the headgear for 2 months to begin with, later they were informed about the timer and continued using for additional 2 months. As patients started monitoring the timer, their use of the appliance increased by 26%.

Despite their known disadvantages, extra-oral appliances can be used in combination with intra-oral distalization appliances to counteract their side effects (T. Graber, 1955; Perez, de Alba, Caputo, & Chaconas, 1980; Tezcan et al., 1989). Cetlin and Ten Hoeve (Cetlin & Ten Hoeve, 1983) used extra-oral appliances in combination with intra-oral appliances in order to achieve a parallel molar distalization. The intra-oral appliance consisted of a modified Hawley appliance with adams clasps on 1. premolars and an acrylic part that also covers the upper anterior teeth for anchorage. The active part of the appliance is the finger springs placed on the mesial surface of 1. molars. By activating these springs with 1-1.5 mm, an average distalization force of 30 grams is applied on molars. Depending on patient´s skeletal pattern, a suitable cervical or high pull headgear is to be used. Distalization achieved by an intra-oral appliance in general generates a distal tipping movement of the crown. The force application vector in the extra-oral appliance being above the center of resistance of molars is thought to apply an uprighting force on the molars.

Johnson (Johnson, 1994), Cetlin et al. (Cetlin & Ten Hoeve, 1983) applied a force of 50-100 grams on the molars for distalization by activating the finger springs in the appliance by 3-4 mm. By using nighttime wear cervical headgears with a 150-gram force on each side, they reported to achieve a molar distalization of 6-8 mm in 5 months.

Aras (Aras, 2000) in his study with J-hook headgear and a removable appliance reported to achieve a maxillary posterior mass distalization. To increase the anterior anchorage with J-hooks applying 100 grams, the extra-oral appliance was worn 10-12 hours daily while the intra-oral appliance was only taken out during meals. The researcher indicated an upper posterior mass distalization achieved in 5 months without any increase in overjet and a total treatment time of 10 months.

In a case study done by Ghosh and Nanda (Ghosh & Nanda, 1996b), an 11 year old female patient with an overjet of 11 mm and an ANB angle of 8° was treated with a Nance button appliance from premolars and open Ni-Ti coils between premolars and molars on 0.016 inch stainless steel wire with a force application of 150 grams. A cervical headgear was used to prevent molar tipping that occurs during distalization and enforce some uprighting. In this study it was reported that molar distalization was achieved in 4 months but that there was a 2 mm mesilization of the premolars.

Akın et al. (Akin, Gurton, & Sagdic, 2006) applied a molar distalizer called ´Removable Molar Distalizer´(RMD) on 28 subjects with an average age of 11.8 years. The appliance consists of 3 parts, 1 anterior and 2 posterior segments. The anterior part starts from the 2. premolars extending to the anterior, bolds on 1.premolars and a vestibular arch with an acrylic plate. Two wires bilaterally on the anterior segment extends towards the posterior. The posterior segment consists of adams clasps on 1. molars and acrylic pieces that slide posteriorly on the anterior wires extending. Distalization forces of 225 grams are applied through open coil springs placed between the anterior and posterior segments. Findings in this research were a molar distalization of 3.98 mm in 4.5 months, 4.61° molar distal tipping, 2.13 mm of distalization in 2. premolars along with 1.54° distal tipping. Some anchorage loss occurred in terms of 1.23 mm mesialization of the 1. premolars.

Extra-oral appliances have successfully been used for maxillary molar distalization throughout many years. As investigated in many studies these appliances require excellent patient compliance, which tends to be problematic, lengthen total treatment time and sometimes result in extractions even in initially non-extraction cases. All these concerns and challenges have pushed orthodontists to investigate options for intra-oral distalization appliances not dependent on patient cooperation. (Carano & Testa, 1996; Fortini, Lupoli, & Parri, 1999; Gianelly, Bednar, & Dietz, 1991; Greenfield, 1995; Haas & Cisneros, 2000; Hilgers, 1992;

Jones & White, 1992; Kalra, 1995; Keles & Sayinsu, 2000; Kucukkeles et al., 2006; Locatelli, 1992; Muse, Fillman, & Mitchell, 1993; Pieringer, Droschl, & Permann, 1997)

4.8 Intra-oral Molar Distalization

First studies designed to investigate orthodontic tooth movement with intra-oral appliances were performed as animal studies. Blechman and Smiley (Blechman & Smiley, 1978) in a cat study, managed to induce tooth movement by the help of magnetic forces. Molar distalization achieved by magnetic forces seem to have many advantages such as being non-compliance dependent, generating a physiologic force that is continuous with easy activation and minimal friction, helping to reduce overall treatment time. This method received great attention that led to many studies in this field (Carano & Testa, 1996; Fortini et al., 1999; Gianelly et al., 1991; Greenfield, 1995; Haas & Cisneros, 2000; Hilgers, 1992; Jones & White, 1992; Kalra, 1995; Keles & Sayinsu, 2000; Kucukkeles et al., 2006; Locatelli, 1992; Muse et al., 1993; Pieringer et al., 1997).

Gianelly et al. (Gianelly, Vaitaa, & Thomas, 1989), applied molar distalization in 8 patients using the acrylic Nance button and 1.premolars as anchorage while distalizing with magnets in 2-5 months depending on distalization need in each case. Researchers reported that distalization occurred as a combination of 80% distal movement of teeth and 20% 1.premolar mesialization and incisor protrusion, in other words anchorage loss.

Itoh et al. (Itoh, 1991), achieved molar distalization in 10 patients with mixed dentition by magnetic forces taking anchorage from the modified Nance appliance followed by activations every 2 weeks. It was reported that anchorage loss was estimated to be about 30-50% of molar distalization gained.

Bondemark and Kurol (Bondemark & Kurol, 1992), performed a study on 10 patients with Class II malocclusion taking anchorage from an acrylic Nance button and premolars. By means of Samarium-Cobalt magnets, molar distalization of 4.2

mm was achieved in 16.6 weeks along with a distal tipping of 8 and a disto-buccal rotation of 8.5 was observed.

Despite the many advantages of magnets, features as toxicity when not adequate isolation, easy break off, too much space requirement in the mouth, not being hygienic, causing often mucosa irritation and not being cost effective are reasons why researchers concentrated more on studies with open coil springs. The more wire a coil consists of the more efficient and light the force for a tooth movement is thought to be (Chaconas, Caputo, & Harvey, 1984).

Gianelly et al. (Gianelly et al., 1991; Gianelly et al., 1989), reported achieving molar distalization between 1-1.5 mm monthly using Ni-Ti open coil springs with a force load of 100 grams and an activation range of 8-10 mm. A Nance button was used to prevent anchorage loss.

Pieringer et al. (Pieringer et al., 1997), also used Nance button as anchorage and sentalloy open coil springs on segmental arch wires with a distalization force of 150-200 grams. They reported treatment duration of 3-18 months, molar distalization of 5-10 mm combined with distal tipping of 8.9-22.2 degrees in molars and about 6 degrees of labial tipping in upper incisors.

Erverdi et al. (Erverdi, Koyutürk, & Küçükkeles, 1997), performed distalization in 15 patients using magnets on one side and open Ni-Ti coil springs on the other side taking anchorage from Nance buttons. Researchers concluded that both distalization systems were applicable but that open the open Ni-Ti coil system was more efficient due to magnets being expensive, rough and requiring activations every week.

Jones and White (Jones & White, 1992), introduced the ´jones jig´ appliance consisting of open Ni-Ti coil springs adapted on thick segmental arch wires. The Nance button being the anchorage unit of this appliance, activations were repeated every 4-5 months with a distalization force of 70-75 grams and compressing the coils by 1-5 mm.

Gulati et al. (Gulati, Kharbanda, & Parkash, 1998), applied molar distalization in 10 patients in about 12 months using open sentalloy coils in the jones jig appliance with anchorage from the palate and a force of 150 grams. In molars they observed a distal tipping of 3.5 degrees, a disto-palatal rotation of 2.40 degrees with distalization of 2.78 mm, combined with a mesial tipping of 2.60 degrees in premolars. An increase of the mandibular plane angle by 1.30 degrees was linked to extrusion in molars, while the increase in overjet was explained as anchorage loss.

Brickman et al. (Brickman, Sinha, & Nanda, 2000), applied the jones jig appliance on 72 patients and examine dits effects on maxillary molars and premolars. Results showed distal tipping by 7.53 degrees, distalization by 2.51 mm along with extrusion by 0.14 mm in molars. For premolars on the other hand, there was a mesial movement by 2 mm, mesial tipping by 4.76 degrees and extrusion by 1.88 mm.

Patel et al. (Patel et al., 2009), compared using the jones jig appliance in 20 patients with the pendulum appliance in other 20 patients. The activation force on molars for the jones jig group was 100 grams while being 250 grams for the pendulum group by activating its arms. The dentoalveolar changes were analysed and results showed that mesialization and extrusion in 2.premolars for the jones jig group was greater hence less anchorage loss in the pendulum group.

Carano and Testa (Carano & Testa, 1996), introduced the ´Distal Jet´ appliance as an alternative to avoid the rotations and tipping movements observed in intra-oral distalization methods. The anchorage unit was the Nance button as in many other appliances. The distalization was achieved by Ni-Ti coils on a thick wire with one side embedded in the Nance acrylic and the other side in the palatal tube of the molar band. Researchers claimed that this tooth movement was parallel and provided a great advantage for these treatments.

Turk and Arici (Turk & Arici, 1998), performed molar distalization on two patients with the distal jet appliance. Dento-alveolar changes post distalization showed also tipping and intrusion in 1. molars, mesial movement and extrusion in 1. premolars.

Ngantung et al. (Ngantung et al., 2001), applied molar distalization with the distal jet appliance on 33 cases. They reported to have resolved the Class II relationship in 6.7 months in average and achieved a parallel tooth movement due to the force vector passing close from the tooth center of resistance. On the other hand anchorage loss was seen as side effect.

Bolla et al. (Bolla et al., 2002) in their study with the distal jet appliance; achieved molar distalization of 3.2 mm with 3.1 degrees of distal tipping, 3.1 mm of mesial movement in 1. premolars, 0.6 degrees of incisor inclination. Researchers found no changes in the mandibular plane angle.

Despite the reports of the distal jet appliance providing a parallel distalization, anchorage loss in premolars and incisors is hard to prevent. Ngatung et al. (Ngantung et al., 2001), Fortini et al. (Fortini et al., 1999), designed ´the First Class Appliance´ to counteract the anchorage loss that was occurring with the distal jet appliance. The appliance consists of two parts, a labial and a palatal one in conjunction with Ni-Ti springs between premolars and molars. Fortini et al. (Fortini et al., 1999), applied molar distalization with the First Class appliance on 62 cases with age range of 8.7 - 14.5 years achieving distalization of 4.8 mm in average in 42 days.

Fortini et al. (Fortini, Lupoli, Giuntoli, & Franchi, 2004) in another study performed on 17 patients with the First Class appliance, achieved a class I relationship in 2.4 months. Results showed 4 mm molar distalization with 4.6 degrees of distal tipping and 1.2 mm extrusion, 2.2 degrees of mesial tipping along with 1.7 mm mesial movement and 1 mm extrusion in 2. premolars. Consequently there was additional anchorage loss in form as 1.3 mm of protrusion and 2.6 degrees of proclination in anterior teeth.

Papadopoulos et al. (Papadopoulos, Melkos, & Athanasiou, 2010), used the First Class appliance (FCA) correcting the Class II relationship in 15 patients with mixed dentition. After 17.2 weeks of distalization there was a distal movement of 1 mm per month, 8.56 degrees of distal tipping and an increase in intermolar distance by 1.37 mm.

The 3D bimetric system is another intra-oral but compliance dependent molar distalization method. Wilson and Wilson (Wilson & Wilson, 1987) , invented this technique combined of 3D bimetric distalization arch, 3D mandibular lingual arch and Class II elastics. They named this system ´the Rapid Molar Distalization´ (BDA). The maxillary arch thickness being 0.022 inch and placed passively in the bracket slot. There are hooks in the posterior part of the arch for intermaxillary elastics and omega bendings in the part inserted to the molar tube. Distalization is done by open coil springs placed between the omega bendings and molar tubes. A utility arch and lip bumper in the lower jaw for anchorage purposes supports the appliance. Class II elastics are utilized in the upper jaw to prevent anterior teeth protrusion.

Muse et al. (Muse et al., 1993), used the Wilson bimetric distalization arch in 19 Class II cases. Class II elastics and open coil springs were utilized for distalization. To increase anchorage in the lower arch, lingual and utility arches were used. Post 16 weeks of distalization time there was a distal tipping of 7.8 degrees and 2.16 mm of distalization in upper molars. While there was observed mesialization in lower molars, there was a protrusion of 0.3 mm combined with 1.6 mm extrusion in maxillary anterior teeth due to anchorage loss.

In another BDA study (T. Üçem, Yüksel, Okay, & Gülsen, 2000), post distalization analysis showed a statistically significant distal tipping in upper molar, premolar and canine teeth in addition to proclination and protrusion in maxillary anterior teeth.

The K-Loop appliance developed by Kalra (Kalra, 1995), is another type of intra-oral molar distalization method introduced to the orthodontic marked. It is made of two loops from a 0.017 X 0.025 TMA wire, shaped as a K letter extending gingivally. A Nance button soldered to bands on premolars is used to strengthen anchorage. The active part of this appliance is placed between the molar tubes and first premolar bands. Researcher reported 1 mm mesial movement in premolars for every 4 mm of distalization in molars. Arms of the segmental arch inserted in the molar tube and 1. premolar bracket are given a 20 degree angle on each side,, which was claimed to help controlling the mesial and distal movements in involved teeth.

Keles and Sayinsu (Keles & Sayinsu, 2000), introduced the ´Intra-oral Bodily Distalizer´ (IMBD) as an non-compliance dependent appliance providing upper molar distalization without distal tipping. The average age in their study sample was 13.5 years for 15 patients. The appliance has a broad acrylic Nance button in the palatal side for anchorage. Distalization springs from TMA are extending from the acrylic to first molars, applying a distalization force of 230 grams on each side and by aids of a second bending molar uprighting is accomplished. Researchers reported a parallel distalization movement in molars of 5.2 mm in 7.5 months. On the contrary, there was seen a mesial movement of 4.33 mm in premolars and 4.77 mm of protrusion in incisors as a side effect in terms of anchorage loss.

Keles (Keles, 2001), introduced the Keles Slider as another parallel molar distalization appliance for Class II cases, applied on 15 cases. The tubes are soldered 5 mm gingival on the molar bands and parallel to the occlusal plane, to provide a force application close to the center of resistance. A distalization force of 200 grams on molars is achieved by open Ni-Ti coil springs placed on the wire extending between the acrylic part and the tube, by activations with special type of stoppers. Distalization of 4.9 mm in 6.1 months was observed without any dental molar tipping. A mesial movement of 1.3 mm in 1. premolars and 1.8 mm of protrusion in incisors were seen. The researcher argued for the parallel distalization movement by emphasizing on the force vector being close to center of resistance. Furthermore, anchorage loss was considered to be less due to the broad acrylic part and molars on the contralateral side being involved as part of the anchorage unit as well.

Sayinsu et al. (Sayinsu, Isik, Allaf, & Arun, 2006), applied the Keles Slider in 17 patients to achieve a unilateral molar distalization. They found that there was an average distalization of 0.48 mm a month and 2.85 mm of molar distalization in total. While there was observed 2 mm of mesial movement and 2.03 mm extrusion in 1. premolars, 1.32 mm protrusion and 1.12 mm extrusion along with a 1.79 degrees of proclination was seen in anterior teeth.

Mavropoulos et al. (Mavropoulos et al., 2006), applied the Keles Slider for unilateral molar distalization on 12 patients with average age of 13.1 years. Distalization force being 150 grams unilaterally, 3.1 mm of distal movement in molar was seen while the anterior teeth protruded by 2.1 mm. There was also seen 6.1 degrees of mesial inclination in the premolar on the side it was used at anchorage. They reported 1 mm of deviation of the midline contralateral to the distalization side.

Nickel titanium alloys were first discovered in the early 1960s. As in many other fields they became of great interest in orthodontics. Andreasen et al. (Andreasen & Morrow, 1978) were the first to apply them, Miura et al. (Miura, Mogi, Ohura, & Hamanaka, 1986) were the first to use them in aligning dental arches.

Locatelly et al. (Locatelli, 1992), stated achieving molar distalization with NiTi in cases arch wires about 1-2 mm per month in cases where 2. premolars were not erupted yet. They added that a Nance button could be used in cases with need for additional anchorage. They also reported that distalization was easier achieved in cases where 2. molars were not erupted yet.

Giancotti and Cozza (Giancotti & Cozza, 1998) modified the Locatelly et al. (Locatelli, 1992) system by adding a partial neosentalloy arch wire with an activation range of 5 mm between 2. molar bands and 2. premolar brackets to be able to distalize 2. molars as well. Class II elastics were used to prevent mesial movement of 2. premolars. Bands were placed on 2. molars in conjunction with lip-bumpers, Class II elastics on thick rectangular arch wires were used to increase anchorage in the lower arch. They reported that a force of 80 grams for 1. molar distalization was sufficient after 2. molars were distalized.

The pendulum appliance first applied by Hilgers (Hilgers, 1992), is another alternative system introduced for successful patient cooperation. A modified Nance appliance was used, 0.032 inch thick TMA springs extending from the acrylic were added to apply constant and light distalizing forces on upper molars. The appliance was activated every 3 weeks, 5 mm of molar distalization was achieved in 3-4 months. They stated that the pendulum springs require a 90-degree of activation, that

30% of the activation gets lost when inserted in palatal tubes and that this activation applies 230 grams of force on molar teeth. Another problem faced with the pendulum is molar teeth going into cross bite while distalizing. Hilgers suggested adding an expansion screw to the acrylic to prevent this side effect and called it ´The Pandex´ appliance.

Gosh et al. (Ghosh & Nanda, 1996b), evaluated the pendulum appliance introduced by Hilgers applied on 41 patients. They reported 60-70 degrees of spring activation and distalization force of 230 grams. In 6.21 months they achieved 3.37 mm of molar distalization, 8.36 degrees of distal tipping. 2.55 mm of mesial movement, 1.29 degrees of mesial tipping and 1.7 mm of extrusion was seen in 1.premolars. Results for 2. molars were 2.27 mm of distalization, 11.99 degrees of distal tipping and 2.23 mm of buccal tipping. They claimed that erupted 2. molars had minimal effect on distalization.

Elekdag-Turk (Elekdağ-Türk, 1999), evaluated two different force application pendulum springs in their study. In the first group the springs were activated by 60 degrees and applied 150 grams of force on molars. The springs in the second group had a 90-degree activation with a force application of 230 grams on molars. Comparing both groups they found that molars in the second group were distalized faster but with more distal tipping and anchorage loss in return.

Although classic pendulum appliances are great for patient compliance, distal tipping seems to be unavoidable (Ghosh & Nanda, 1996b; Hilgers, 1992). Many modifications were made to the appliance in order to prevent the distal tipping problematic (Byloff, Darendeliler, Clar, & Darendeliler, 1997; G. Kinzinger, Fritz, & Diedrich, 2002; G. Kinzinger, Fuhrmann, Gross, & Diedrich, 2000; Scuzzo, Pisani, & Takemoto, 1999).

Byloff and Darendeliler (Byloff et al., 1997), added a 10-15 degrees of uprighting bendings to the spring part inserted into the palatal tubes in order to prevent distal tipping. They reported decreasing the distal tipping by these bendings but leading to an increase in anchorage loss and treatment time.

Kinzinger et al. (G. Kinzinger et al., 2000), applied the pendulum appliance with a distal screw and uprighting bendings to prevent distal tipping. They reported a monthly molar distalization by 0.67 mm stating that 72.5% of the space was gained due to molar distalization and 27.5% by mesial movement of anterior teeth. They also added that molar tipping and extrusion, labial tipping of anterior teeth was seen despite of the uprighting bendings. Kinzinger et al. (G. Kinzinger et al., 2002), in another study with attempt to distalize second molars as well, made a modification in the pendulum appliance by adding a second helix. As only a unilateral molar distalization was needed in the first case, the second helix was activated for the 2. molar first followed by activation of the 1. helix for 1. molar 3 weeks later. In the second case only helixes for 2.molars were activated during 10 months thus distalized first. First molars were distalized by interseptal fibers to a certain extent but not sufficiently. Post 13 months helixes for were deactivated for 2.molars and activated for 1.molars. In 20 months distalization of both molars was finally achieved.

Another modification of the pendulum appliance is the ´M pendulum´, developed by Scuzzo et al. (Scuzzo et al., 1999). They adjusted the loops on the springs in the classic pendulum appliance by directing them posteriorly. They claimed applying a force of 125 grams, activating the distalization springs by 40 - 45 degrees. They added that any tipping post distalization could be corrected by loop activations.

Transpalatal arches (TPA) in general are known to add anchorage for molars, correct molar rotations or provide a dental expansion. Haas and Cisneros (Haas & Cisneros, 2000), reported achieving some distalization by making some modifications to the TPA and apply 1/4 or 1/8 of the force applied together with headgears. They called the appliance used in their study ´the Goshgarian transpalatal bar´. The appliance has an active and a passive component. The passive part inserting the palatal tube takes an inclination of 35 degrees towards the part to be distalized. By this slope the TPA is expected to apply a force of 32-48 grams, helping distalize by 2 mm in 5 months. An increase in inter-molar width and molar rotation were considered as unwanted side effects of the appliance.

Kucukkeles et al. (Kucukkeles et al., 2006), placed the Hyrax screw perpendicularly on the palatal suture aiming to evaluate its efficiency. The hyrax screw was soldered to the 2.premolar bands in the anterior and to 1.molar bands in the posterior. To strengthen anchorage a lip bumper ending in the vestibular 2.premolar level was used. They reported achieving 4.17 mm molar distalization by activating the screw twice a week. Anchorage loss in terms of 4.17 mm mesial movement in 2.premolars and 5.89 degrees of proclination in anterior teeth was observed.

Greenfield (Greenfield, 1995), introduced ´the Piston Appliance´ for molar distalization in 1995. Bands were placed on 1.premolars and 1.molars, a Nance buton was soldered to premolar bands for anchorage. For bilateral distalization a 0.36 mm diameter tube was soldered on premolar bands both labially and palatally. A wire passing freely though this tube and soldered on the molar band on one end, is extended anteriorly to the1.premolar as far as the distalization need. This wire soldered on the molar and its passage through the tube is called the piston system. A stopper, applying a distalization force, activates open Ni-Ti springs on the piston. The researcher reported no dental tipping in molars due to bilateral distalization.

Intra-oral molar distalization appliances have advantages such as being more comfortable and easy compared with extra-oral appliances, more accepted esthetically, providing shorter treatment time due to constant forces. On the contrary, they have significant side effects such as molar rotation and distal tipping, mesialization and extrusion in premolars, protrusion and labial inclination in anterior teeth and an increase in overjet. Due to these issues, an emphasis on skeletal anchorage for intra-oral appliances has increased over the course of years and up to date.

4.9 Skeletal Anchorage

As in other medical fields, the first studies done to investigate skeletal anchorage were performed on animals (Oosthuizen et al., 1973). Roberts et al. (Roberts, Smith, Zilberman, Mozsary, & Smith, 1984), applied continuous forces on dental implants placed in animals and claimed that stability was maintained throughout. This way they suggested skeletal anchorage as solution to side effects occurring during orthodontic tooth movement. Triaca et al. (Triaca, Antonini, & Wintermantel, 1992) in 1992, were the first to apply palatal implants for skeletal anchorage in orthodontics. In the following years this topic became a popular topic of interest to investigate further about with several studies. (Cornelis & De Clerck, 2006, 2007; Gelgör et al., 2004; Kaya, Arman, & Uçkan, 2009; G. S. Kinzinger, Gülden, Yildizhan, & Diedrich, 2009; Kircelli, Pektas, & Kircelli, 2006; Lim & Hong, 2008; Oberti, Villegas, Ealo, Palacio, & Baccetti, 2009; Papadopoulos, 2008; H.-S. Park, Kwon, & Sung, 2004; H.-S. Park, Lee, & Kwon, 2005; Yamada, Kuroda, Deguchi, Takano-Yamamoto, & Yamashiro, 2009)

Yamada et al. (Yamada et al., 2009), placed mini-screws for molar distalization at an oblique angle of 20-30 degrees between 2.premolars and 1.molars on patients with no growth potential left. Molar distalization was achieved in 8.4 months with distal movement in molars by 2.8 mm, 4.8 degrees of distal tipping and 0.6 mm intrusion. They also observed a distal movement in maxillary incisors by 2.7 mm with 4.3 degrees of palatal inclination. They claimed achieving molar distalization by mini-screws placed in the inter-radicular area from the buccal, without any anchorage loss or any increase in the mandibular plane angle.

Kaan et al. (Kaan et al., 2007), used a modified mini implant anchored Lokar appliance on 20 patients to evaluate its efficiency. To make the force pass as close to the center of resistance as possible an activator tube soldered to the lokar was again soldered buccally on the molar band. A distalization force was applied by activating the Ni-Ti coil springs on the lokar, taking anchorage from mini implants placed between 1.molars and 2.premolars. Results post distalization after 10.8 months showed, distal movement in molars by 3.28 mm with a distal tipping by 5.48 degrees. Distal movement in upper incisors was insignificant with 0.93 degrees of distal tipping hence a decrease in overjet values.

In contrast to issues occurring with mini-screws in terms of the narrow buccal inter-radicular area and possible root damage while distalizing, difficulties faced with the surgical procedure needed for zygomatic anchorage systems, other sites for skeletal anchorage was investigated as the palate. The cortical bone thickness in the palate being sufficient and away from structures as nerves, vessels and roots thought to be suitable for mini-screws in the palate. Several researchers started to investigate the palate as anchorage site (Escobar et al., 2007; Gelgör et al., 2004; Gelgör, Karaman, & Buyukyilmaz, 2007; Kärcher, Byloff, & Clar, 2002; Kircelli et al., 2006; Oberti et al., 2009).

Gelgör et al. (Gelgör et al., 2004), performed molar distalization from the vestibule taking anchorage from the palate on 25 patients. They inserted a 1.8 mm x 14 mm mini-screw 5 mm behind the incisive canal. Bands were placed on 1.premolars and 1.molars with open springs in between, applying 250 grams on each side. A TPA was constructed to prevent mesial movement of 1.premolars. TPA is soldered to premolars bands with its U-part being supported by the mini-screw. The U-part is attached to the mini-screw by composite, serving as indirect anchorage. Post distalization time of 4.6 months there was a distal molar tipping by 8.8 degrees, 3.9 mm of distalization together with a disto-palatal rotation in molars. For incisor teeth there was seen protrusion by 0.5 mm.

Gelgör et al. (Gelgör et al., 2007) in another study performed on 40 patients, they divided the study sample in two applying two different molar distalization systems. In both groups a 1.8 x 14 mm mini-screw was used as anchorage in the premaxilla. The design of the appliance in the first group is as described above. In the second group an activator tube was soldered to the molar band. The laboratory prepared wire extending posteriorly from the activator tube, is parallel to the occlusal plane. Open Ni-Ti springs were placed on the laboratory wire between the activator tube and the acrylic part, before being cemented intra-orally. A composite stopper is placed anteriorly to the coil springs to apply 250 grams after cementation. For the Group 1 distalization time was 4.6 months with distal molar tipping by 9.05 degrees and 3.95 mm distalization. For Group 2 distalization time was 5.4 months with distal molar tipping by 0.75 degrees and 3.88 mm distalization. Researchers reported less distal tipping and rotation in Group 2, but a longer distalization time and more impaired hygiene.

Kärcher et al. (Kärcher et al., 2002), used the pendulum appliance in conjunction with the Graz implant in palate to prevent side-effects that occurs with the classic pendulum during molar distalization. They applied this appliance on 7 patients with 250 grams of distalization force during 8 months. They stated there was no mesial movement in anterior teeth using this appliance with the Graz implant. Another reported advantage of the appliance was being operator friendly and activation easy.

Kırcelli et al. (Kircelli et al., 2006), different from Kärcher et al. (Kärcher et al., 2002), used a 2 x 8 mm mini-screw in the palate instead of the graz implant together with the pendulum appliance. They gained 6.4 mm distalization, a spontaneous distal drifting of premolars due to not being engaged in the anchorage unit in contrast to the traditional pendulum appliance.

Escobar et al. (Escobar et al., 2007), applied the pendulum appliance on 15 patients with 2 mini-screws in the palate. They reported after 7.8 months of distalization; 6 mm distal movement in 1.molars and 11.3 degrees of distal tipping, 4.85 mm distalization and 8.6 degrees of distal tipping in 2.premolars, 0.5 mm retrusion and 1.27 degrees of palatal tipping in upper incisors.

Chang et al. (Chang, Hsiao, Tsai, & Roberts, 2006), placed mini-screws between 1.molars and 2.premolars to prevent the anchorage loss seen while distalizing with the pendulum appliance. They ligated the 1.premolar to the mini-screw preventing any mesial movement of the premolar. Open Ni-Ti coil springs were placed on the arch wire mesial to the 1.premolar post distalization and activated taking anchorage from the mini-screws, achieving distalization of the premolars as well.

Önçağ et al. (Önçağ et al., 2007), performed a study on 30 patients comparing the traditional pendulum appliance with the one taking anchorage from oseointegrated implants. They reported significant values of dental tipping in molars, mesialization and tipping in premolars and protrusion in anterior teeth.

Karaman et al. (Karaman et al., 2002), achieved distalization in a unilateral Class II patient with 2.molars not erupted yet, using the Distal Jet appliance in conjunction with mini-screws in the palate area. They reported 5 mm molar distalization in 4 months without any anchorage loss seen in the traditional Distal Jet appliance.

Kinzinger et al. (G. S. Kinzinger et al., 2009), performed another study about the modified Distal Jet appliance used for molar distalization in 10 patients. Post 6.7 months of distalization there was reported 3.92 mm distal movement in molars. The mesial part of molars was rotated inwards and outwards distally, linked to the force being applied from the palatal side alone. A mesial movement by 0.72 mm was seen in 1.premolars being a part of the anchorage unit.

Park et al. (H.-S. Park et al., 2004), aimed for bodily molar distalization in 2 cases they worked on. In the first case they placed a 1.2 x 10 mm mini-screw between the 1. and 2.molar palatally. In the second case they placed a 1.2 x 8 mm mini-screw between the 2.premolar and 1.molar from the buccal. Distalization in the lower arch was carried out with mini-screws placed in the retro-molar area. Park et al. (H.-S. Park et al., 2005), conducted another study with mini-screws placed as in the previous study, expect for 2 cases where they were placed them between 1. and 2.molars in the lower arch. They claimed that molar distalization with anchorage support from mini-screws is an efficient way of distalization without any anchorage loss.

Kyung et al. (Kyung, Hong, & Park, 2003), aimed for molar distalization in 2 cases placing the mini-screws posteriorly to the mid-palatal area. In the first case 5 mm molar distalization was achieved in 3 months by using tight chains between the mini-screws and hooks soldered on to the TPA, applying 400 grams of force on molars. In the second case 2 mini-screws were used palatally providing 5 mm molar distalization in 5 months. Researchers reported no anchorage loss in both cases.

The force application from the palate allows closer proximity to the center of resistance of 1.molars compared with the vestibule. Keles et al. (Keles, Erverdi, & Sezen, 2003), modified the Keles slider based off this idea and placed a 4.5 x 8 mm mini-screw in the palate for anchorage. Taking support from the mini-screw and an activator tube soldered to the molar band at the trifurcation level, 3 mm molar distalization was achieved by applying the force close to the center of resistance.

They stated achieving a bodily movement of the molar and no anchorage loss.

Another researcher who used a modification of the Keles slider is Papadopoulos (Papadopoulos, 2008). He placed 2 mini-screws on an 11.5 years old female patient, in the anterior palate right and left to the palatal suture. The rest of the appliance consisted of a laboratory prepared palatal wire, cemented with glassionomer to the mini-screws, with open Ni-Ti coil springs on extending to the activator tube on molar bands. He used stoppers to activate the open Ni-Ti coil springs and stated achieving a bodily molar distalization without any anchorage loss.

Nalçacı (Nalcaci, 2008) applied molar distalization by placing 2 mini-screws in the palate, in 21 patients in their thesis study. In order to achieve a parallel molar distalization the palatal wire was made of 1.1 mm stainless steel, a horizontal U-bending was made distally to the activator tube to make the system more rigid. The wire as well as the miniscrews was covered with an acrylic plate in the anterior. Post 9.61 months of distalization they reported 3.95 mm of parallel distal movement of the 1.molars, distal drifting in the premolars by interseptal fibers due to not being involved in the anchorage unit. Distal movement by 2.5 mm and 1.33 degrees of distal tipping was observed in incisors without any anchorage loss.

Several studies point out unwanted rotation in molars where a unilateral molar distalization was applied (Gelgör et al., 2004; Gelgör et al., 2007; Ghosh & Nanda, 1996b; Itoh, 1991; G. S. Kinzinger et al., 2009; Kircelli et al., 2006; Mavropoulos et al., 2006). Lim and Hong (Lim & Hong, 2008), used therefore mini-screws both from the palatal and buccal side to achieve a bodily molar distalization. Being supported by mini-screws placed posteriorly in the palate, a TPA inserting the sheets on the molar bands, a distal pulling force of 300 grams was applied on the molars. On the buccal side there was a bending from 0.019 x 0.025 stainless steel wire with a stopper mesial to the molar and a hook like structure distal to the premolar. By a chain connection from the hook down to the mini-screw placed between the 1.molar and 2.premolar, a force of 150 grams was applied on the molars from the buccal.

Oberti et al. (Oberti et al., 2009), believed in a more bodily molar distalization when a dual force was applied rather than a single force application. They achieved molar distalization in 5 months by applying a dual force (palatal and buccal) taking anchorage from two 2 x 11 mm mini-screws placed in the palate. Post 5 months of distalization, they reported 5.6 degrees of distal tipping and 5.9 mm of distal movement in molars, 4.26 mm of distal movement and 5.4 degrees of tipping in premolars, 4.7 mm increase in the inter-molar distance. They claimed that by a dual force a more bodily distalization and a shorter distalization time is possible compared with single force application systems.

Sar et. al (Sar, Kaya, Ozsoy, & Özcirpici, 2012) conducted a study on 28 patients comparing the mini-screw implant supported distalization system (MISDS) versus the bone-anchored pendulum appliance (BAPA). The pretreatment and post-treatment lateral cephalograms were analyzed. Upper posterior teeth were distalized successfully in both groups. Nearly bodily distalization was seen in the MISDS group, whereas significant distal tipping of the upper first molars was observed in the BAPA group. There were no statistically significant changes in the sagittal position of the maxilla and mandible and in the position of the upper incisors as a result of treatment in either group. They concluded that both methods provided absolute anchorage for distalization of posterior teeth; however, almost translatory distal movement was encountered in the MISDS group, and substantial distal tipping of the maxillary molars accompanied distalization in the BAPA group.

Bechtold et al. (Bechtold, Kim, Choi, Park, & Lee, 2012), studied the distalization pattern of the maxillary arch depending on the number of orthodontic miniscrews. Twenty-five adult patients with mild to moderate Class II dentition and minimal crowding were collected. Either single (group A, n = 12) or dual (group B, n = 13) mini-screws were inserted on the posterior inter-radicular area to deliver a distalizing force to the main arch wire. The displacement patterns of maxillary incisors and molars were measured and compared. Significant distalization in the molars and incisors was shown in both groups. Significantly greater distalization and intrusion of the first molar and intrusive displacement of the incisor, together with significant reduction of the mandibular plane, were noted in group B, in contrast to the rotation of the occlusal plane in group A. Inter-radicular mini-screws predictably induced total arch distalization, leading to the correction of Class II. Additional mini-screws in the premolar area appear to facilitate intrusion and distalization of the entire arch according to the position of the force vectors.

Longerich et al. (Longerich, Thurau, & Kolk, 2014) introduced the Longslider as new maxillary molar distalization device, generating forces of up to gf 600 (5.88 N). They stated that Ni-Ti springs with high pseudoelastic forces are required to overcome friction and concomitantly create ideal translation force for molar distalization. The device reportedly deactivated itself automatically at the end of the distance in all cases without dental tipping or any implant-related complications. They stated that the use of 2-coupled mini-implants with exchangeable abutments in combination with a molar guidance appliance is an effective, safe, and a clinically comfortable device for maxillary molar distalization. The study sample was small, involving 6 patients. Nevertheless, authors claimed that the Longslider could overcome the high dynamic frictional forces encountered during guided molar distalization.

In a meta-analysis by Grec et al. (da Costa Grec et al., 2013), the aim was to quantify and compare the amounts of distalization and anchorage loss of conventional and skeletal anchorage methods in the correction of Class II malocclusion with intraoral distalizers. After applying the inclusion and exclusion criteria, 40 studies were included in the systematic review. For the meta-analysis, 6 studies were included, and they showed average molar distalization amounts of 3.34 mm with conventional anchorage and 5.10 mm with skeletal anchorage. The meta-analysis of premolar movement showed estimates of combined effects of 2.30 mm (mesialization) in studies with conventional anchorage and 4.01 mm (distalization) in studies with skeletal anchorage. In conclusion, there was scientific evidence that both anchorage systems are effective for distalization; however, with skeletal anchorage, there was no anchorage loss when direct anchorage was used.

Kook et al. (Kook et al., 2014) studied the treatment effects of a modified palatal anchorage plate for distalization evaluated with cone-beam computed tomography images of 20 Class II patients. The occlusal plane angle was increased significantly ($P = 0.0001$). The maxillary first molar was distalized by 3.3 mm at the crown and

2.2 mm at root levels, with distal tipping of 3.4° and intrusion of 1.8 ± 1.4 mm. Moreover, the maxillary incisors moved 3.0 ± 2.7 mm lingually, with lingual tipping of 6.2° ±7.6° and insignificant extrusion (1.1 mm; P = 0.06).

Cozzani et al. (Cozzani et al., 2016) compared direct versus indirect anchorage in two miniscrew- supported distalizing devices, the MGBM System (MGBM) and the Distal Screw appliance (DS), in 53 dental Class II patients. The mean distalization time was 6 ± 2 months for MGBM and 9 ± 2 months for DS. Maxillary superimpositions showed that the maxillary first molar distalized an average of 5.5 mm in the MGBM and 3.2 mm in the DS between T1 and T2; distal molar tipping was greater in the MGBM (10.3°) than in the DS (3.0 °). First premolar showed a mean mesial movement of 1.4 mm, with a mesial tipping of 4.4° in the MGBM; on the contrary, first premolar showed a distal movement of 2.2 mm, with a distal tipping of 6.2°, in the DS. In conclusion, the MGBM system resulted in greater distal molar movement and less treatment time, resulting in more efficient movement than was associated with the DS; DS showed less molar tipping during distalization.

Duran et el. (Duran, Görgülü, & Dindaroğlu, 2016) studied the three-dimensional analysis of tooth movements after palatal miniscrew-supported molar distalization. This study sample comprised 21 patients at an average age of 13.6 years with a bilateral Class II molar relationship. In the sagittal direction, the first molars showed a mean linear movement of 4.10 ± 1.57 mm, with distal tipping of 11.02°; the central incisors showed a mean distal movement of 0.95 ± 0.40 mm, with retroclination of 1.59 ± 0.59°. In the vertical direction, only the first molars showed intrusion, with a mean value of –0.59 ±0.50 mm. Rotation of the first molars was 4.92 ± 3.09°. The second molars had the greatest rotation. Through support from the anterior palatal region, the maxillary first molars were distalized without anchorage loss. Furthermore, movement was observed in all 3 planes of space with reduction from the posterior to the anterior in the maxillary arch.

4.9.1 Miniplates

Distalization systems with anchorage provided by mini-screws placed in the inter-radicular area on the vestibule soon showed some limitations such as; limited distalization and teeth roots approximating these mini-screws or even get damage while distalizing. These issues gave rise to a new site for skeletal anchorage, the zygomatic buttress.

Sugawara et al. (Sugawara et al., 2006), applied the ´Skeletal Anchorage System´(SAS) on 25 patients with no remaining growth potential using the zygomatic buttress area as anchorage for molar distalization. They achieved 3.78 mm of molar distalization at crown level and 3.20 mm at root level. They claimed SAS being an effective distalization system for patients with no growth spurt left.

De Clerk and Cornelis (Cornelis & De Clerck, 2006), performed another study on 153 patients using the zygomatic buttress as anchorage for molar distalization. They stated achieving molar distalization in 6-9 months without any anchorage loss with zygomatic miniplates and the modified sliding jig appliance.

Cornelis and De Clerck (Cornelis & De Clerck, 2007), used miniplates for molar distalization in another study performed on 17 adult patients. Elastics were used from hooks on the miniplates down to hooks on the sliding jig 3 weeks post surgery. This way a force of 150 grams is applied on the molar by activating the open coil springs between the sliding jig and the molar tube. Post 7 months of distalization, a distal movement by 3.27 mm in molars was achieved along with a Class I molar relationship. A decrease in overjet by 0.99 mm and an increase in intermolar width by 2.78 mm were other registered results.

Kaya et al. (Kaya et al., 2009), conducted a study comparing the zygoma miniplate system (ZAS) with cervical headgears (CH) for molar distalization in 30 patients. Half of the study group used the ZAS system while the other half used the CH. Premolars were bonded in both groups and a 0.016 x 0.022 stainless steel wire was placed. In the ZAS group the closed Ni-Ti coils were attached to a sliding hook on wire, which located mesial to 1.premolar bracket on one end and to the miniplate hooks on the other end. A distalization force of 450 grams was applied and 4.5-5 mm molar distalization was achieved in 9 months. In the CH group 3.5-4 mm molar distalization was reported achieved in 9 months. They reported distal tipping in premolars and no vertical skeletal changes in the ZAS group, distal tipping in premolars and an increase in vertical changes skeletally in the CH group.

Kaya et al. (Kaya, Şar, Arman-Özçırpıcı, & Polat-Özsoy, 2012) in a study conducted on 30 patients compared the implant-supported pendulum (ISP) and the zygoma anchorage system (ZAS). Point A and upper incisors protruded in the ISP group, retruded in the ZAS group. Upper posterior teeth were distalized in both groups, but more in the ZAS group. Significant differences were observed between the groups for the sagittal movements of Point A, incisors, and posterior teeth. Overbite decreased in the ISP group, overjet decreased in the ZAS group, upper and lower lips retruded only in the ZAS group. Both methods provided absolute anchorage for distalization of posterior teeth, but the skeletal and soft tissue outcome and distalization obtained was greater in the ZAS group. They concluded that both methods could be used as alternatives to extra-oral traction and conventional molar distalization appliances with different patient requirements.

Kilkis et al. (Kilkis, Celikoglu, Nur, Bayram, & Candirli, 2016) studied the effects of zygoma-gear appliance on 21 patients for unilateral maxillary molar distalization in a prospective clinical study. The mean amount of distalization for the maxillary first molar was found to be 5.31 ± 2.46 mm (P <0.001) in 0.45 ± 0.12 years, showing an amount of 0.98 mm of distalization per month. It was also accompanied by a slight intrusion (0.76 ± 2.85 mm; P>0.05) and distal tipping (6.39 ± 5.39; P<0.001) of the maxillary molars. The maxillary premolar also spontaneously moved distally 1.63 ± 1.90 mm (P <0.01) with distal tipping (4.05 ± 3.47; P <0.001). Moreover, the inclination of the maxillary incisors and overjet were decreased (-1.59 ±1.45, P <0.001; and 0.29 ± 0.63 mm, P <0.05; respectively) showing no anchorage loss. No statistically significant changes were found for the skeletal and soft tissue measurements (P >0.05).

Papadopoulos et al. in chapter 49 (Papadopoulos, Papageorgiou, & Zogakis, 2014) explained complications that could during mini-screw use. First, during insertion as lack of initial stability if placed in inadequate cortical bone thickness or injury of adjacent structures (periodontal ligament, tooth root, nerves, blood vessels or sinus perforation). Second, during orthodontic treatment as inflammation and infection of surrounding tissues, loss of mini-screw stability attributable to inflammation or bone remodeling. Last, during removal in terms of fracture.

The maxillary sinus may have pathological alterations before any orthodontic treatment is commenced; cone beam CT carried out before treatment showed incidental pathological alterations in approximately 50%, including mucosal thinning, polyps and acute sinusitis (Pazera, Bornstein, Pazera, Sendi, & Katsaros, 2011). This would suggest that a preliminary otorhinolaryngology consultation would be useful to evaluate the condition of the sinus, detect any predisposing factors for iatrogenic damage and solve any pathological problems before initiation of orthodontic treatment (Gracco, Tracey, & Baciliero, 2010).

In a systematic review of temporary skeletal anchorage devices by Schatzle et al. (Schätzle, Männchen, Zwahlen, & Lang, 2009), the average failure rates of various devices were 7.3% for mini- plates, 10.5% for palatal implants, and 16.4% for mini-screws. The survival rates for mini-plates were 2.8% in Nagasaka et al. (Nagasaka et al., 1999), 7% in Choi et al. (B.-H. Choi, Zhu, & Kim, 2005), 6% in Takaki et al. (Takaki et al., 2010), 3% in De Clerck and Swennen (E. E. De Clerck & Swennen, 2011).

Clearly, although the numbers vary, all of these reports indicate the overwhelming success of miniplates, whether used in the maxilla or the mandible. The use of miniplates is specially advised in patients with a borderline skeletal malocclusion who require camouflage treatment without premolar extractions. Miniplates prove much higher anchorage value and better stability than other temporary skeletal anchorage devices (Sugawara, 2014).

Typical features of mini-plates is to distalize and rotate molars distally, expand the maxillary dentition, mandibular distalization is made possible, no risk of injury to the roots or the inferior alveolar nerve.

The common features of Class II malocclusions are a narrow maxillary arch and mesial rotation of the maxillary molars. In such cases, the most rational approach is to distalize the maxillary molars using absolute anchorage placed in the buccal side rather than the lingual side. This makes it possible to distalize the molars and rotate them distally simultaneously; this in turn expands the maxillary dentition.

If miniscrews are the temporary skeletal anchorage device of choice, then they should be installed in the palate to distalize the maxillary molars. However, because the distalization mechanics with palatally installed miniscrews tends to aggravate the mesial rotation of the maxillary molars, complicated orthodontic mechanics are necessary to offset these undesirable side effects. Miniplates are simply a better option in such cases. The advantage of stability and durability even under high orthodontic forces is a superior feature as well as ease of placement at different anatomic sites.

Although mini-screws can be used as anchorage for en masse retraction, there is a significant correlation between mini-screw failure rate and increased mandibular plane angle; consequently, miniplates may offer a better approach in patients with a high mandibular plane angle.

Moreover, the stability and durability of mini-screws under multidirectional forces is less clear at present. By comparison, zygoma anchors can be used efficiently for both the intrusion of maxillary molars and the en masse retraction of the maxillary anterior segment simultaneously in patients with Class II high mandibular plane angle (Özçırpıcı, Kaya, & Şar, 2014).

The vertical control mechanism to intrude posterior teeth with miniplates can be applied at both maxillary and mandibular molar regions. Consequently, miniplate anchorage can be used successfully in patients with Class II high-angle vertical growth pattern plus increased mandibular plane angles to obtain antero-superior rotation in the mandible as well as to eliminate disto-occlusion with the accompanying convex profile. Hence, the effectively applied multidirectional retraction and intrusion biomechanics can be used in severe cases as an alternative to orthognathic surgery.

Other specific advantages are shortening treatment time significantly, making it possible to control the vertical component of the distalization or retraction force vector. Zygoma anchors can be used to control the anteroposterior rotation of occlusal and mandibular planes. The skeletal and soft tissue improvements obtained with zygoma anchorage are only matched by those achieved with use of cervical or occipital headgear (Kaya et al., 2009). Being able to apply high distalization forces, similar to those achieved with cervical headgear is an important advantage of zygoma anchors.

Mini-screws on the contrary, which have to be of small diameter and have a relatively small surface in contact with the alveolar bone, are relatively fragile and can only withstand low forces: a maximum of 200 g for a mini-screw of diameter 1.2 mm and length 8 mm (H.-S. Park et al., 2005).

Many authors noted that when a two-stage procedure is used, with the maxillary first molars initially distalized with an intraoral molar distalization appliance, it is difficult to maintain the distalized position of the molars during the second stage. Therefore, they considered that the distalization obtained with zygoma anchors should be evaluated as true molar distalization since there is no second stage involving retraction of maxillary premolars and anterior teeth that could result in a mesial movement of the maxillary first molars.

5. MATERIALS AND METHODS

5.1. Materials:

The Ethical Committee of the Institute of Health Sciences, Marmara University approved this retrospective study. The records of 12 out of 15 patients with Class II malocclusion, who had undergone maxillary molar distalization with zygomatic anchorage, were collected from the archives of the Department of Orthodontics, Faculty of Dentistry, Marmara University. Three patients were eliminated due to missing records.

Our study sample consisted of 7 females and 5 male patients. The patient age range was between 14.5 to 26.25 years with mean age 18.0±3.42 years. Reported distalization time range was 4 months to 6 months and 3 weeks with a mean of 5.58±0.92 months. All miniplates used in this study were stable during distalization, no reports in patient files in terms of infection or mobility.

Gender	*Male*	*Female*	***Total***
Number of Patients	5	7	12
Mean Age (y)	17.55±1.56	18.46±4.78	18.0±3.42
Mean Distalization Time (mo)	5.71±0.6	5.46±1.21	5.58±0.92

Table 1: Chronological ages, gender distribution and distalization periods of the patients

5.2. Patient Selection:

Patients who underwent this treatment protocol were originally selected based upon the following criteria:

- Having a Class I or II skeletal relationship
- Having normal to low angle skeletal relationship
- Being in a post-peak growth or adult stage

- A unilateral or bilateral dental Class II relationship (at least cusp to cusp) with crowding or protruded incisors in the maxilla
- No or minor crowding in the mandible
- Both first and second maxillary molars present on the side(s) with a Class II relationship
- Upper third molars being extracted
- Increased overjet and overbite or upper anterior arch constriction
- An indication for distal molar movement with no anchorage loss rather than an extraction treatment protocol
- Patients who had complete initial and post distalization records in terms of intra- and extra-oral photos, panoramic and lateral cephalometric radiographs, dental casts.
- All records being taken on the day of start and end of the distalization procedure.

5.3 Buccal Segment Distalization with Zygomatic Anchorage

5.3.1 Background Information

All treatments were planned and completed under supervision at the Department of Orthodontics, University of Marmara. Upper 1.premolars and 2.molars were bonded (Roth .018 slot); 1.molars were banded on the side of the distalization. Following the leveling of the segment with Ni-Ti archwires, a 0.016 stainless steel wire was used together with Ni-Ti coils for the sliding mechanics. Maxillary molar distalization procedure started 2-4 weeks after mini-plate placement minor surgery. The patients were seen every 4 weeks to monitor progress, while the system was reactivated when needed by shifting the sliding lock towards distal or by placing a longer open coil spring (Fig.5.3.2). Distalization was completed in approximately 4-6 months depending on the case.

A stop tube with stop screw (Dentaurum) and an activator tube (Dentaurum) were linked together with a loop shaped 1.1 mm thick stainless steel round wire, soldered at both ends by a dental technician (Fig.5.3.1.). The modifiable loop design gave the operator the flexibility to adapt this part between the miniplate arm and teeth according to each patient´s anatomy.

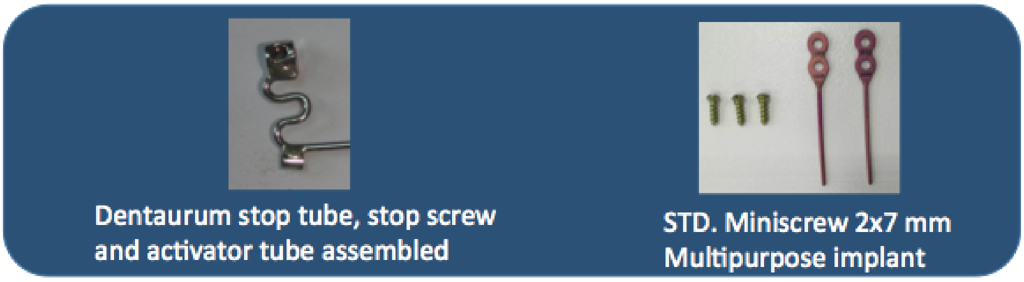


Figure 5.3.1: Representation of the connecting system and miniplates used in study.

Figure 5.3.2: Application of the zygomatic miniplate and distalization mechanics.

Orthodontic treatment was continued using fixed appliances for the final alignment of the arches and detailing of the occlusion, during which time molar position was maintained.

5.3.2 Placement of the Zygomatic Miniplate

Miniscrew supported zygomatic miniplates were placed on the zygomatic buttress for anchorage. The body of the titanium miniplate (Multipurpose Implant) consists of 2 mini-holes made to insert 2 miniscrews for fixation. After the miniplates are fixated onto the zygomatic bone, the other end of the miniplate is exerted through the attached mucosa on the furcation level of the 1.molar.

The procedure of the miniplate placement surgery is performed under local anesthesia and by the same operating surgeon (S.A.) at Department of Oral Surgery, University of Marmara. After an L-shaped incision is made, a mucoperiostal flap is lifted to expose the cortical bone surface for miniplate placement. After the miniplate is adapted to the zygomatico-maxillary buttress crest, 2 miniscrews are used to fixate it to the bone. The mucoperiostum is then placed back and sutured (3.0 vicryl (Ethicon, Jhonson & Jhonson, Belgium). The postoperative protocol was as follows: Analgesics (550 mg Apranax Forte, 2x1), antibiotics (1000 mg Augmentin, 2x1) and antiseptic mouth rise (% 0.02 Clorhex gluconate mouth rinse, 2x1).

One week later the sutures were removed and as healing was secured the distalization procedure started shortly after within 2 - 4 weeks post surgery.

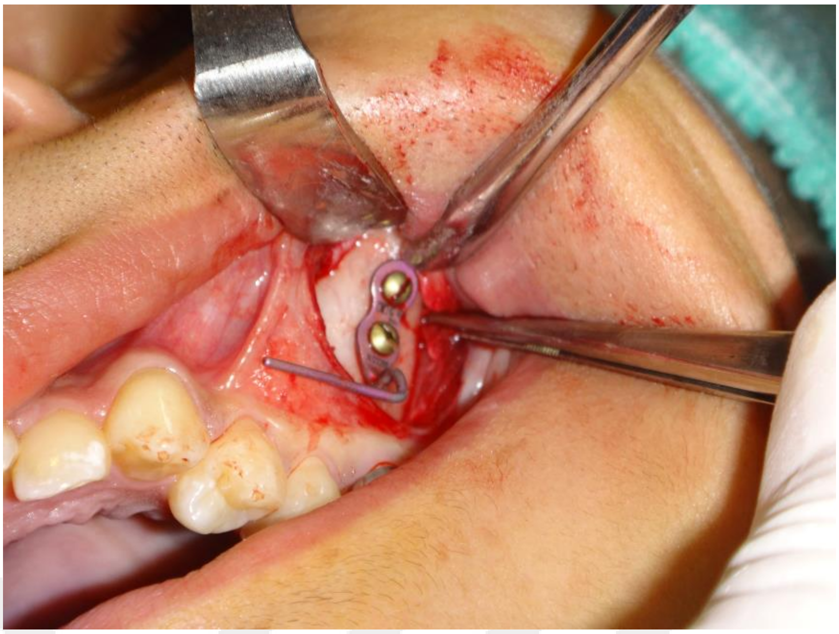


Figure 5.3.2.1: Placement of the zygomatic miniplate.

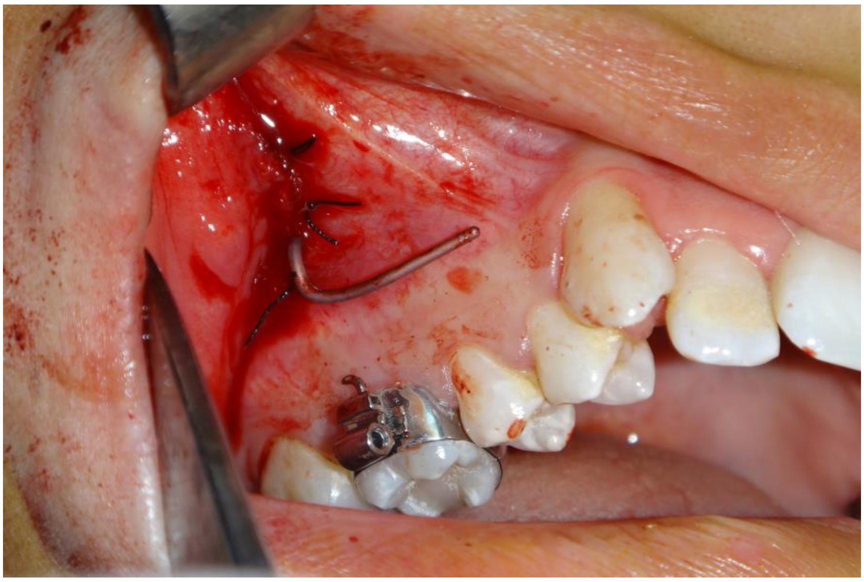
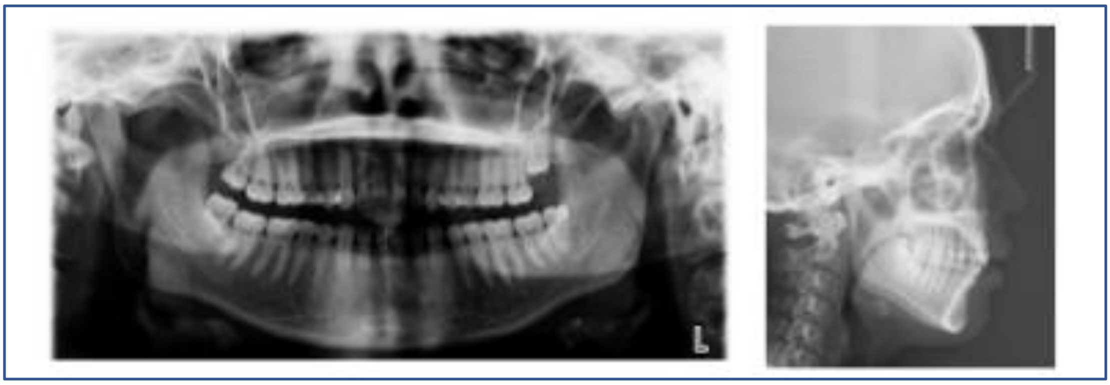


Figure 5.3.2.2: Suturing post surgery



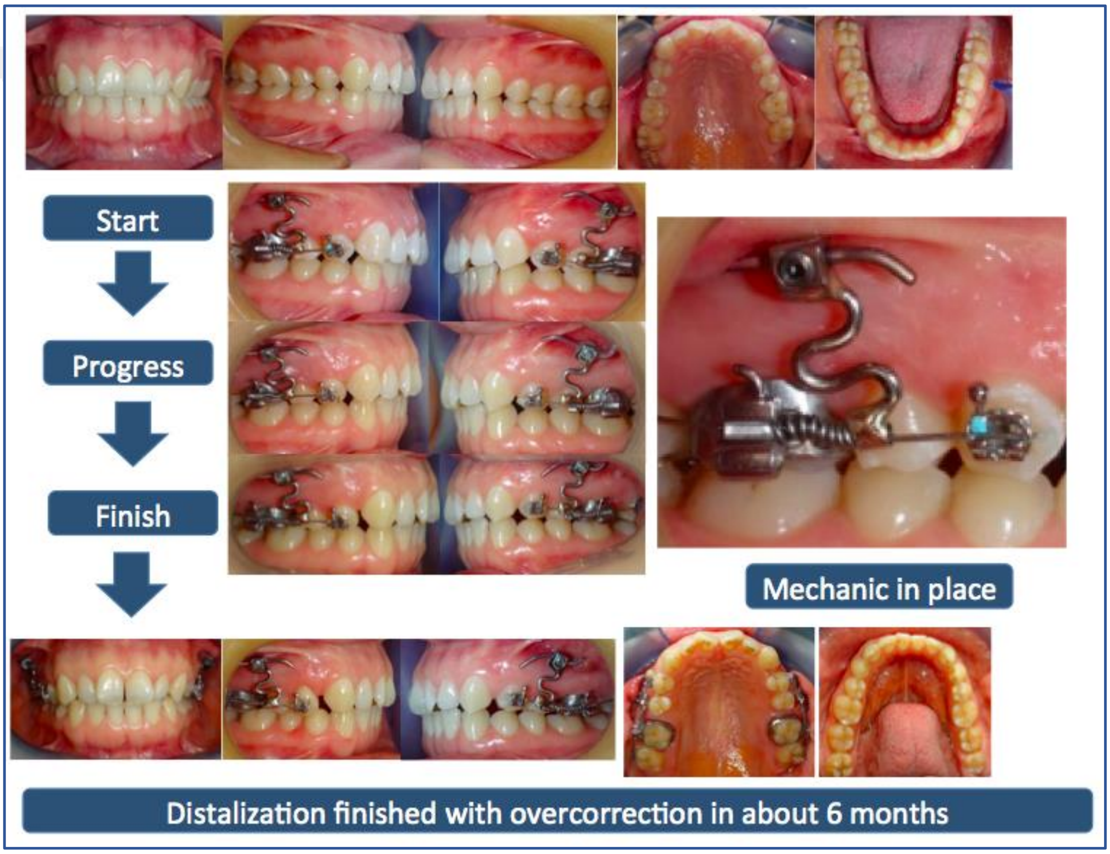


Figure 5.3.2.3: Monthly progress of a bilateral distalization patient.

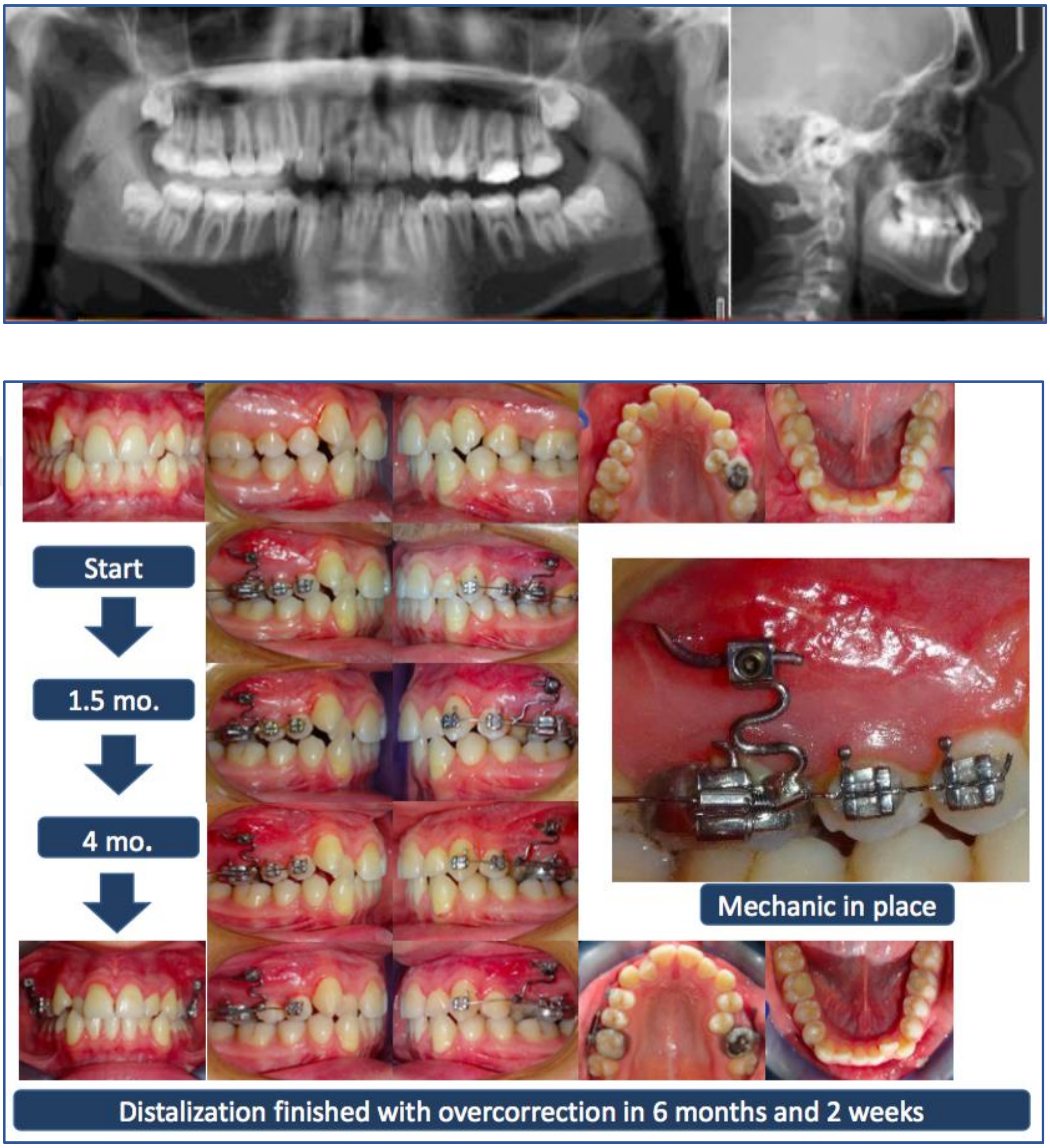


Figure 5.3.2.4: Monthly progress of another bilateral case.

5.4 The Cephalometric Analysis

Any skeletal, dental or soft-tissue changes due to treatment were assessed on lateral cephalometric radiographs obtained before and after distalization.

5.4.1 Skeletal Points

1. S: Sella. The geometrical midpoint of Sella Turcica.
2. N: Nasion. The most anterior intersected point of the nasiofrontal suture in the sagittal plane.
3. Po: Porion. The most superior point of meatus acusticus externus.
4. Or: Orbitale. The most inferior point of the orbital cavity.
5. Ba: Basion. The most postero-inferior point of the basillary part of the occipital bone, the most antero-inferior part of foramen magnum.
6. PNS: The posterior nasal spine. The most posterior point of hard palate.
7. ANS: The anterior nasal spine. The most anterior point of the maxilla supporting the nose, seen on the radiograph.
8. A: Subspinale. The most inner point on the mid-contour of the alverolar process located between the anterior nasal spine and prosthion.
9. B: Supramentale. The most inner point of the concavity seen between Pogonion and the mandibulary infradental point.
10. Pg: Pogonion. The most anterior curvature of the mandible in the sagittal plane.
11. Gn: Gnathion. The midpoint of menton and pogonion.
12. Me: Menton. The most inferior point of the lower surface of the mandibular symphysis.
13. Go: Gonion. The most posterior and inferior point of the mandibular symphysis.

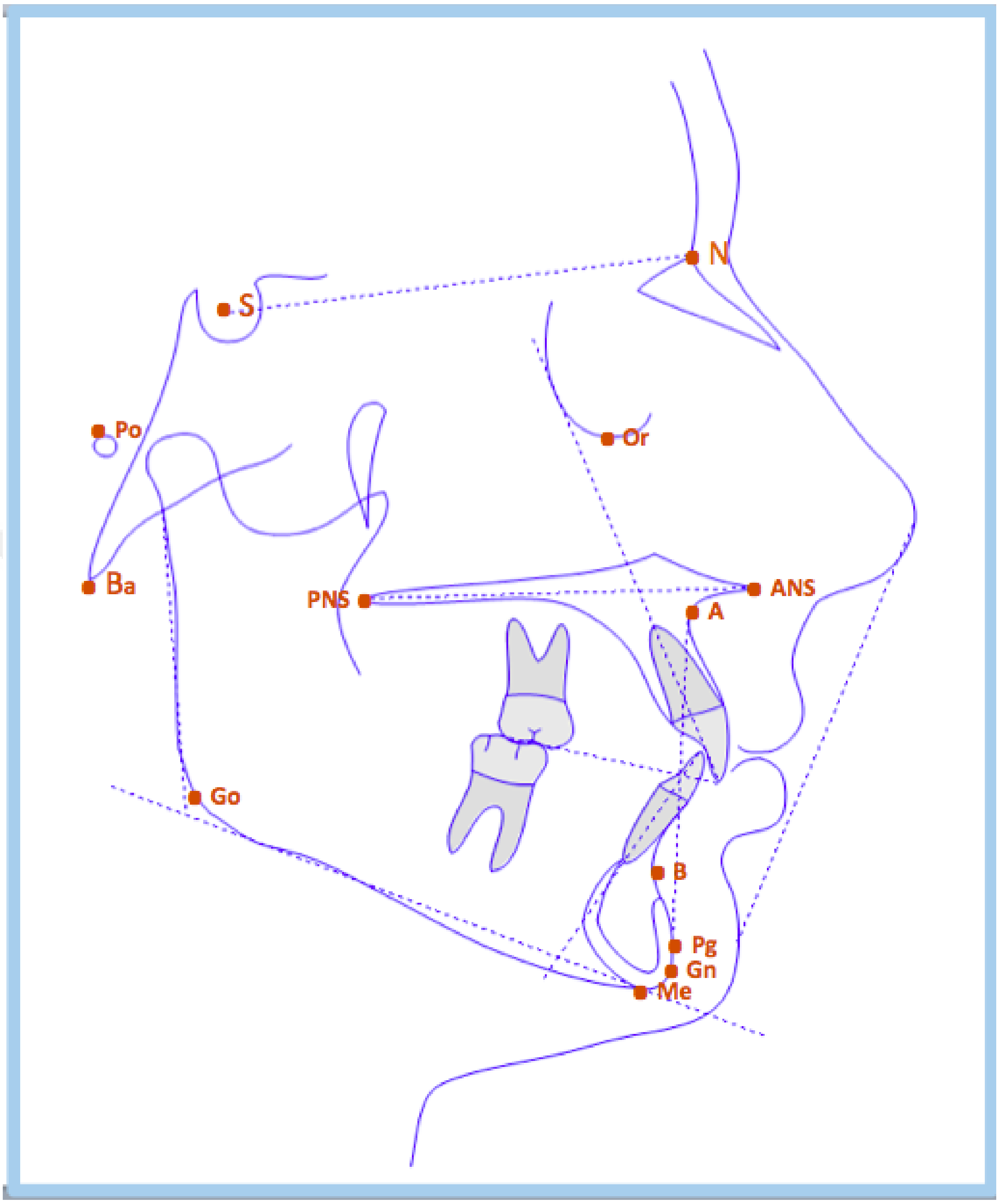


Figure 5.4.1: Cephalometric skeletal points

5.4.2 Dental Points

14. U1i: Incisal edge of the upper incisor
15. U1a: Apex of the upper incisor
16. U4t: Cusp tip of upper 1.premolar
17. U4a: Apex of upper 1.premolar
18. U5t: Cusp tip of upper 2.premolar
19. U5a: Apex of upper 2.premolar
20. U6t: Mesial cusp tip of upper 1.molar.
21. U6a: Mesial root apex of upper 1.molar.
22. U6bp:The bifurcation point of the two buccal roots of upper 1.molar.
23. U6bdg: Buccal developmental grove of upper 1.molar.
24. L1i: Incisal edge of the lower incisor
25. L1a: Apex of the upper incisor

5.4.3 Soft-tissue Points

26. Sn: Subnasale. The intersection point of the nose and the upper lip.
27. Ls: Labiale superior. The most prominent point of the upper lip in the sagittal plane.
28. Li: Labiale inferior. The most prominent point of the lower lip in the sagittal plane.
29. Si: Sulcus inferior. The most inner point of the lower lip curvature.
30. Pgs: Soft-tissue Pogonion. The most prominent point of the chin in the sagittal plane.

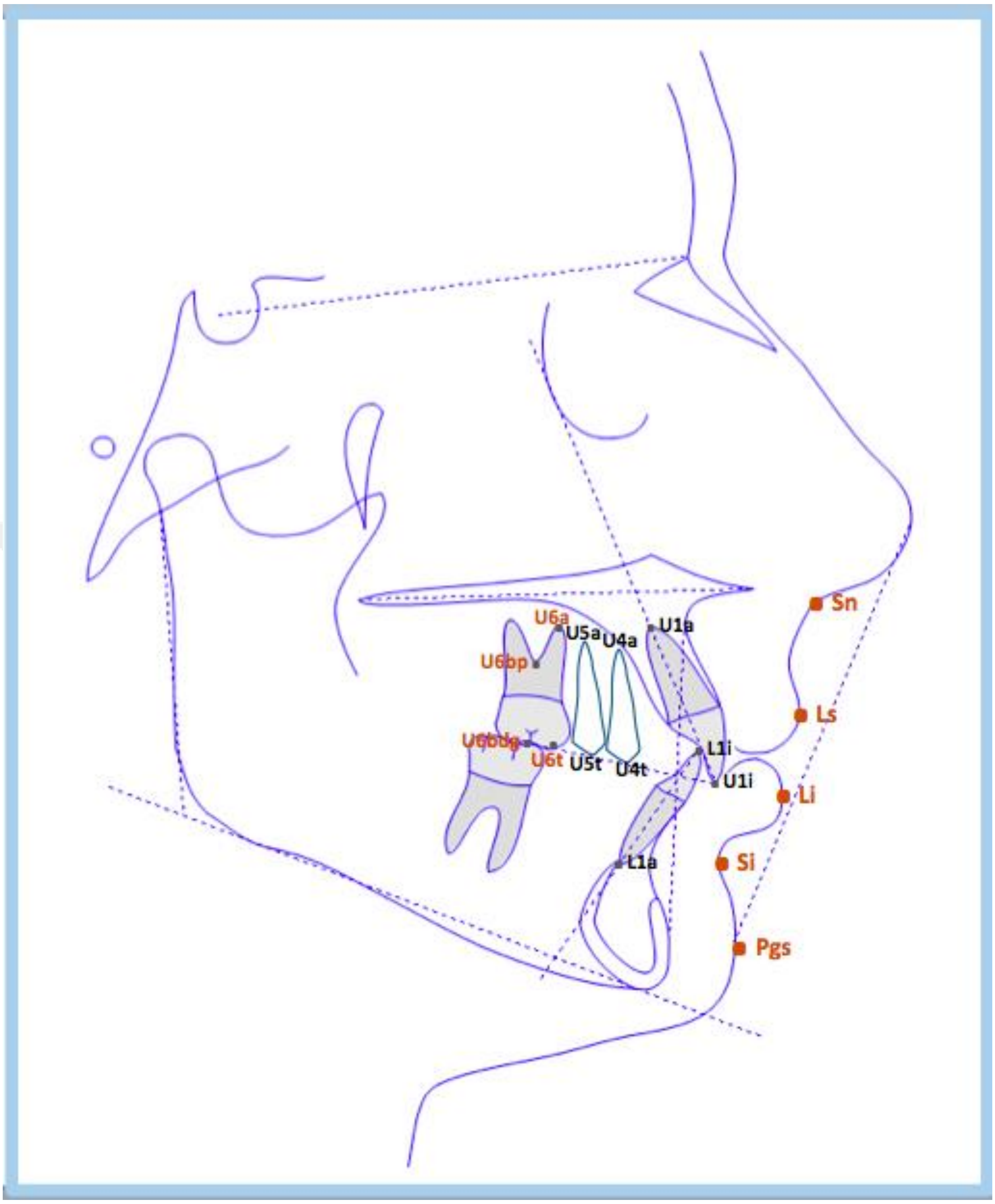


Figure 5.4.2: Cephalometric soft-tissue and dental points

5.5 Cephalometric and Reference Planes

1. SN: the plane passing through the sella and nasion points. The SN-plane is our reference plane for the angular dental measurements.
2. Palatal Plane (PP): the plane passing through the anterior and posterior nasal spine.
3. Occlusal Plane (OP): the plane passing through the disto-buccal cusp tips of upper and lower molars posteriorly, and through the incisal edges of upper and lower incisors anteriorly.
4. Mandibular Plane (MP): the plane passing through gonion and menton points.

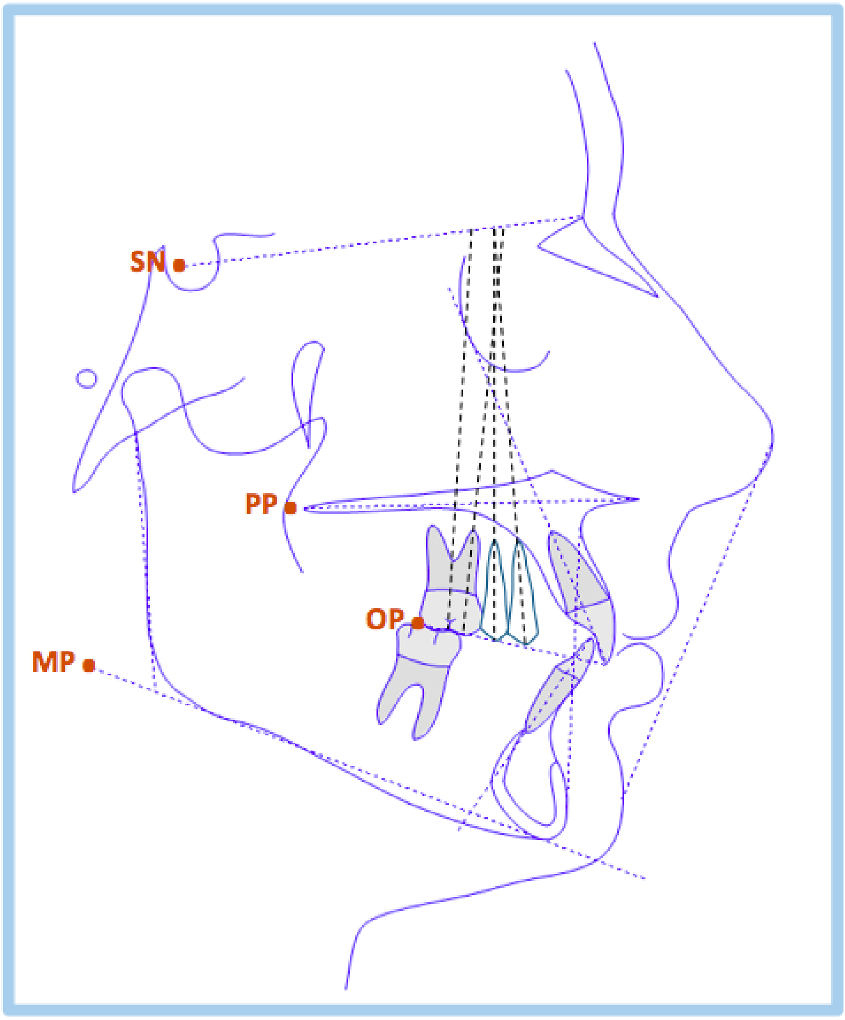


Figure 5.4.3: Cephalometric and reference planes

5.6 Cephalometric Measurements Used in Study:

5.6.1 Vertical

1. Gonion Menton-SN: the angle between the anterior cranial base and the plane passing through the gonion and menton points.
2. Palatal Plane-SN: the angle between the cranial base and the palatal plane.
3. Occlusion to S-N: the angle between the anterior cranial base and the occlusal plane.
4. Frankfurt- MP: the angle between the Frankfurt horizontal plane and the mandibular plane.
5. Palatal Plane- MP: the angle between the palatal plane and the mandibular plane.

5.6.2 Sagittal

1. SNA: the angle between the S-N and the N-A plane.
2. SNB: the angle between the S-N and the N-B plane.
3. ANB: the angle between the N-A and the N-B plane that determines the sagittal relationship between the maxilla and mandible.
4. Wits: a measure of jaw relationships anteroposteriorly, by drawing perpendiculars from points A and B on the maxilla and mandible, respectively, onto the occlusal plane.
5. N per A: Distance point A from nasion perpendicular to Frankfurt plane.
6. Sella Nasion: the distance between the sella and nasion points.

5.6.3 Dental

1. Overjet: the horizontal distance parallel to the occlusal plane, between the incisal edges of the upper and lower incisor.
2. Overbite: the vertical distance between the incisal edges of the upper and lower incisor perpendicular to the occlusal plane.

3. UI^N-S: the angle between the axis of maxillary central incisor and the anterior cranial base.
4. IMPA: the angle between the axis of lower incisor and the mandibular plane.
5. LI to UI (Angle): The interincisal angle. The angle between the axes of upper and lower incisor.
6. Occlusion-SN: the angle between the occlusal plane and sella-nasion.
7. Molar angulation (U6/SN): the angle between the maxillary first molar and the anterior cranial base.
8. Molar mesial root angulation: The angle between the axis of the mesial root of the 1.molar and the anterior cranial base.
9. 2.premolar angulation (U5/SN): the angle between the maxillary second premolar and the anterior cranial base.
10. 1.premolar angulation (U4/SN): the angle between the maxillary first premolar and the anterior cranial base.

5.6.4 Soft-tissue

1. Nasiolabial angle: the angle between the tangent to the columella of the nose and the upper lip line formed between points Subnasale (Sn) and Labrale superius (Ls).
2. Soft-tissue profile: the angle of the soft-tissue facial convexity excluding the nose, formed by points soft-tissue Nasion, Subnasale and soft-tissue Pogonion (N-Sn-Pg).
3. Skeletal profile: the angle of skeletal convexity between N-A-Pg.
4. Total profile: the angle of total facial convexity formed between soft-tissue Nasion, nose tip (Pronasale-Pr) and soft-tissue Pogonion (N-Pr-Pg).
5. Upper lip-E line: the anteroposterior position of the upper lip to E-line. E-Line is drawn from Pronasale (Pr) to soft tissue pogonion (Pg) and lip prominence with reference to this line is assessed.
6. Lower lip-E line: the antero-posterior position of the lower lip to E-line.

5.7 Study Cast Analysis

Plaster model casts made before and after molar distalization were scanned digitally (Orthomodel 2007). All pre- and post- files including maxilla, mandible and occlusion files were transferred to the Mimics software (version 16.0) for analysis. All linear measurements were made on the digitized casts.

The T0 and T1 digital models of the same subject were aligned with the best-fit (surface-to-surface matching) method (D.-S. Choi, Jeong, Jang, Jost-Brinkmann, & Cha, 2010). In other words, the maxillary arches were superimposed on the maxillary rugae area before and after distalization. The maxillary rugae is considered a reliable reference anatomical site in literature due to its stable nature (Hoggan & Sadowsky, 2001).

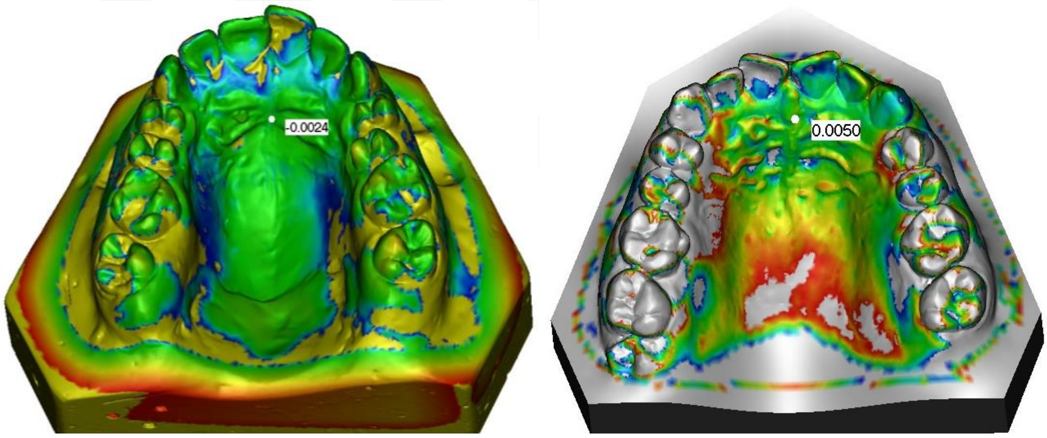
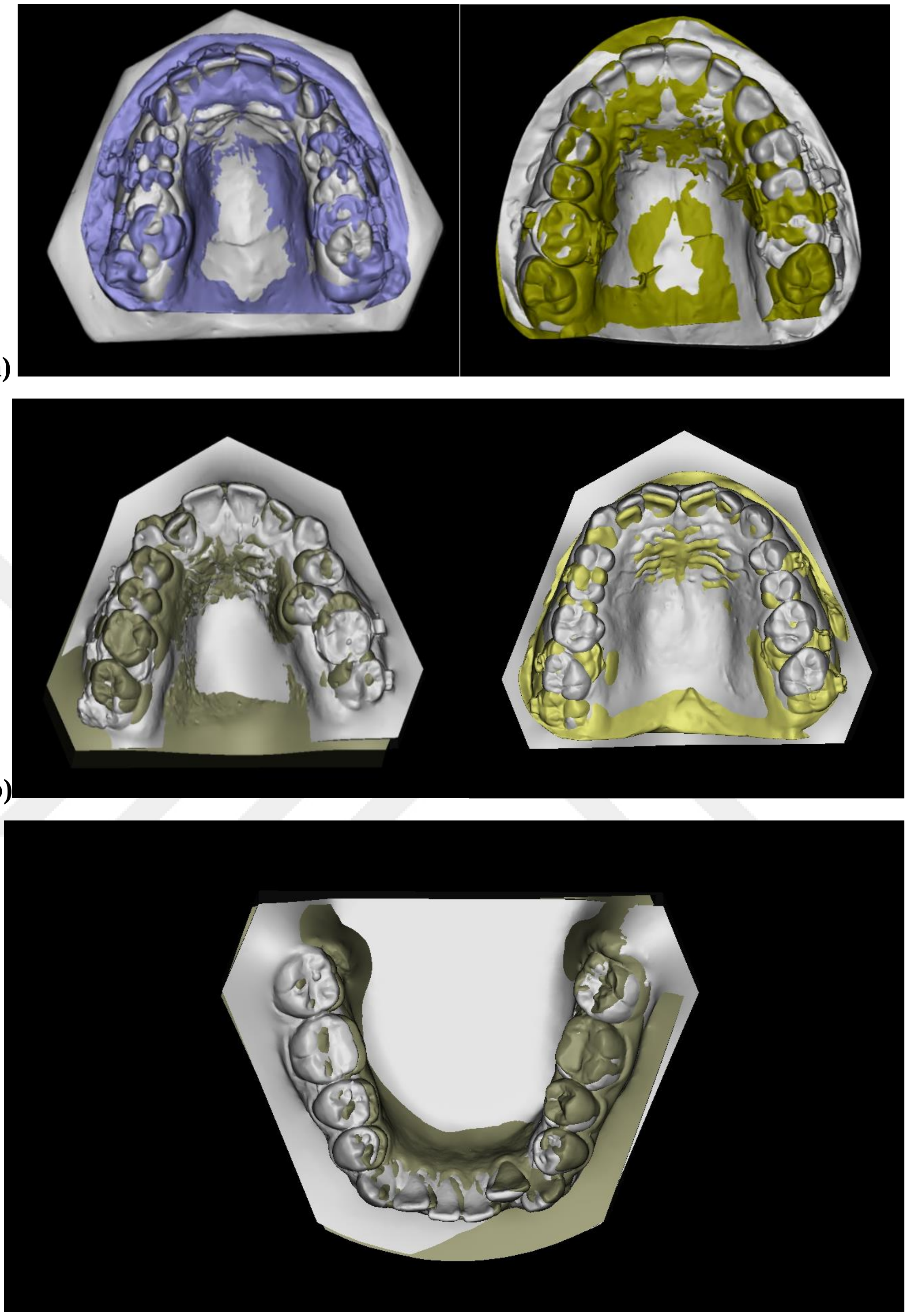


Figure 5.7.1: Accuracy of superimposition on rugae.

Following the maxillary superimposition pre-op maxilla (1) is superimposed with occlusion (1), occlusion (1) with mandible (1). Furthermore, post-op maxilla (2) is superimposed with occlusion (2), occlusion (2) with mandible (2). All these superimpositions are now performed according to the maxillary rugae, this way both mandibles are also superimposed according to the same reference area. All in all, 5 sets of superimpositions per patient were performed.



a)

b)

c)

Figure 5.7.2: Superimposition of (a) and (b) maxillary, (c) of mandibular arches.

All below mentioned points were registered twice and marked as (1) for before/pre and (2) as after/post treatment.

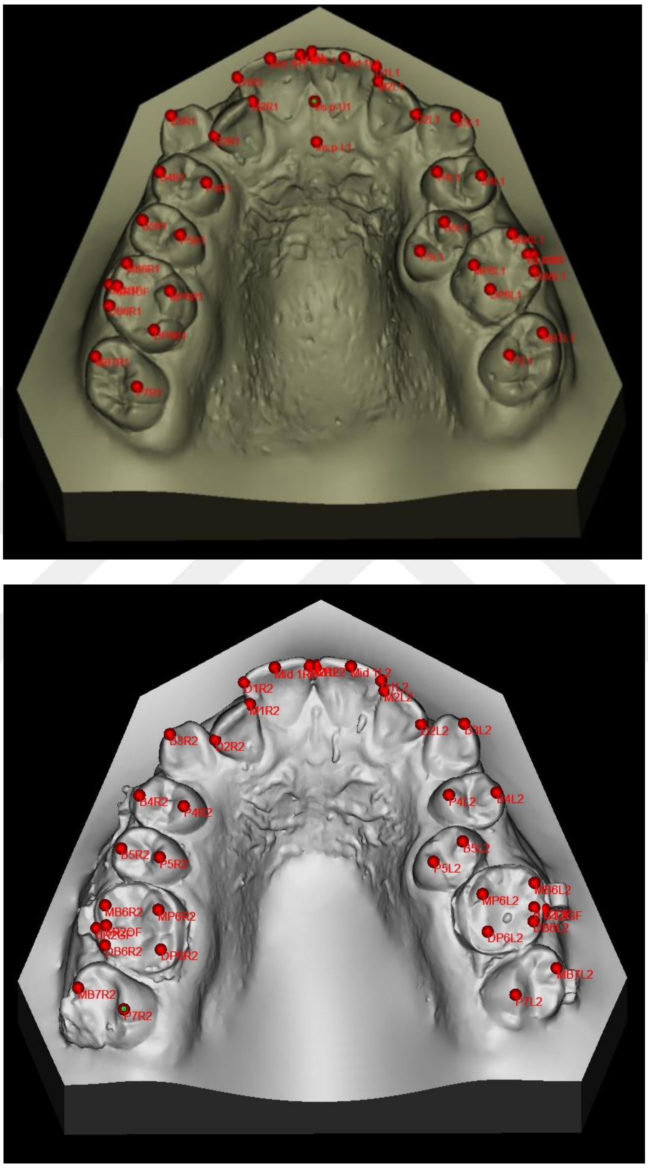
5.7.1 Maxillary Points:

1. MB7R: mesio-buccal cusp tip of upper right second molar
2. P7R: palatal cusp tip of upper right second molar
3. MB6R: mesio-buccal cusp tip of upper right first molar
4. DB6R: disto-buccal cusp tip of upper right first molar
5. MP6R: mesio-palatal cusp tip of upper right first molar
6. DP6R: disto-palatal cusp tip of upper right first molar
7. B5R: buccal cusp tip of upper right second premolar
8. P5R: palatal cusp tip of upper right second premolar
9. B4R: buccal cusp tip of upper right first premolar
10. P4R: buccal cusp tip of upper right first premolar
11. B3R: buccal cusp tip of upper right canine
12. D2R: distal incisal edge of upper right lateral
13. M2R: mesial incisal edge of upper right lateral
14. D1R: distal incisal edge of upper right central
15. M1R: mesial incisal edge of upper right central
16. M1L: mesial incisal edge of upper left central
17. D1L: distal incisal edge of upper left central
18. M2L: mesial incisal edge of upper left lateral
19. D2L: distal incisal edge of upper left lateral
20. B3L: buccal cusp tip of upper left canine
21. B4L: buccal cusp tip of upper right left premolar
22. P4L: palatal cusp tip of upper right left premolar
23. B5L: buccal cusp tip of upper left second premolar
24. P5L: palatal cusp tip of upper left second premolar
25. MB6L: mesio-buccal cusp tip of upper left first molar
26. DB6L: disto-buccal cusp tip of upper left first molar
27. MP6L: mesio-palatal cusp tip of upper left first molar

28. DP6L: disto-palatal cusp tip of upper left first molar

29. MB7L: mesio-buccal cusp tip of upper left second molar

30. P7L: palatal cusp tip of upper left second molar



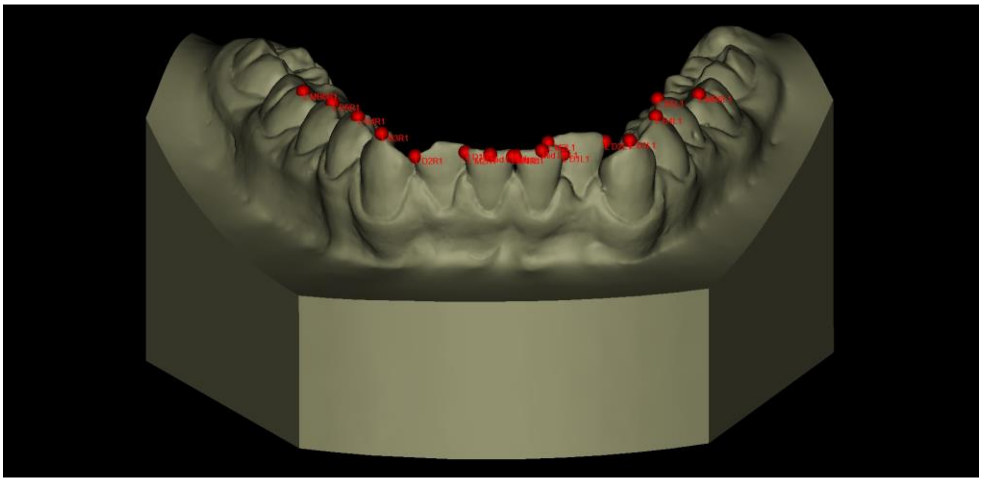
a) b)

Figure 5.7.3: Maxillary dental points on (a) preop. maxilla and (b) postop. maxilla.

5.7.2 Mandibular Points:

1. L MB6R : mesio-buccal cusp tip of lower right first molar
2. L B5R: buccal cusp tip of lower right second premolar
3. L B4R: buccal cusp tip of lower right first premolar
4. L B3R: buccal cusp tip of lower right canine
5. L D2R: distal incisal edge of lower right lateral
6. L M2R: mesial incisal edge of lower right lateral
7. L D1R: distal incisal edge of lower right central
8. L M1R: mesial incisal edge of lower right central
9. L M1L: mesial incisal edge of lower left central
10. L D1L: distal incisal edge of lower left central
11. L M2L: mesial incisal edge of lower left lateral
12. L D2L: distal incisal edge of lower left lateral
13. L B3L: buccal cusp tip of lower left canine
14. L B4L: buccal cusp tip of lower left premolar
15. L B5L: buccal cusp tip of lower left second premolar
16. L MB6L: mesio-buccal cusp tip of lower left first molar

a)



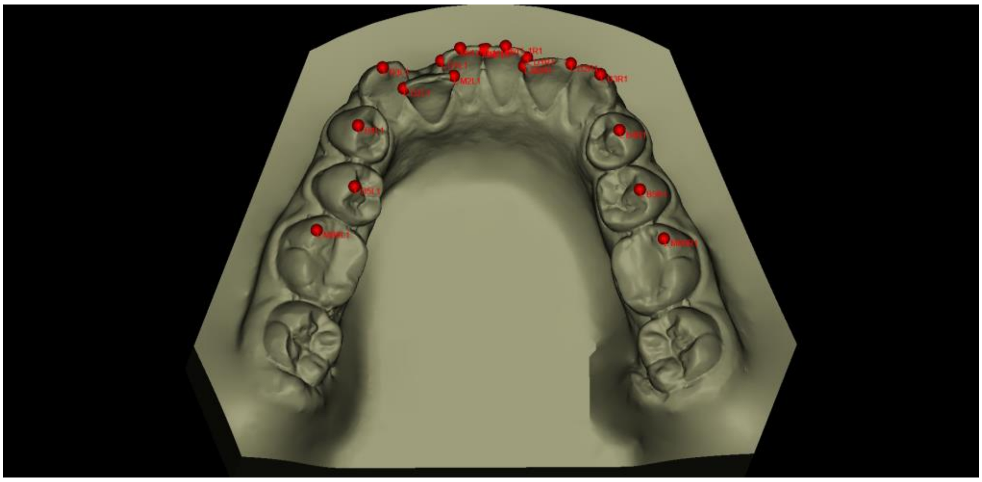
b) 

Figure 5.7.4: (a) Frontal and (b) occlusal view of mandibular dental points.

5.7.3 Reference Points:

1. Mid1R : incisal midpoint of upper right central
2. L Mid1R: incisal midpoint of lower right central
3. Mid1L: incisal midpoint of upper left central
4. L Mid1L: incisal midpoint of lower left central
5. Inter 1-1: incisal contact point between upper right and left central (anterior reference point of the occlusal plane)
6. Anterior Incisive Papille Point: anterior border of the incisive papille landmark.
7. Posterior Incisive Papille Point: posterior border of the incisive papille landmark.
8. Overbite Point: A random location of point, preferably inferior and anterior on the mandibular cast for standardization. A reference point for the overbite plane.

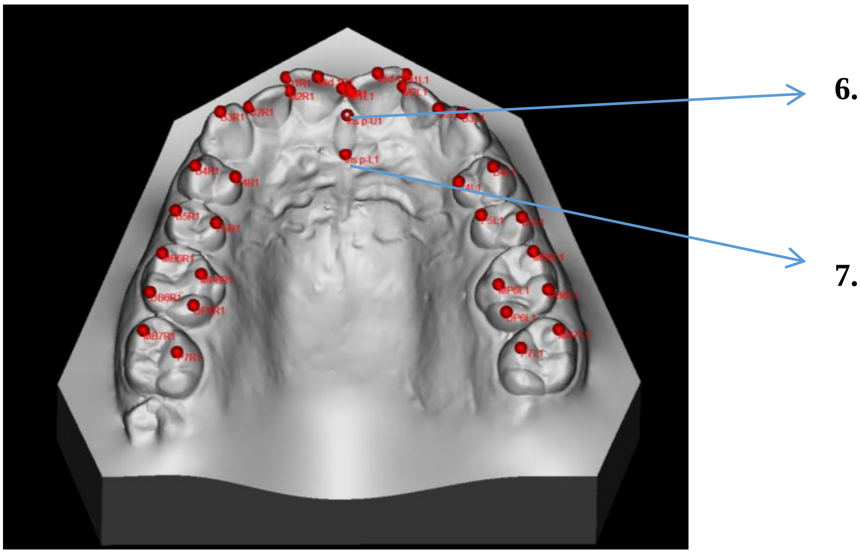


Figure 5.7.5: Representation of reference points on the maxillary cast.

5.8 Reference Planes:

1. Occlusal Plane: reference plane passing through the Inter 1-1 point anteriorly and MB6R1 and MB6L1 posteriorly, marked on the preop maxillary cast. Used to measure vertical dental changes in terms of intrusion/extrusion.
2. Sagittal Plane: reference plane perpendicular to the occlusal plane passing through the anterior and posterior incisive papille points, marked on the preop maxillary cast. Used to measure sagittal dental changes in terms of bucco-palatal movements.
3. Coronal Plane: reference plane perpendicular to the sagittal plane intersecting on the anterior incisive papille point, marked on the preop maxillary cast.
4. Overbite Plane: reference plane passing through the overbite point, marked on the preop mandibular cast.

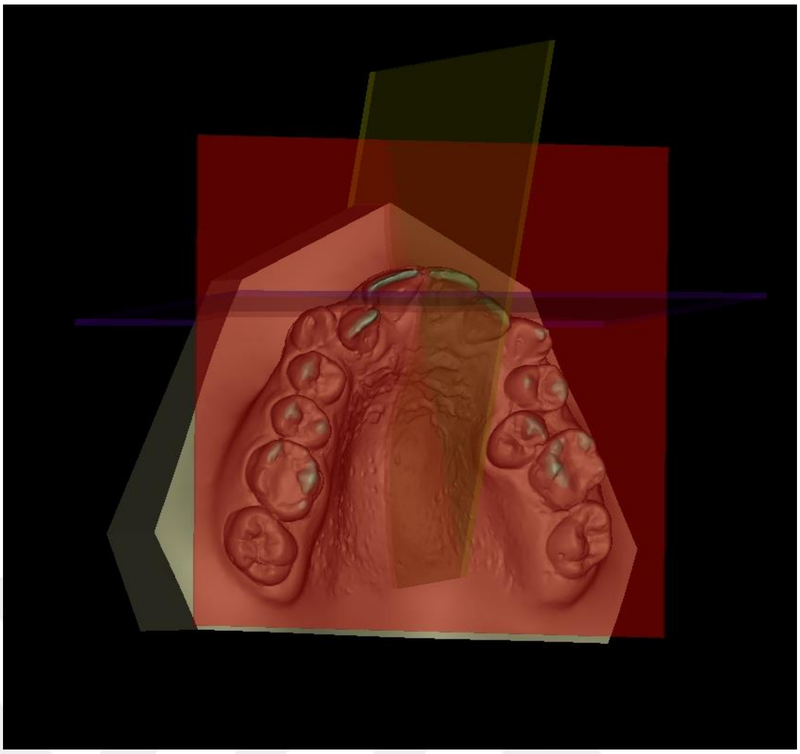


Figure 5.8.1: Representation of reference planes (occlusal, sagittal and coronal) on the maxillary cast.

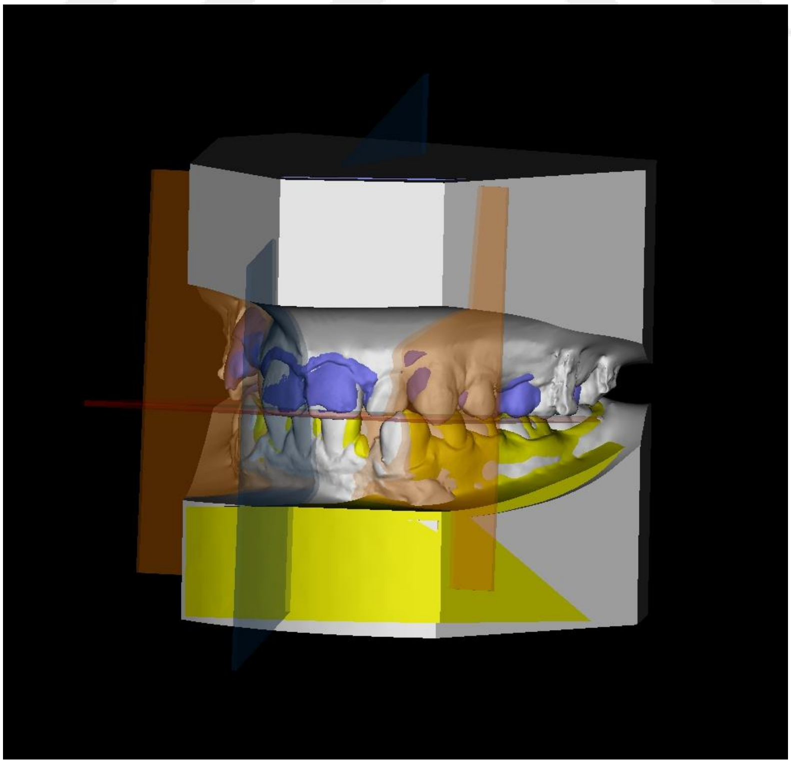


Figure 5.8.2: Representation of reference planes on a maxillary and mandibular cast in occlusion.

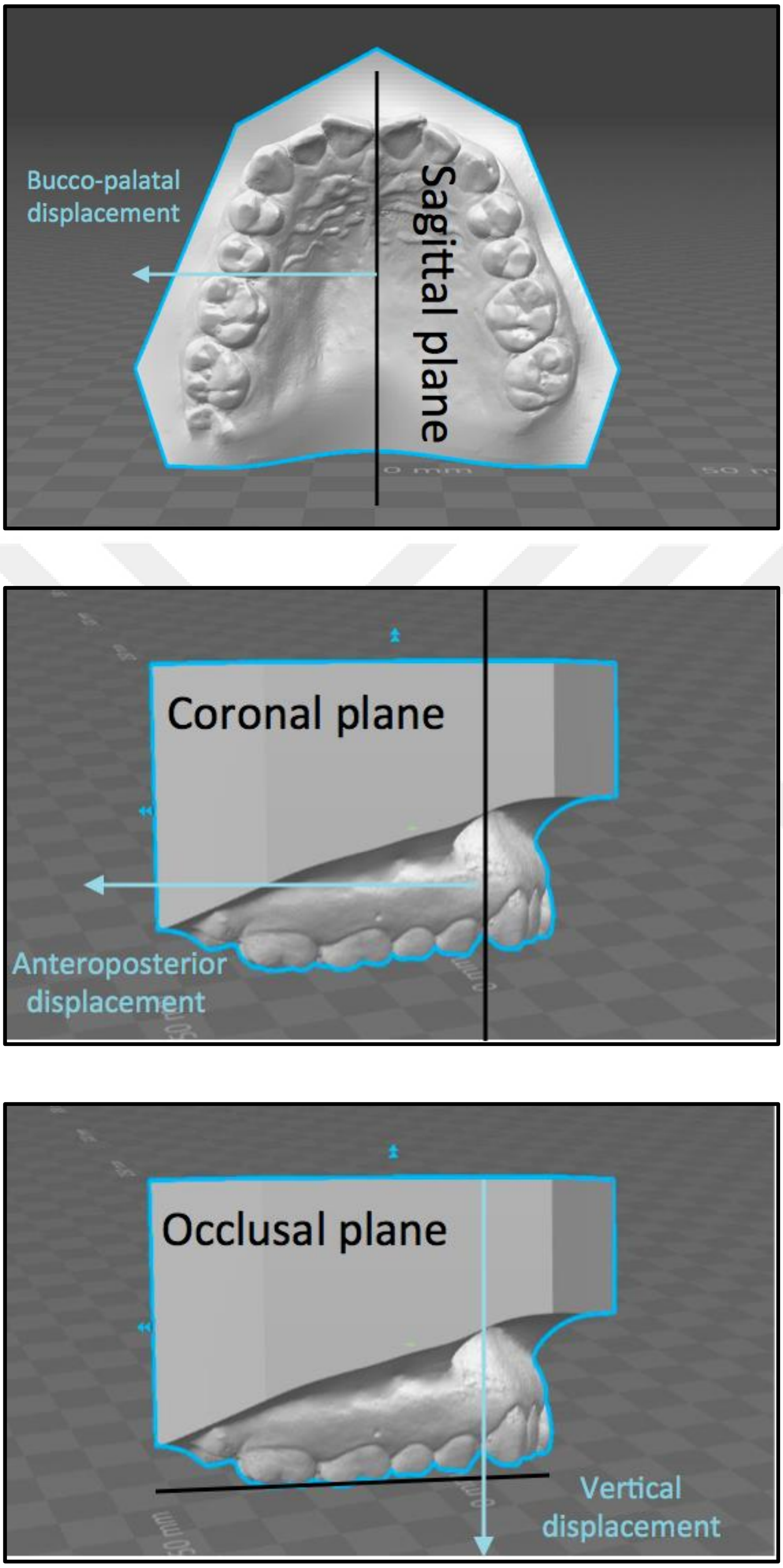


Figure 5.8.3: Representation of each reference plane from different angles.

5.9 Study Cast Measurements:

All below mentioned measurements were registered twice and marked as (1) for before/pre and (2) as after/post treatment.

1. Max Intercanine: the distance between upper right and left canine cusps
2. Max Intermolar: the distance between upper right and left mesio-buccal cusps of first molars
3. Mand Intercanine: the distance between lower right and left canine cusps
4. Mand Intermolar: the distance between lower right and left mesio-buccal cusps of first molars

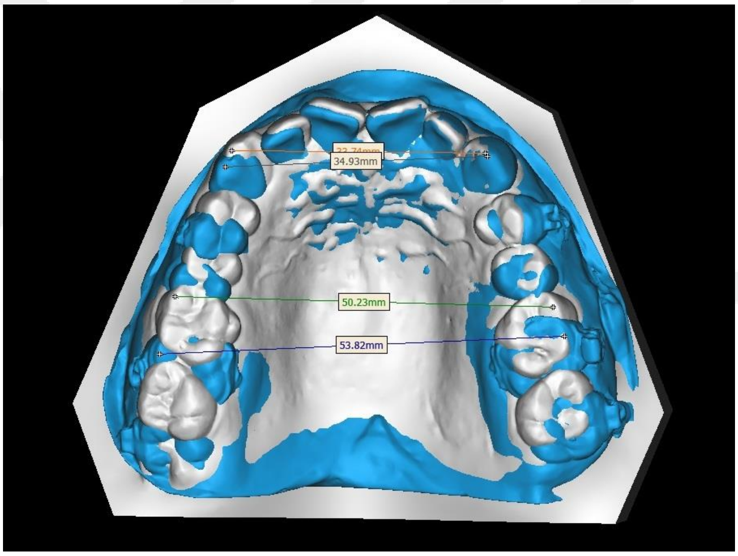


Figure 5.9.1: Representation of changes in the inter-canine and inter-molar width.

5. Each maxillary and mandibular dental point was compared to these 3 planes:
    a. Occlusal Plane
    b. Sagittal Plane
    c. Coronal Plane

6 measurements in total for each mentioned point on pre- (1) and post-op. (2) cast, evaluated according to the above-mentioned 3 planes.

6. Overbite: The overbite measurement is the difference between the vertical distance from each one of these points to the overbite plane:

    a. Mid1R / overbite plane - L Mid1R / overbite plane
    b. Mid1L / overbite plane - L Mid1L / overbite plane

The difference between pre- (1) and post-op. (2) for each of these measurements (a and b) show the possible changes in the overbite parameter.

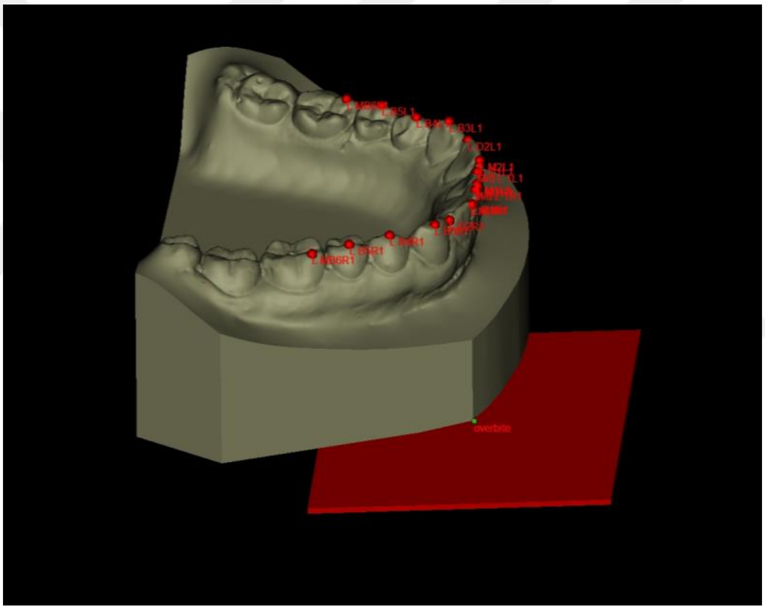


Figure 5.9.2: Representation of the overbite plane.

6. STATISTICAL ANALYSIS

During the assessment of the data obtained in the study, the IBM SPSS 22 (Istanbul, Turkey) program was used for statistical analysis. Evaluating the study data, conformity of the parameters to the normal distribution was assessed by the Shapiro Wilks test and it was determined that the parameters were conformed to the normal distribution. Paired Samples t test was used for the in-group comparisons. In the analysis of method error regarding parameter measurements, intraclass correlation coefficient (ICC) was calculated. Significance was evaluated at a level of $p<0.05$.

The G*Power program was used to calculate to sample size of the study and analyzed to be minimum 9 subjects.

7. RESULTS

7.1 3D Study Cast Results

The mean amount of distalization for the maxillary right first molar was found to be 5.84±1.37 mm ($P<0.05$), showing an amount of 1.05 mm distalization rate per month. The maxillary right first molar distalization was accompanied by slight extrusion (1.28±0.98 mm; $P<0.05$), buccal displacement (2.41±1.58 mm; $P<0.05$) and distal tipping (-4.25±2.92°; $P<0.05$) (Table-14). The mean distalization of the maxillary left molar was 6.03±1.38 mm ($P<0.05$) with extrusion (0.85±0.5 mm; $P<0.05$) and buccal dislocation (1.63±1.16 mm; $P<0.05$) (Table-2).

The mean amount of distalization for the maxillary right second molar was found to be 4.57±1.28 mm ($P<0.05$) with a mean extrusion by 1.7±1.25 mm ($P<0.05$), and buccal movement by 1.46±0.91 mm ($P<0.05$). The equivalent measurements of the maxillary left second molar were 4.73±1.49 mm distalization, 1.12±1.17 mm extrusion and 1.13±1.65 mm buccal shift, all significant at $P<0.05$ (Table-2).

The maxillary right second premolar also spontaneously moved by distal drifting 3.04±1.46 mm ($P<0.05$) with non-significant distal tipping (-2,25±4,49°; $P>0.05$), also exhibiting some buccal displacement (2.3±1.56 mm; $P<0.05$). Slight significant vertical changes were only registered for upper left second premolars of this sample (0.48±0.45 mm; $P<0.05$), differing by a slight margin from upper right second premolars (0.45±0.71 mm; $P>0.05$). The mean amount of distalization for the maxillary left second premolar was 3.53±1.02 mm ($P<0.05$) along with some buccal expansion (1.89±1.4 mm; $P<0.05$) (Table-3).

The mean amount of distalization for the maxillary right first premolar was 3.2±1.32 mm ($P<0.05$) along with extrusion (0.9±0.89 mm; $P<0.05$), buccal shift (2.67±1.97 mm; $P<0.05$) and tipping movement (-4,58±4,27°; $P<0.05$) (Table-14). The equivalent measurements for the upper left first premolar were also significant at

3.02±1.23 mm (P<0.05) of distalization, 0.52±0.7 mm (P<0.05) extrusion and 2.04±1.59 mm (P<0.05) buccal movement (Table-3).

Upper maxillary canines showed no significant vertical changes according to the occlusal reference plane (Table-4). The mean amount of distalization for upper right canine was 1.42±1.53 mm (P<0.05) together with buccal shift 1.05±0.64 mm (P<0.05). The same values for upper left canine were 1.17±1.09 mm (P<0.05) and 0.92±0.57 mm (P<0.05) respectively (Table-3).

Moreover, the inclination of the maxillary incisors decreased (Table-14), reflecting on the overjet results (Table-10). Vertical changes according to the occlusal plane were not significant for all incisors (Table-4), reflecting on the overbite results (Table-10).

The mean increase in the maxillary inter-canine distance was significant at 1.88±0.99 mm (P<0.05) and non significant for the mandibular arch. The mean increase in the maxillary inter-molar distance was significant at 3.44±2.1 mm (P<0.05) and non significant for the mandibular arch (Table-11).

None of the changes in the mandibular arch were significant except the lower right first premolar measurements in the sagittal plane (0.87±0.84 mm; P<0.05) (Table-5, Table-6).

Table-7 compares preop-postop sagittal differences specific for different points on each of the first premolar, second premolar, first molar and second molar. The results are significant both for MB-DP and MB-DB points on the maxillary first molars, both right and left. This comparison indirectly indicates a significant rotation in molars while moving distally. No significant rotation was noted for the remaining teeth, suggesting a translation movement.

Table-8 compares preop-postop occlusal differences specific for different points on each of the first premolar, second premolar, first molar and second molar. None of the differences in any teeth are significant in the occlusal plane.

Table-9 compares preop-postop coronal differences specific for different points on each of the first premolar, second premolar, first molar and second molar. The results are significant for the MB-DP points on the maxillary first molars, both right and left. This comparison also indirectly indicates that some rotation occurred during distalization, suggesting crown tipping. The results were also significant for the B-P points on the second premolars bilaterally. The differences in the coronal plane were not significant for the remaining teeth, implying a parallel movement.

7.2 Cephalometric Results

No statistically significant changes were found for the vertical cephalometric measurements (Table-12). The only significant sagittal cephalometric measurements (Table-13) were registered for SNA (-0.75±1.06; P<0.05) and N-I-A (-0.58±0.76; P<0.05).

Among dental cephalometric measurements (Table-14), changes in UI^N-S (-3.5±4.95; P<0.05), 1.premolar angulation (-4.58±4.27; P<0.05), molar angulation (4,25±2,92; P<0.05) and molar mesial root angulation (-4.75±3.6; P<0.05) were found to be significant post-operatively. Both parameters used for molar tipping showed very similar results.

None of soft-tissue cephalometric measurements were found to be significant (Table-15).

Table-2: 3D evaluation of upper molars to reference planes.

Mimics	Preop	Postop	Difference	p
	Mean±SD	Mean±SD	Mean±SD	
MB6R-Coronal	20,99±4,2	26,82±4,55	5,84±1,37	**0,001***
MB6R-Sagittal	25,33±3,03	27,74±4	2,41±1,58	**0,001***
MB6R-Occlusal	0±0	1,28±0,98	1,28±0,98	**0,003***
MB6L-Coronal	22,48±2,94	28,52±3,38	6,03±1,38	**0,001***
MB6L-Sagittal	25,12±2,49	26,75±3,17	1,63±1,16	**0,002***
MB6L-Occlusal	0±0	0,85±0,5	0,85±0,5	**0,001***
MP6R-Coronal	24,93±4,5	28,22±4,36	3,29±2,81	**0,005***
MP6R-Sagittal	20,59±3,07	21,57±3,75	0,98±1,62	**0,088**
MP6R-Occlusal	0,66±0,86	0,99±0,5	0,32±0,97	**0,319**
MP6L-Coronal	26,33±3,44	29,98±2,96	3,66±3,03	**0,004***
MP6L-Sagittal	20,24±2,43	20,45±2,86	0,21±1,41	**0,647**
MP6L-Occlusal	0,67±0,42	1±0,62	0,33±0,78	**0,216**
DB6R-Coronal	26,03±4,35	31,82±4,51	5,79±1,33	**0,001***
DB6R-Sagittal	27,19±2,85	27,45±3,71	0,26±1,26	**0,535**
DB6R-Occlusal	0,28±0,25	2,07±0,98	1,79±0,91	**0,001***
DB6L-Coronal	27,67±3,38	33,9±3,62	6,23±1,64	**0,001***
DB6L-Sagittal	26,54±2,45	26,24±3,05	-0,31±1,19	**0,432**
DB6L-Occlusal	0,28±0,15	1,4±0,97	1,12±0,99	**0,006***
DP6R-Coronal	29,12±4,2	32,85±4,34	3,73±1,54	**0,001***
DP6R-Sagittal	21,69±3,06	21,22±4,03	-0,48±1,36	**0,296**
DP6R-Occlusal	0,38±0,27	1,91±0,85	1,54±0,8	**0,001***
DP6L-Coronal	30,33±2,86	34,55±3,06	4,22±1,12	**0,001***
DP6L-Sagittal	20,98±2,47	20,05±3,09	-0,93±1,03	**0,019***
DP6L-Occlusal	0,51±0,28	1,49±1	0,98±1,04	**0,016***
MB7R-Coronal	32,01±4,78	36,58±5,17	4,57±1,28	**0,001***
MB7R-Sagittal	28,81±3,23	30,27±3,66	1,46±0,91	**0,001***
MB7R-Occlusal	1,53±0,72	3,23±1,18	1,7±1,25	**0,002***
MB7L-Coronal	34,02±3,59	38,75±3,81	4,73±1,49	**0,001***
MB7L-Sagittal	27,84±2,56	28,97±2,99	1,13±1,65	**0,058**
MB7L-Occlusal	1,42±0,77	2,54±0,92	1,12±1,17	**0,014***
P7R-Coronal	35,63±4,57	39,73±4,5	4,09±1,32	**0,001***
P7R-Sagittal	24,04±3,33	25,22±3,55	1,18±0,64	**0,001***
P7R-Occlusal	1,04±0,63	2,59±1,18	1,55±1,04	**0,001***
P7L-Coronal	37,34±3,35	41,66±3,35	4,32±1,14	**0,001***
P7L-Sagittal	22,96±2,48	23,82±2,96	0,86±1,63	**0,130**
P7L-Occlusal	0,8±0,52	2,16±1,1	1,37±1,12	**0,004***

Paired Samples t Test *$p<0.05$

Table-3: 3D evaluation of upper premolars and canines to reference planes.

Mimics	Preop	Postop	Difference	p
	Mean±SD	Mean±SD	Mean±SD	
B5R-Coronal	15,62±3,98	18,66±5,24	3,04±1,46	**0,001***
B5R-Sagittal	22,61±2,35	24,91±3,06	2,3±1,56	**0,001***
B5R-Occlusal	0,68±0,75	1,13±0,83	0,45±0,71	**0,074**
B5L-Coronal	17,09±2,72	20,62±2,96	3,53±1,02	**0,001***
B5L-Sagittal	22,04±2,47	23,93±2,65	1,89±1,4	**0,002***
B5L-Occlusal	0,58±0,63	1,06±0,74	0,48±0,45	**0,008***
B4R-Coronal	9,03±3,82	12,23±3,7	3,2±1,32	**0,001***
B4R-Sagittal	20,29±1,73	22,96±3,5	2,67±1,97	**0,002***
B4R-Occlusal	1,08±0,75	1,98±1,2	0,9±0,89	**0,011***
B4L-Coronal	10,6±2,57	13,62±2,79	3,02±1,23	**0,001***
B4L-Sagittal	20,47±1,54	22,51±2,81	2,04±1,59	**0,003***
B4L-Occlusal	0,92±0,77	1,44±1,01	0,52±0,7	**0,044***
B3R-Coronal	3,34±2,38	4,76±3,01	1,42±1,53	**0,017***
B3R-Sagittal	16,49±1,83	17,54±1,94	1,05±0,64	**0,001***
B3R-Occlusal	1,92±1,07	2,01±1,7	0,1±1,25	**0,812**
B3L-Coronal	3,01±2,09	4,18±2,19	1,17±1,09	**0,008***
B3L-Sagittal	16,74±1,7	17,66±1,68	0,92±0,57	**0,001***
B3L-Occlusal	1,63±1,08	1,73±1,37	0,09±0,8	**0,720**
P5R-Coronal	17,1±3,69	19,7±4,82	2,61±1,45	**0,001***
P5R-Sagittal	17,63±2,02	19,72±2,77	2,09±1,27	**0,001***
P5R-Occlusal	0,94±0,81	1,13±1,02	0,19±0,68	**0,407**
P5L-Coronal	18,46±3,46	21,58±3,5	3,12±1,1	**0,001***
P5L-Sagittal	16,68±1,88	18,45±2,35	1,77±1,34	**0,002***
P5L-Occlusal	0,85±0,6	0,97±0,97	0,12±0,65	**0,582**
P4R-Coronal	10,46±3,64	12,64±4,45	2,18±1,58	**0,002***
P4R-Sagittal	15,45±1,53	17,99±3,23	2,54±2,19	**0,005***
P4R-Occlusal	1,52±0,83	1,7±1,26	0,18±1,1	**0,611**
P4L-Coronal	11,49±2,42	14,12±2,71	2,63±0,98	**0,001***
P4L-Sagittal	15,37±0,99	17,21±2,46	1,84±1,75	**0,009***
P4L-Occlusal	1,31±0,84	1,59±1,36	0,29±0,96	**0,372**

Paired Samples t Test *$p<0.05$

Table-4: 3D evaluation of upper incisors to reference planes.

Mimics	Preop	Postop	Difference	p
	Mean±SD	Mean±SD	Mean±SD	
M1R-Coronal	4,94±1,99	4,15±2,48	-0,8±0,7	**0,006***
M1R-Sagittal	0,82±0,48	0,93±0,68	0,12±0,43	**0,415**
M1R-Occlusal	0,87±0,83	1,09±0,98	0,21±0,78	**0,414**
M1L-Coronal	4,84±1,58	3,87±2,11	-0,98±0,77	**0,003***
M1L-Sagittal	0,41±0,28	0,69±0,54	0,28±0,57	**0,162**
M1L-Occlusal	0,82±0,84	1,17±1,03	0,35±0,67	**0,135**
M2R-Coronal	2,47±1,97	2,22±2,43	-0,25±0,94	**0,418**
M2R-Sagittal	7,81±1,5	7,61±2,98	-0,2±2,76	**0,821**
M2R-Occlusal	1,2±0,81	1,57±1,02	0,37±0,72	**0,144**
M2L-Coronal	2,69±2,24	1,91±1,74	-0,78±0,9	**0,023***
M2L-Sagittal	8,31±0,96	8,88±0,94	0,57±0,34	**0,001***
M2L-Occlusal	1,09±0,86	1,61±0,94	0,52±0,93	**0,111**
D1R-Coronal	4,29±2,48	3,49±2,51	-0,79±0,76	**0,009***
D1R-Sagittal	8,38±0,87	8,56±0,89	0,18±0,44	**0,225**
D1R-Occlusal	0,89±0,82	1,58±0,7	0,69±0,85	**0,031***
D1L-Coronal	4,07±1,62	3,17±1,65	-0,9±0,67	**0,002***
D1L-Sagittal	8,2±0,92	8,65±0,95	0,45±0,28	**0,001***
D1L-Occlusal	0,98±0,99	1,49±0,8	0,51±0,71	**0,049***
D2R-Coronal	2,23±1,83	2,74±1,65	0,51±0,84	**0,086**
D2R-Sagittal	13,28±1,44	13,9±1,37	0,62±0,32	**0,001***
D2R-Occlusal	1,14±0,59	1,4±0,68	0,27±0,69	**0,255**
D2L-Coronal	1,54±1,27	2±1,36	0,46±0,82	**0,108**
D2L-Sagittal	13,6±0,92	14,21±1,07	0,61±0,34	**0,001***
D2L-Occlusal	1,13±0,83	1,42±0,68	0,29±0,68	**0,208**

Paired Samples t Test *p<0.05

Table-5: 3D evaluation of lower molars, premolars and canines to reference planes.

Mimics	Preop	Postop	Difference	p
	Mean±SD	Mean±SD	Mean±SD	
L MB6R-Coronal	21,8±3,37	21,91±3,38	0,11±0,85	**0,657**
L MB6R-Sagittal	22,97±1,62	23,33±2,11	0,36±0,98	**0,235**
L MB6R-Occlusal	0,75±0,36	1,15±0,89	0,4±0,93	**0,162**
L MB6L-Coronal	23,28±2,52	23,31±2,43	0,03±0,96	**0,915**
L MB6L-Sagittal	22,33±2,1	22,31±2,18	-0,02±0,87	**0,943**
L MB6L-Occlusal	0,58±0,42	0,87±0,85	0,29±1,05	**0,365**
L B3R-Coronal	3,76±1,98	3,86±2,46	0,1±0,74	**0,653**
L B3R-Sagittal	13,02±1,31	13,16±1,38	0,15±1,01	**0,622**
L B3R-Occlusal	1,93±1,13	2±0,8	0,07±0,67	**0,742**
L B3L-Coronal	4,09±2,14	4,46±2,4	0,36±0,83	**0,159**
L B3L-Sagittal	13,4±1,84	13,43±1,3	0,03±1,04	**0,931**
L B3L-Occlusal	1,72±0,92	1,54±0,6	-0,18±0,79	**0,444**
L B5R-Coronal	16,82±2,61	16,75±2,48	-0,06±0,88	**0,823**
L B5R-Sagittal	20,25±1,94	20,94±1,7	0,69±1,08	**0,060**
L B5R-Occlusal	1,13±0,55	1,36±1	0,23±1,09	**0,491**
L B5L-Coronal	17,29±2,22	17,43±2,22	0,14±0,79	**0,569**
L B5L-Sagittal	20,22±1,68	20,3±1,39	0,07±0,7	**0,737**
L B5L-Occlusal	0,95±0,56	1,02±0,99	0,06±1,07	**0,850**
L B4R-Coronal	9,63±2,73	9,43±3,02	-0,2±0,79	**0,400**
L B4R-Sagittal	17,11±1,59	17,98±1,23	0,87±0,84	**0,004***
L B4R-Occlusal	1,31±0,78	1,61±0,94	0,3±0,8	**0,225**
L B4L-Coronal	10,38±2,04	10,5±2,14	0,13±0,78	**0,584**
L B4L-Sagittal	17,39±1,47	17,47±1,42	0,08±0,68	**0,689**
L B4L-Occlusal	1,01±0,62	0,92±0,83	-0,08±0,9	**0,751**

Paired Samples t Test *$p<0.05$

Table-6: 3D evaluation of lower incisors to reference planes.

Mimics	Preop	Postop	Difference	p
	Mean±SD	Mean±SD	Mean±SD	
L M2R-Coronal	2,38±1,7	2,28±1,74	-0,1±0,91	**0,704**
L M2R-Sagittal	5,12±1,38	5,14±1,05	0,02±0,99	**0,943**
L M2R-Occlusal	1,48±1,21	1,39±0,99	-0,09±0,78	**0,705**
L M2L-Coronal	1,75±1,42	1,74±1,79	-0,01±0,81	**0,961**
L M2L-Sagittal	5,65±1,29	5,49±0,9	-0,16±0,93	**0,565**
L M2L-Occlusal	1,44±0,94	1,34±0,99	-0,1±0,63	**0,588**
L M1R-Coronal	2,22±1,42	2,16±1,47	-0,06±0,91	**0,823**
L M1R-Sagittal	1,04±0,86	0,79±0,87	-0,25±0,48	**0,095**
L M1R-Occlusal	1,42±0,97	1,34±1,16	-0,08±0,63	**0,668**
L M1L-Coronal	2,28±1,29	2,28±1,45	0±0,67	**0,987**
L M1L-Sagittal	1,08±0,87	0,83±0,76	-0,25±0,59	**0,166**
L M1L-Occlusal	1,26±0,78	1,27±1,09	0,01±0,59	**0,962**
L D2R-Coronal	2,33±1,57	2,21±1,44	-0,12±1,12	**0,725**
L D2R-Sagittal	10,51±1,13	10,24±1,88	-0,27±1,63	**0,574**
L D2R-Occlusal	1,13±1,11	1,37±1,43	0,24±0,63	**0,220**
L D2L-Coronal	2,51±1,34	2,83±1,3	0,33±0,88	**0,227**
L D2L-Sagittal	10,99±1,49	10,94±0,95	-0,05±0,94	**0,872**
L D2L-Occlusal	1,09±1	1,16±1,34	0,08±0,58	**0,653**
L D1R-Coronal	2,07±1,41	2,33±1,33	0,26±1,25	**0,481**
L D1R-Sagittal	5,4±1,36	5,9±1,89	0,49±1,83	**0,371**
L D1R-Occlusal	1,26±1,12	1,53±1,17	0,27±0,66	**0,183**
L D1L-Coronal	1,63±1,44	1,7±1,41	0,07±0,73	**0,753**
L D1L-Sagittal	5,6±1,5	5,57±1,07	-0,03±0,99	**0,912**
L D1L-Occlusal	1,25±0,92	1,35±1,26	0,1±0,61	**0,594**

Paired Samples t Test *$p<0.05$

Table-7: Evaluation of transversal changes for upper posterior teeth in the sagittal plane.

Sagittal	Mean±SS	Difference Mean±SD	p
1.molar MB right	-2,41±1,58	-2,88±0,79	**0,001***
1.molar DP right	0,48±1,36		
1.molar MB left	-1,63±1,16	-2,56±0,67	**0,001***
1.molar DP left	0,93±1,03		
1.molar MB right	-2,41±1,58	-2,15±0,72	**0,001***
1.molar DB right	-0,26±1,26		
1.molar MB left	-1,63±1,16	-1,94±0,5	**0,001***
1.molar DB left	0,31±1,19		
2.molar MB right	-1,46±0,91	-0,28±0,72	**0,250**
2.molar P right	-1,18±0,64		
2.molar MB left	-1,13±1,65	-0,27±0,5	**0,121**
2.molar P left	-0,86±1,63		
1.premolar B right	-2,67±1,97	-0,13±0,73	**0,589**
1.premolar P right	-2,54±2,19		
1.premolar B left	-2,04±1,59	-0,2±0,46	**0,195**
1.premolar P left	-1,84±1,75		
2.premolar B right	-2,3±1,56	-0,21±0,43	**0,156**
2.premolar P right	-2,09±1,27		
2.premolar B left	-1,89±1,4	-0,12±0,36	**0,314**
2.premolar P left	-1,77±1,34		

Paired Samples t Test *$p<0.05$

Table-8: Evaluation of vertical changes for upper posterior teeth in the occlusal plane.

Occlusal	Mean±SS	Difference Mean±SD	p
1.molar MB right	-1,28±0,98	0,26±0,97	**0,423**
1.molar DP right	-1,54±0,8		
1.molar MB left	-0,85±0,5	0,13±1,09	**0,724**
1.molar DP left	-0,98±1,04		
1.molar MB right	-1,28±0,98	0,51±0,76	**0,063**
1.molar DB right	-1,79±0,91		
1.molar MB left	-0,85±0,5	0,27±1,08	**0,452**
1.molar DB left	-1,12±0,99		
2.molar MB right	-1,7±1,25	-0,14±0,55	**0,430**
2.molar P right	-1,55±1,04		
2.molar MB left	-1,05±1,15	0,32±0,62	**0,139**
2.molar P left	-1,37±1,12		
1.premolar B right	-0,9±0,89	-0,72±1,17	**0,084**
1.premolar P right	-0,18±1,1		
1.premolar B left	-0,52±0,7	-0,23±0,73	**0,338**
1.premolar P left	-0,29±0,96		
2.premolar B right	-0,45±0,71	-0,27±0,71	**0,271**
2.premolar P right	-0,19±0,68		
2.premolar B left	-0,48±0,45	-0,37±0,55	**0,063**
2.premolar P left	-0,12±0,65		

Paired Samples t Test **p<0.05*

Table-9: Evaluation of antero-posterior changes for upper posterior teeth in the coronal plane.

Coronal	Mean±SD	Difference Mean±SD	p
1.molar MB right	-5,84±1,37	-2,11±0,48	**0,001***
1.molar DP right	-3,73±1,54		
1.molar MB left	-6,03±1,38	-1,81±0,71	**0,001***
1.molar DP left	-4,22±1,12		
1.molar MB right	-5,84±1,37	-0,05±0,4	**0,700**
1.molar DB right	-5,79±1,33		
1.molar MB left	-5,72±1,07	0,5±1,33	**0,261**
1.molar DB left	-6,23±1,64		
2.molar MB right	-4,57±1,28	-0,47±0,75	**0,078**
2.molar P right	-4,09±1,32		
2.molar MB left	-4,73±1,49	-0,41±0,74	**0,115**
2.molar P left	-4,32±1,14		
1.premolar B right	-3,2±1,32	1,61±0,51	**0,076**
1.premolar P right	-2,18±1,58		
1.premolar B left	-3,02±1,23	0,65±0,21	**0,092**
1.premolar P left	-2,63±0,98		
2.premolar B right	-3,04±1,46	0,57±0,18	**0,038***
2.premolar P right	-2,61±1,45		
2.premolar B left	-3,53±1,02	-0,41±0,54	**0,039***
2.premolar P left	-3,12±1,1		

Paired Samples t Test *$p<0.05$

Table-10: Evaluation of overjet and overbite

Mimics	Preop	Postop	Difference	p
	Mean±SD	Mean±SD	Mean±SD	
M1R-Coronal	4,94±1,99	4,15±2,48	-0,8±0,7	**0,006***
L M1R-Coronal	2,22±1,42	2,16±1,47	-0,06±0,91	**0,823**
Overjet	2,75±1,82	1,83±1,85	0,92±0,80	**0,005***
Mid 1R-overbite plane	30,32±4,45	30,26±4,6	-0,06±1,03	**0,858**
Mid L 1R-overbite plane	32,23±3,79	32,03±4,06	-0,2±0,66	**0,373**
Overbite	-1,90±1,41	-1,77±1,61	-0,14±0,97	**0,668**

Paired Samples t Test **p<0.05*

Table-11: Evaluation of inter-canine and inter-molar width

	Preop	Postop	Difference	p
	Mean±SD	Mean±SD	Mean±SD	
Mand Intercanine	26,48±2,72	26,69±2,24	0,21±1,03	**0,493**
Mand Intermolar	45,41±2,59	45,79±3,04	0,38±1,1	**0,260**
Max Intercanine	33,61±3,24	35,49±3,41	1,88±0,99	**0,001***
Max Intermolar	50,41±4,24	53,85±5,11	3,44±2,1	**0,001***

Paired Samples t Test **p<0.05*

Table-12: Evaluation of vertical cephalometric measurements

Vertical Measurements	Preop	Postop	Difference	p
	Mean±SD	Mean±SD	Mean±SD	
Palatal plate-SN	7,5±4,15	8,17±4,45	0,67±1,07	**0,054**
Gonion Menton-SN	35,17±3,41	35,67±3,82	0,5±1	**0,111**
Frankfurt-Mandibular plane	27,83±3,56	28,42±3,68	0,58±1	**0,067**
Palatal plane - mand plane	27,58±5,21	27,67±5,55	0,08±1	**0,777**
Occl. To S-N	19,33±4,27	19,42±2,75	0,08±3,18	**0,929**

Paired Samples t Test **p<0.05*

Table-13: Evaluation of sagittal cephalometric measurements

Sagittal Measurements	Preop	Postop	Difference	p
	Mean±SD	Mean±SD	Mean±SD	
SNA	82,67±3,14	81,92±3,15	-0,75±1,06	**0,032***
SNB	77,5±2,24	77,17±1,85	-0,33±0,98	**0,266**
ANB	4,83±1,7	5±1,95	0,17±0,72	**0,438**
Wits	0,57±2,41	0,49±2,51	-0,08±1,53	**0,868**
N-I-A	-0,39±3,12	-0,98±3	-0,58±0,76	**0,023***
SELLA NASION	67,17±2,95	67,05±3,23	-0,12±1,31	**0,764**

Paired Samples t Test **p<0.05*

Table-14: Evaluation of dental cephalometric measurements

Dental Measurements	Preop	Postop	Difference	p
	Mean±SD	Mean±SD	Mean±SD	
Overjet	5,07±1,93	4,57±2,05	-0,5±1,11	**0,147**
Overbite	2,13±1,62	2,28±1,63	0,14±1,21	**0,692**
UI^N-S	107,25±8,54	103,75±6,69	-3,5±4,95	**0,032***
IMPA	97,42±3,63	97±4,84	-0,42±1,78	**0,435**
LI to UI (Angle)	120,08±7,53	123,42±6,96	3,33±5,48	**0,059**
UOccl. To S-N	18,58±5,07	19,08±2,84	0,5±4,06	**0,678**
Molar angulation	71,17±3,13	66,92±4,12	-4,25±2,92	**0,001***
2. premolar angulation	73,25±4,59	71±3,25	-2,25±4,49	**0,111**
1.premolar angulation	82,33±4,96	77,75±7,31	-4,58±4,27	**0,003***
Molar mesial root	70±3,38	65,25±4,61	-4,75±3,6	**0,001***

Paired Samples t Test *$p<0.05$

Table- 15: Evaluation of soft-tissue cephalometric measurments

Soft-tissue Measurements	Preop	Postop	Difference	p
	Mean±SD	Mean±SD	Mean±SD	
Nasolabial Angle	110,08±8,33	108,67±7,97	-1,42±4,58	**0,307**
Soft tissue profile	157,42±6,49	156,33±6,07	-1,08±1,44	**0,325**
Skeletal profile	170,5±4,72	171±5,08	0,5±1,93	**0,389**
Total profile	125,25±5,36	124,25±5,34	-1±1,81	**0,082**
Upper lip-E line	-3,06±2,26	-2,8±1,81	0,26±2,17	**0,687**
Lower lip-E line	-2,5±1,82	-2,01±1,25	0,49±1,36	**0,236**

Paired Samples t Test *$p<0.05$

The data presented below demonstrate a high agreement between the duplicate measurements of mimics and cephalometrics by the same examiner (N.S.). Intraclass correlation coefficient (ICC) was calculated. Significance was evaluated at a level of $p<0.05$.

Table- 16: Evaluation of method error for all measurements

		ICC	%95 CI		p
			Lower	Upper	
MB6R-Coronal	**Preop**	0,833	0,306	0,969	0,005*
	Postop	0,881	0,462	0,978	0,002*
MB6R-Sagittal	**Preop**	0,943	0,709	0,990	0,001*
	Postop	0,957	0,772	0,992	0,001*
MB6R-Occlusal	**Preop**	-	-	-	-
	Postop	0,965	0,811	0,994	0,001*
MB6L-Coronal	**Preop**	0,856	0,378	0,974	0,003*
	Postop	0,906	0,553	0,983	0,001*
MB6L-Sagittal	**Preop**	0,766	0,129	0,955	0,013*
	Postop	0,806	0,230	0,964	0,008*
MB6L-Occlusal	**Preop**	-	-	-	-
	Postop	0,925	0,629	0,987	0,001*
DB6R-Coronal	**Preop**	0,862	0,399	0,975	0,003*
	Postop	0,887	0,483	0,980	0,002*
DB6R-Sagittal	**Preop**	0,918	0,602	0,985	0,001*
	Postop	0,960	0,789	0,993	0,001*
DB6R-Occlusal	**Preop**	0,842	0,467	0,903	0,003*
	Postop	0,881	0,461	0,978	0,002*
DB6L-Coronal	**Preop**	0,904	0,547	0,983	0,001*
	Postop	0,919	0,607	0,986	0,001*
DB6L-Sagittal	**Preop**	0,846	0,347	0,972	0,004*
	Postop	0,865	0,406	0,975	0,003*
DB6L-Occlusal	**Preop**	0,869	0,330	0,910	0,003*
	Postop	0,884	0,473	0,979	0,002*
MP6R-Coronal	**Preop**	0,846	0,346	0,972	0,004*
	Postop	0,902	0,539	0,982	0,001*
MP6R -Sagittal	**Preop**	0,861	0,394	0,975	0,003*
	Postop	0,929	0,645	0,987	0,001*
MP6R-Occlusal	**Preop**	0,705	-0,003	0,942	0,025*
	Postop	0,833	0,307	0,969	0,005*
MP6L-Coronal	**Preop**	0,837	0,319	0,970	0,005*

	Postop	0,885	0,474	0,979	0,002*
MP6L-Sagittal	**Preop**	0,747	0,084	0,951	0,017*
	Postop	0,835	0,312	0,969	0,005*
MP6L-Occlusal	**Preop**	0,926	0,633	0,987	0,001*
	Postop	0,928	0,641	0,987	0,001*
DP6R-Coronal	**Preop**	0,829	0,296	0,968	0,005*
	Postop	0,869	0,421	0,976	0,003*
DP6R-Sagittal	**Preop**	0,897	0,520	0,982	0,001*
	Postop	0,937	0,684	0,989	0,001*
DP6R-Occlusal	**Preop**	0,808	0,310	0,894	0,002*
	Postop	0,740	0,070	0,950	0,018*
DP6L-Coronal	**Preop**	0,813	0,250	0,965	0,007*
	Postop	0,823	0,277	0,967	0,006*
DP6L-Sagittal	**Preop**	0,830	0,298	0,969	0,005*
	Postop	0,821	0,274	0,967	0,006*
DP6L-Occlusal	**Preop**	0,714	0,014	0,944	0,023*
	Postop	0,846	0,346	0,972	0,004*
MB7R-Coronal	**Preop**	0,878	0,452	0,978	0,002*
	Postop	0,894	0,509	0,981	0,001*
MB7R-Sagittal	**Preop**	0,910	0,569	0,984	0,001*
	Postop	0,899	0,528	0,982	0,001*
MB7R-Occlusal	**Preop**	0,706	0,476	0,919	0,015*
	Postop	0,760	0,115	0,954	0,014*
MB7L-Coronal	**Preop**	0,913	0,582	0,985	0,001*
	Postop	0,924	0,625	0,986	0,001*
MB7L-Sagittal	**Preop**	0,734	0,057	0,949	0,019*
	Postop	0,851	0,363	0,973	0,004*
MB7L-Occlusal	**Preop**	0,834	0,311	0,969	0,005*
	Postop	0,870	0,456	0,953	0,004*
P7R-Coronal	**Preop**	0,872	0,432	0,977	0,002*
	Postop	0,874	0,439	0,977	0,002*
P7R-Sagittal	**Preop**	0,897	0,520	0,982	0,001*
	Postop	0,879	0,453	0,978	0,002*
P7R-Occlusal	**Preop**	0,878	0,605	0,986	0,004*
	Postop	0,744	0,265	0,903	0,012*
P7L-Coronal	**Preop**	0,887	0,483	0,980	0,002*
	Postop	0,896	0,518	0,981	0,001*
P7L-Sagittal	**Preop**	0,762	0,119	0,955	0,014*
	Postop	0,877	0,446	0,978	0,002*
P7L-Occlusal	**Preop**	0,873	0,538	0,921	0,002*
	Postop	0,885	0,207	0,914	0,001*

B5R-Coronal	**Preop**	0,801	0,218	0,963	0,008*
	Postop	0,897	0,519	0,981	0,001*
B5R-Sagittal	**Preop**	0,941	0,700	0,990	0,001*
	Postop	0,958	0,779	0,993	0,001*
B5R-Occlusal	**Preop**	0,960	0,787	0,993	0,001*
	Postop	0,985	0,918	0,997	0,001*
B5L-Coronal	**Preop**	0,824	0,281	0,967	0,006*
	Postop	0,900	0,532	0,982	0,001*
B5L-Sagittal	**Preop**	0,966	0,819	0,994	0,001*
	Postop	0,955	0,762	0,992	0,001*
B5L-Occlusal	**Preop**	0,864	0,405	0,975	0,003*
	Postop	0,987	0,928	0,998	0,001*
P5R-Coronal	**Preop**	0,773	0,146	0,957	0,012*
	Postop	0,823	0,497	0,938	0,018*
P5R -Sagittal	**Preop**	0,893	0,503	0,981	0,001*
	Postop	0,866	0,410	0,976	0,003*
P5R-Occlusal	**Preop**	0,990	0,945	0,998	0,001*
	Postop	0,931	0,656	0,988	0,001*
P5L-Coronal	**Preop**	0,885	0,475	0,979	0,002*
	Postop	0,948	0,733	0,991	0,001*
P5L -Sagittal	**Preop**	0,939	0,688	0,989	0,001*
	Postop	0,879	0,216	0,912	0,006*
P5L-Occlusal	**Preop**	0,964	0,809	0,994	0,001*
	Postop	0,945	0,716	0,990	0,001*
B4R-Coronal	**Preop**	0,810	0,243	0,965	0,007*
	Postop	0,955	0,762	0,992	0,001*
B4R-Sagittal	**Preop**	0,987	0,926	0,998	0,001*
	Postop	0,985	0,916	0,997	0,001*
B4R-Occlusal	**Preop**	0,804	0,226	0,963	0,008*
	Postop	0,915	0,590	0,985	0,001*
B4L-Coronal	**Preop**	0,765	0,128	0,955	0,013*
	Postop	0,848	0,353	0,972	0,004*
B4L-Sagittal	**Preop**	0,963	0,801	0,993	0,001*
	Postop	0,981	0,893	0,997	0,001*
B4L-Occlusal	**Preop**	0,790	0,190	0,961	0,010*
	Postop	0,901	0,534	0,982	0,001*
P4R-Coronal	**Preop**	0,812	0,247	0,965	0,007*
	Postop	0,984	0,910	0,997	0,001*
P4R-Sagittal	**Preop**	0,940	0,694	0,989	0,001*
	Postop	0,970	0,837	0,995	0,001*
P4R-Occlusal	**Preop**	0,772	0,142	0,957	0,012*

	Postop	0,954	0,760	0,992	0,001*
P4L-Coronal	**Preop**	0,689	-0,035	0,939	0,029*
	Postop	0,827	0,289	0,968	0,006*
P4L-Sagittal	**Preop**	0,852	0,364	0,973	0,004*
	Postop	0,944	0,712	0,990	0,001*
P4L-Occlusal	**Preop**	0,792	0,194	0,961	0,010*
	Postop	0,985	0,917	0,997	0,001*
B3R-Coronal	**Preop**	0,871	0,353	0,904	0,001*
	Postop	0,738	0,065	0,950	0,018*
B3R-Sagittal	**Preop**	0,997	0,982	0,999	0,001*
	Postop	0,995	0,970	0,999	0,001*
B3R-Occlusal	**Preop**	0,788	0,204	0,915	0,013*
	Postop	0,852	0,366	0,973	0,004*
B3L-Coronal	**Preop**	0,858	0,385	0,974	0,003*
	Postop	0,798	0,209	0,962	0,009*
B3L-Sagittal	**Preop**	0,987	0,926	0,998	0,001*
	Postop	0,992	0,952	0,999	0,001*
B3L-Occlusal	**Preop**	0,682	-0,047	0,937	0,031*
	Postop	0,750	0,092	0,952	0,016*
M2R-Coronal	**Preop**	0,892	0,435	0,906	0,001*
	Postop	0,800	0,427	0,863	0,003*
M2R-Sagittal	**Preop**	0,988	0,931	0,998	0,001*
	Postop	0,871	0,740	0,970	0,001*
M2R-Occlusal	**Preop**	0,788	0,334	0,888	0,010*
	Postop	0,708	0,584	0,798	0,012*
M2L-Coronal	**Preop**	0,822	0,293	0,898	0,002*
	Postop	0,764	0,614	0,880	0,019*
M2L-Sagittal	**Preop**	0,964	0,809	0,994	0,001*
	Postop	0,955	0,763	0,992	0,001*
M2L-Occlusal	**Preop**	0,859	0,617	0,978	0,001*
	Postop	0,865	0,360	0,982	0,001*
D2R-Coronal	**Preop**	0,921	0,407	0,969	0,001*
	Postop	0,938	0,485	0,943	0,001*
D2R-Sagittal	**Preop**	0,996	0,976	0,999	0,001*
	Postop	0,923	0,620	0,986	0,001*
D2R-Occlusal	**Preop**	0,754	0,470	0,849	0,005*
	Postop	0,885	0,788	0,337	0,002*
D2L-Coronal	**Preop**	0,833	0,308	0,969	0,005*
	Postop	0,834	0,311	0,969	0,005*
D2L-Sagittal	**Preop**	0,969	0,834	0,995	0,001*
	Postop	0,777	0,156	0,958	0,012*

D2L-Occlusal	**Preop**	0,893	0,434	0,961	0,008*
	Postop	0,738	0,065	0,949	0,018*
M1R-Coronal	**Preop**	0,846	0,262	0,904	0,002*
	Postop	0,856	0,248	0,907	0,006*
M1R-Sagittal	**Preop**	0,894	0,509	0,981	0,001*
	Postop	0,868	0,612	0,982	0,002*
M1R-Occlusal	**Preop**	0,755	0,549	0,870	0,006*
	Postop	0,747	0,412	0,857	0012*
M1L-Coronal	**Preop**	0,818	0,501	0,937	0,001*
	Postop	0,828	0,400	0,871	0,001*
M1L-Sagittal	**Preop**	0,743	0,560	0,810	0,011*
	Postop	0,935	0,671	0,988	0,001*
M1L-Occlusal	**Preop**	0,829	0,398	0,872	0,004*
	Postop	0,832	0,723	0,890	0,003*
D1R-Coronal	**Preop**	0,724	0,291	0,898	0,009*
	Postop	0,709	0,309	0,894	0,011*
D1R-Sagittal	**Preop**	0,978	0,878	0,996	0,001*
	Postop	0,982	0,900	0,997	0,001*
D1R-Occlusal	**Preop**	0,733	0,423	0,890	0,013*
	Postop	0,718	0,343	0,861	0,020*
D1L-Coronal	**Preop**	0,805	0,313	0,893	0,001*
	Postop	0,857	0,468	0,895	0,001*
D1L-Sagittal	**Preop**	0,981	0,895	0,997	0,001*
	Postop	0,967	0,824	0,994	0,001*
D1L-Occlusal	**Preop**	0,720	0,407	0,869	0,015*
	Postop	0,710	0,169	0,920	0,014*
L MB6R-Coronal	**Preop**	0,793	0,323	0,949	0,003*
	Postop	0,817	0,384	0,956	0,002*
L MB6R-Sagittal	**Preop**	0,851	0,475	0,964	0,001*
	Postop	0,888	0,583	0,974	0,001*
L MB6R-Occlusal	**Preop**	0,966	0,859	0,992	0,001*
	Postop	0,989	0,952	0,997	0,001*
L MB6L-Coronal	**Preop**	0,802	0,345	0,952	0,003*
	Postop	0,766	0,260	0,942	0,005*
L MB6L-Sagittal	**Preop**	0,885	0,574	0,973	0,001*
	Postop	0,906	0,641	0,978	0,001*
L MB6L-Occlusal	**Preop**	0,973	0,886	0,994	0,001*
	Postop	0,994	0,975	0,999	0,001*
L B5R-Coronal	**Preop**	0,720	0,224	0,881	0,006*
	Postop	0,725	0,218	0,883	0,003*
L B5R-Sagittal	**Preop**	0,760	0,211	0,921	0,026*

	Postop	0,918	0,649	0,983	0,001*
L B5R-Occlusal	**Preop**	0,929	0,688	0,985	0,001*
	Postop	0,968	0,850	0,994	0,001*
L B5L-Coronal	**Preop**	0,711	0,084	0,935	0,016*
	Postop	0,753	0,173	0,945	0,010*
L B5L-Sagittal	**Preop**	0,839	0,392	0,966	0,002*
	Postop	0,820	0,338	0,961	0,003*
L B5L-Occlusal	**Preop**	0,876	0,503	0,974	0,001*
	Postop	0,971	0,862	0,994	0,001*
L B4R-Coronal	**Preop**	0,672	0,070	0,915	0,017*
	Postop	0,742	0,208	0,935	0,007*
L B4R-Sagittal	**Preop**	0,974	0,892	0,994	0,001*
	Postop	0,956	0,817	0,990	0,001*
L B4R-Occlusal	**Preop**	0,857	0,490	0,966	0,001*
	Postop	0,949	0,793	0,988	0,001*
L B4L-Coronal	**Preop**	0,697	0,116	0,923	0,013*
	Postop	0,702	0,127	0,924	0,012*
L B4L-Sagittal	**Preop**	0,942	0,766	0,987	0,001*
	Postop	0,890	0,591	0,974	0,001*
L B4L-Occlusal	**Preop**	0,781	0,217	0,854	0,008*
	Postop	0,917	0,679	0,981	0,001*
L B3R-Coronal	**Preop**	0,841	0,447	0,962	0,001*
	Postop	0,906	0,642	0,978	0,001*
L B3R-Sagittal	**Preop**	0,994	0,973	0,999	0,001*
	Postop	0,966	0,857	0,992	0,001*
L B3R-Occlusal	**Preop**	0,804	0,350	0,952	0,003*
	Postop	0,832	0,421	0,959	0,001*
L B3L-Coronal	**Preop**	0,706	0,134	0,925	0,011*
	Postop	0,748	0,220	0,937	0,006*
L B3L-Sagittal	**Preop**	0,960	0,834	0,991	0,001*
	Postop	0,948	0,787	0,988	0,001*
L B3L-Occlusal	**Preop**	0,698	0,119	0,923	0,012*
	Postop	0,697	0,116	0,923	0,013*
L M2R-Coronal	**Preop**	0,891	0,204	0,957	0,001*
	Postop	0,858	0,354	0,907	0,003*
L M2R-Sagittal	**Preop**	0,969	0,871	0,993	0,001*
	Postop	0,917	0,679	0,981	0,001*
L M2R-Occlusal	**Preop**	0,905	0,637	0,978	0,001*
	Postop	0,795	0,359	0,892	0,035*
L M2L-Coronal	**Preop**	0,773	0,392	0,885	0,042*
	Postop	0,789	0,314	0,948	0,003*

L M2L-Sagittal	**Preop**	0,993	0,967	0,998	0,001*
	Postop	0,955	0,814	0,990	0,001*
L M2L-Occlusal	**Preop**	0,760	0,448	0,912	0,019*
	Postop	0,726	0,175	0,931	0,009*
L D2R-Coronal	**Preop**	0,871	0,436	0,971	0,003*
	Postop	0,853	0,351	0,943	0,004*
L D2R-Sagittal	**Preop**	0,967	0,863	0,993	0,001*
	Postop	0,867	0,234	0,949	0,002*
L D2R-Occlusal	**Preop**	0,919	0,686	0,981	0,001*
	Postop	0,889	0,587	0,974	0,001*
L D2L-Coronal	**Preop**	0,766	0,260	0,942	0,005*
	Postop	0,871	0,531	0,969	0,001*
L D2L-Sagittal	**Preop**	0,998	0,991	1,000	0,001*
	Postop	0,991	0,962	0,998	0,001*
L D2L-Occlusal	**Preop**	0,855	0,487	0,965	0,001*
	Postop	0,885	0,574	0,973	0,001*
L M1R-Coronal	**Preop**	0,873	0,386	0,974	0,001*
	Postop	0,849	0,455	0,961	0,001*
L M1R-Sagittal	**Preop**	0,911	0,658	0,979	0,001*
	Postop	0,848	0,464	0,963	0,001*
L M1R-Occlusal	**Preop**	0,774	0,277	0,944	0,004*
	Postop	0,662	0,052	0,912	0,019*
L M1L-Coronal	**Preop**	0,788	0,433	0,904	0,008*
	Postop	0,790	0,502	0,834	0,005*
L M1L-Sagittal	**Preop**	0,974	0,890	0,994	0,001*
	Postop	0,968	0,867	0,993	0,001*
L M1L-Occlusal	**Preop**	0,746	0,323	0,907	0,012*
	Postop	0,723	0,167	0,930	0,009*
L D1R-Coronal	**Preop**	0,729	0,548	0,903	0,003*
	Postop	0,794	0,321	0,817	0,002*
L D1R-Sagittal	**Preop**	0,990	0,956	0,998	0,001*
	Postop	0,767	0,360	0,914	0,018*
L D1R-Occlusal	**Preop**	0,730	0,183	0,932	0,008*
	Postop	0,854	0,483	0,965	0,001*
L D1L-Coronal	**Preop**	0,819	0,554	0,899	0,001*
	Postop	0,840	0,540	0,909	0,001*
L D1L-Sagittal	**Preop**	0,995	0,978	0,999	0,001*
	Postop	0,989	0,953	0,998	0,001*
L D1L-Occlusal	**Preop**	0,796	0,315	0,922	0,013*
	Postop	0,835	0,430	0,960	0,001*
Mid 1R-overbite plane	**Preop**	0,922	0,619	0,986	0,001*

	Postop	0,963	0,844	0,991	0,001*
Mid 1L - overbite plane	**Preop**	0,969	0,835	0,995	0,001*
	Postop	0,972	0,848	0,995	0,001*
Mid L 1R-overbite plane	**Preop**	0,908	0,562	0,984	0,001*
	Postop	0,905	0,549	0,983	0,001*
Mid L 1L-overbite plane	**Preop**	0,969	0,835	0,995	0,001*
	Postop	0,969	0,830	0,995	0,001*
Mand Intercanine	**Preop**	0,988	0,947	0,997	0,001*
	Postop	0,992	0,964	0,998	0,001*
Mand Intermolar	**Preop**	0,992	0,966	0,998	0,001*
	Postop	0,993	0,967	0,998	0,001*
Max. Intercanine	**Preop**	0,996	0,983	0,999	0,001*
	Postop	0,996	0,982	0,999	0,001*
Max. Intermolar	**Preop**	0,998	0,990	0,999	0,001*
	Postop	0,999	0,996	1,000	0,001*
Palatal plate-SN	**Preop**	0,987	0,814	0,999	0,001*
	Postop	0,985	0,865	0,998	0,001*
Gonion Menton-SN	**Preop**	0,744	0,388	0,981	0,005*
	Postop	0,945	0,572	0,994	0,002*
Frankfurt-Mandibular plane	**Preop**	0,715	0,572	0,970	0,015*
	Postop	0,924	,0448	0,992	0,004*
Palatal plane-mand plane	**Preop**	0,960	0,521	0,997	0,005*
	Postop	0,961	0,682	0,996	0,001*
Occl. To S-N	**Preop**	0,737	0,401	0,981	0,038*
	Postop	0,878	0,233	0,987	0,011*
SNA	**Preop**	1,000	1,000	1,000	-
	Postop	0,963	0,692	0,996	0,001*
SNB	**Preop**	0,986	0,801	0,999	0,001*
	Postop	0,969	0,739	0,997	0,001*
ANB	**Preop**	0,976	0,688	0,998	0,002*
	Postop	0,971	0,756	0,997	0,001*
Wits	**Preop**	0,715	0,518	0,920	0,035*
	Postop	0,796	0,344	0,977	0,029*
N-I-A	**Preop**	0,994	0,905	1,000	0,001*
	Postop	0,992	0,926	0,999	0,001*
SELLA NASION	**Preop**	0,976	0,689	0,998	0,002*
	Postop	0,920	0,426	0,991	0,005*
Overjet	**Preop**	0,990	0,860	0,999	0,001*
	Postop	0,989	0,897	0,999	0,001*
Overbite	**Preop**	0,849	-0,117	0,989	0,035*
	Postop	0,933	0,499	0,993	0,003*

UI^N-S	**Preop**	0,948	0,418	0,997	0,007*
	Postop	0,932	0,495	0,993	0,003*
IMPA	**Preop**	0,733	0,649	0,961	0,007*
	Postop	0,983	0,847	0,998	0,001*
LI to UI (Angle)	**Preop**	0,811	0,235	0,987	0,048*
	Postop	0,943	0,561	0,994	0,002*
UOccl. To S-N	**Preop**	0,720	0,460	0,978	0,003*
	Postop	0,887	0,268	0,988	0,009*
Occl. To S-N	**Preop**	0,737	0,401	0,981	0,018*
	Postop	0,878	0,233	0,987	0,011*
Molar angulation	**Preop**	0,856	0,760	0,940	0,018*
	Postop	0,866	0,184	0,985	0,013*
2. premolar angulation	**Preop**	0,899	0,098	0,993	0,019*
	Postop	0,865	0,455	0,944	0,001*
1.premolar angulation	**Preop**	0,846	-0,127	0,989	0,036*
	Postop	0,813	0,006	0,979	0,024*
Molar mesial root	**Preop**	0,924	0,240	0,995	0,013*
	Postop	0,945	0,575	0,994	0,002*
Nasolabial Angle	**Preop**	0,921	0,225	0,995	0,013*
	Postop	0,995	0,952	0,999	0,001*
Soft tissue profile	**Preop**	0,904	0,125	0,993	0,018*
	Postop	0,993	0,939	0,999	0,001*
Skeletal profile	**Preop**	0,987	0,817	0,999	0,001*
	Postop	0,985	0,862	0,998	0,001*
Total profile	**Preop**	1,000	1,000	1,000	-
	Postop	0,936	0,517	0,993	0,003*
Upper lip-E line	**Preop**	0,990	0,861	0,999	0,001*
	Postop	0,960	0,671	0,996	0,001*
Lower lip-E line	**Preop**	0,975	0,675	0,998	0,002*
	Postop	0,740	-0,179	0,969	0,046*

ICC: Intraclass Correlation Coefficient *$* p<0.05$*

8. DISCUSSION

8.1 Discussion of Aim

Class II malocclusions are one of the most prevalent, standing for one third of all malocclusions (Proffit, Fields Jr, & Sarver, 2014). The distalization treatment protocol has been established as a valid alternative to the extraction protocol, even generating a stronger indication for certain cases. Many intra-oral distalization systems have been developed throughout the past years as an option to the extra-oral headgear systems (Acar, Gürsoy, & Dinçer, 2010; Angelieri, de Almeida, de Almeida, & Fuziy, 2006; Bolla et al., 2002; Bondemark, 2000; Bondemark & Karlsson, 2005; Brickman et al., 2000; Bussick & McNamara, 2000; Chiu et al., 2005; Flores-Mir, McGrath, Heo, & Major, 2013; Fortini et al., 2004; Güngör, 2004; Haas & Cisneros, 2000; Haydar & Üner, 2000; Karlsson & Bondemark, 2006; Keles & Sayinsu, 2000; Ngantung et al., 2001; Patel et al., 2009; Taner, Yukay, Pehlivanoglu, & Çakırer, 2003; T. Üçem et al., 2000). Anchorage loss in anterior teeth and premolars has been a known side effect of these conventional intra-oral appliances (Gelgör et al., 2004; Nur, Bayram, Celikoglu, Kilkis, & Pampu, 2011; Polat-Ozsoy, 2008). Utilizing upper molars as anchorage to retract back these mesialized teeth is a common reason to the following relapse tendencies (Gianelly, 1998).

Gianelly (Gianelly, 1998), suggested that distalized molars shouldn´t be used as anchorage for retraction of premolars for about 4-5 months in order to avoid relapse. In studies carried out with intra-oral distalization mechanics, though the molar distalization time is usually short, the total treatment time is prolonged due to these anchorage issues.

Over the following years, implant-supported distalization systems were introduced to eliminate side effects as anchorage loss when treating Class II malocclusions (Byloff, Kärcher, Clar, & Stoff, 1999; Escobar et al., 2007; Gelgör et al., 2004; Gelgör et al., 2007; Karaman et al., 2002; Kärcher et al., 2002; Keles et al., 2003; Kircelli et al., 2006; Männchen, 1999; Önçağ et al., 2007; H.-S. Park et al., 2004; H.-S. Park et al., 2005; Sugawara et al., 2006; Triaca et al., 1992). The most pivotal advantage of these systems is that they do not take anchorage from any teeth or the dento-alveolar area, not creating any reciprocal forces on premolars or anterior teeth. Skeletal anchorage reduces the demands on a patient's compliance and increases overall control and predictability of the orthodontic treatment.

In implant-supported systems not only molar distalization has been possible to be achieved, but also some distalization of premolars and retrusion of anterior teeth (Escobar et al., 2007; Keles et al., 2003; Kircelli et al., 2006; Önçağ et al., 2007). In some studies with miniscrews, even a buccal segment group distalization has been observed (H.-S. Park et al., 2004; H.-S. Park et al., 2005). They have several advantages as having convenient application for the orthodontist, being esthetically acceptable and compliance independent and applying constant forces as aimed. Hence an essential focus and interest has been dedicated to improve and advance these systems treating Class II malocclusions.

Miniscrew-supported distalization appliances have been well studied in the literature; however, few studies have focused on the effects of maxillary molar distalization using miniplate anchorage (H. De Clerck, Geerinckx, & Siciliano, 2002; Kaya et al., 2009; Kaya et al., 2012; Nur et al., 2011; Yu et al., 2014); (Cornelis & De Clerck, 2007; Kilkis et al., 2016; Sugawara et al., 2006).

Treatment objectives for cases used in our study has been to establish a Class I relationship while distalizing upper molars and achieving some buccal segment group distalization. While maxillary posterior teeth were being distalized, maxillary anterior crowding and/or increased overjet was expected to decrease. By using zygomatic miniplates as anchorage for distalizing, anchorage loss was expected to be minimal or none, providing a shorter total treatment time for the patient. Keeping these objectives in mind, the aim of our study was to evaluate molar distalization with zygomatic miniplates, assessing the results and outcomes on treated archive cases.

8.2 Discussion of Method

The mean age for all patients in this retrospective study at treatment start was 18.0±3.42. Treated patients had initial Class I or II skeletal relationship, with a cusp-cusp or full cusp Class II dental relationship. The vertical growth pattern for these patients was normal to low angle skeletal relationship. Other requirements were having a positive overbite, no missing teeth other than third molars, upper anterior arch constriction and/or increased overjet, minimum or no space discrepancy in the lower arch. Patients who did not meet these requirements were not qualified for this treatment.

Upper second molars being fully erupted in all patients constituted a crucial requirement for the treatment mechanics. All posterior teeth were distalized with sliding mechanics on 0.016 stainless steel arch wire. Besides bands on upper first molars, upper second molars were bonded together with upper 1.premolars. This way upper second molars were thought to be distalized in a controlled manner, avoiding expected problems like disturbance in occlusion or alignment due to second molars not being incorporated in the treatment mechanics from the very beginning.

Some studies suggest that less distal movement is achieved taking longer time, also causing some anchorage loss from teeth involved when incorporating upper second molars in intra-oral distalization mechanics (Gianelly, 1998; Gianelly et al., 1989; Gianelly, Vaitas, Thomas, & Berger, 1988; Hilgers, 1992; Karlsson & Bondemark, 2006; Locatelli, 1992). On the contrary, there are other studies claiming that second molars have no such a significant effect (Bussick & McNamara, 2000; Byloff & Darendeliler, 1997; Ghosh & Nanda, 1996a). Gianelly (Gianelly, 1998), reported that distalizing upper second molars first is a more accurate approach when using intra-oral distalizing systems but that treatment time gets prolonged by minimum 6 months. He added that upper thirds molars could be a limitation when distalizing, that a surgical removal in advance could be performed where possible. Since upper third molars were present in the x-rays in our study sample, this could be thought to contribute to an overall prolonged distalization time. In case of risk of impaction or impingement between the posterior maxilla and tuber area, upper thirds molar germs in favorable position and stage were indicated for extraction prior to treatment start.

The main reasons behind choosing zygomatic miniplates instead of palatal implants or alveolar miniscrews for these patients have been; its proximity to the posterior maxillary teeth to be moved, being solid with a safe location on the cortical bone (H. De Clerck et al., 2002). In comparison with palatal implants and dento-alveolar miniscrews they can be loaded with much higher forces, with no complication risk as injury to crucial tissues such as the incisive canal, dental roots or nerves. Another superior property of miniplates is that they are supported by 2-3 mini-screws for fixation, which makes it possible to apply higher forces and distalize much more.

In a study by Kaya et al. (Kaya et al., 2009), distalization with zygomatic anchorage was performed on continuous wires and closed Ni-Ti coils extending from power arms placed on canine brackets to the zygomatic miniplate. This study shows some similarities with the Clerk et al. (H. De Clerck et al., 2002) study in terms of force application magnitude and vector.

In similarity to studies of Kaya et al., Cornelis and De Clerck and Kilkis et al. (Cornelis & De Clerck, 2007; Kaya et al., 2009; Kilkis et al., 2016), the zygomatic miniplates used in our study were placed on the cortical bone of buttress area, fixated with miniscrews of dimensions 2 mm x 7 mm, providing solid anchorage for applied forces. The preference of higher forces is that they can exceed the anchorage value of teeth as molars and premolars and assist in moving them together. On the other hand, being low enough for hyalinization with indirect bone resorption not to occur, producing the optimum force magnitude. Lower forces are thought not to be sufficient enough to move all posterior teeth on the same level, and in case of higher forces side effects as pathological tooth resorbtions are of concern. Taking solid support from the above-mentioned anchorage system and applying forces at 230-250 grams via Ni-Ti coils, it is thought that it was operated on the safe yet efficient side in our sample group.

In our study sample there was no reported mobility or loss of primary stability in any of the miniplates placed in 12 patients (4 unilateral, 8 bilateral). Optimum forces were applied on 20 miniplates in total with a 100% of success rate. In a study conducted by Park et al. (H.-S. Park et al., 2005) of miniscrews for buccal segment distalization, 27 out of 30 miniscrews stayed stable after a force application of 200 gram each, giving a success rate by 90%. In studies performed with zygomatic miniplates for canine, molar and buccal segment distalization; no loss of miniplate was observed due to mobility but similar to our study sample, a low degree of inflammation around the implant was observed in some cases (H. De Clerck et al., 2002; Sugawara et al., 2006). This was linked to inadequate oral hygiene in some cases or miniplates placed too superiorly in the vestibule in some other. All in all, when miniscrews are compared to miniplates in stability for buccal segment distalization, the success rate is way higher for miniplates despite the application of higher forces (H.-S. Park et al., 2005; Sugawara et al., 2006).

According to the findings of Nur et al. (Nur et al., 2011) 2 of 17 patients (11.8%) were excluded from the study because of infection, whereas Kaya et al. (Kaya et al., 2009; Kaya et al., 2012) reported that all miniplates used in their studies were stable during distalization, and no patients were excluded from the study because of infection or mobility. The stability of the zygoma anchors were also found to be high (20 of 21 subjects; 95.2%) in Kilkis et al. (Kilkis et al., 2016). These findings are in agreement with our results. This high success rate is similar to study of Cornelis et al. (Cornelis & De Clerck, 2007). Patients generally appear to accept miniplate placement well, and they report preferring miniplates to headgear (Cornelis, Scheffler, Nyssen-Behets, De Clerck, & Tulloch, 2008).

In order to achieve a proper occlusion and stable results, it is desired to obtain a parallel movement in other words translation than tipping. The center of resistance for the molar tooth is known to be at the trifurcation level of the molar, while the center of resistance for all maxillary teeth is located between the first and second premolar sagittally and mid-root length vertically (Proffit et al., 2014). The center of resistance also depends on the morphology of the alveolar bone surrounding the teeth together with the periodontal tissue health; its location is approximately anticipated for each case. Taking this information into account, the center of resistance for teeth in our study sample was assumed to be between the roots of first molar and second premolar in the sagittal plane, mid-root length in the vertical plane. When the point of force application passes inferior to this point it might cause distal tipping and/or buccal segment posterior rotation; if it passes superiorly on the other hand mesial tipping and/or buccal segment anterior rotation can be the outcome.

Placing the zygomatic miniplates onto the buttress bone, factors as the miniplate arm being close on the first molar furcation level sagittally and exiting into the oral cavity at the attached gingiva level vertically were taken into consideration. The connecting piece is displayed in figure 5.3.1, extending from the miniplate arm superiorly and connected to the archwire inferiorly. The distalization force is applied on the molar with Ni-Ti coil springs on the archwire level. This miniplate placement technique and the following system design helps preventing and minimizing unwanted vertical changes and excessive tipping movements in posterior teeth.

Daskalogiannakis and McLachan (Daskalogiannakis & McLachlan, 1996), stated that continuous force application results in faster tooth movement than intermittent force application. Studies about molar distalization report that continuous force intra-oral systems result in shorter treatment time compared with intermittent force extra-oral systems (Bondemark & Kurol, 1992; Carano & Testa, 1996; Ghosh & Nanda, 1996a; Gianelly et al., 1989; Itoh, 1991; Jones & White, 1992). Hence why Ni-Ti coil springs have been the material of choice for numerous buccal segment implant supported distalization studies.

The buccal segment distalization in our study sample was evaluated by cephalometric analysis and digitized dental casts. For cephalometric analysis, conventional dimension and angular measurements used in routine analysis were utilized. Skeletal, dental and soft-tissue changes were evaluated in addition to angular measurements for the upper central, first premolar, second premolar, first molar and second molar. The latter was used to assess dental tipping in each tooth respectively, in accordance with the Sella-Nasion reference plane.

The conventional method to measure the amount of teeth movement post distalization is to use lateral cephalometric radiographies and dental cast photocopies. Cephalometric radiographs may cause errors in landmark identification because of superimpositions of symmetrical anatomic structures (T.-J. Park, Lee, & Lee, 2012). Three-dimensional evaluations cannot be performed alone in either method; therefore, these 2 methods should be used in combination. It was reported that using digital models to evaluate dental changes after distalization treatment is reliable and has minor measurement differences when compared with conventional superimposition methods (Nalcaci, Kocoglu-Altan, Bicakci, Ozturk, & Babacan, 2015). Cornelis et al.(Cornelis & De Clerck, 2007) agreed with the results of other authors who stated that digital models are a clinically acceptable replacement for plaster casts (Stevens et al., 2006). With this method, the movement of each tooth over the arch can be analyzed in all 3 planes of the space and measurements can be performed frequently, since digital models do not involve radiation.

In a study, the maxillary digital models were superimposed on stable miniscrews in extraction patients, and it was stated that the palatal rugae region is stable and could be included for alignment to evaluate orthodontic tooth movements (Chen et al., 2011; Jang et al., 2009). This area was found to be stable throughout a person's lifetime and also has been used for establishing identity in forensics (Ashmore et al., 2002).

A limitation of our study was that root movements were only investigated on 2D cephalometric radiographs. Root movements can more accurately be examined with 3D imaging techniques such as cone-beam computed tomography and computed tomography. There is a need for studies that evaluate the angular changes by imaging the roots and crowns together.

8.3 Discussion of Results

Evaluating maxilla´s sagittal position regarding SNA angle and N-A distance, the A point has moved posteriorly (Table-13). Various studies have shown that extra-oral forces applied towards posterior, make the maxilla shift posteriorly, that the forces also affect the neighboring bones (Brousseau & Kubisch, 1977; Chaconas, Caputo, & Davis, 1976). Many clinical studies performed with different headgear types have reported that the SNA and A point had moved backwards (Hubbard, Nanda, & Currier, 1994; Kim & Muhl, 2001; Kirjavainen, Kirjavainen, Hurmerinta, & Haavikko, 2000; Lima Filho, Lima, & de Oliveira Ruellas, 2003; Ülger, Arun, Sayınsu, & Isik, 2006). Maxillary molar distalization carried out with standard intra-oral appliances, have often exhibited no skeletal effect on the maxilla or even increased the SNA angle (Gianelly et al., 1989; Gianelly et al., 1988; Itoh, 1991). Implant-supported intra-oral molar distalization appliances have also no reported effect on the maxillary sagittal position, some of them even moved the A point slightly forward (Gelgör et al., 2004; Gelgör et al., 2007; Karaman et al., 2002; Keles et al., 2003; Kircelli et al., 2006; Önçağ et al., 2007; H.-S. Park et al., 2004; H.-S. Park et al., 2005). Since anchorage loss in anterior teeth is not a commonly seen side effect with implant-supported systems, but rather some retroclination in incisors; the slight forward movement in the A point could be explained by incisor crowns inclining palatal thus roots moving buccally.

When making a comparison between the systems; the zygoma anchorage system utilized in our study sample and other similar studies (Kaya et al., 2009; Kaya et al., 2012; Kilkis et al., 2016; Nur et al., 2011), show a superior advantage to all other implant-supported systems by retroclining both the maxillary anterior teeth and the A point simultaneously.

No significant changes in the B point were observed; in contrast with Kaya et al. (Kaya et al., 2009) noting some backward movement of the B point explained by a possible posterior and downwards rotation of the mandible. Other implant-supported studies also agreed on these findings, observing the mandible in the same position or even some backward movement in some cases (Gelgör et al., 2004; Gelgör et al., 2007; Karaman et al., 2002; Kircelli et al., 2006; Önçağ et al., 2007).

No significant changes were seen in the palatal plane inclination (Table-12), agreeing with other studies of implant-supported methods and buccal segment distalization (Kaya et al., 2009; Kircelli et al., 2006; Önçağ et al., 2007; H.-S. Park et al., 2005).

Studies of many intra-oral distalization mechanics and their side effects, have reported an increase in the mandibular plane angle (Bondemark, Kurol, & Bernhold, 1994; Erverdi et al., 1997; Ghosh & Nanda, 1996a; Jones & White, 1992). Studies on implant-supported intra-oral distalization mechanics have shown similar results in terms of a posterior rotation of the mandible (Gelgör et al., 2004; Gelgör et al., 2007; H.-S. Park et al., 2005). Our results on the contrary, showed no significant changes in the mandibular plane angle.

In many studies where a posterior force application was used, a decrease in the SNA angle hence a decrease in the ANB angle was reported (Armstrong, 1971; Barton, 1972; Baumrind et al., 1983; Baumrind, Molthen, West, & Miller, 1979; Caldwell, Hymas, & Timm, 1984; Firouz, Zernik, & Nanda, 1992; Fotis et al., 1984; Joffe & Jacobson, 1979). Numerous studies on cervical headgears have shown a significant decrease in the ANB angle (Haralabakis & Sifakakis, 2004; Kim & Muhl, 2001; Kirjavainen et al., 2000; Ülger et al., 2006). On the other hand, implant-supported intra-oral distalization methods have exhibited no significant skeletal changes in the ANB angle (Gelgör et al., 2004; Gelgör et al., 2007; Karaman et al., 2002; Keles et al., 2003; Kircelli et al., 2006; Önçağ et al., 2007; H.-S. Park et al., 2004). This findings are agreement with our study sample results, in contrast with Kaya et al. (Kaya et al., 2009).

There are multiple studies on correcting Class II malocclusion by molar distalization with various headgears (Armstrong, 1971; Badell, 1976; Bernstein, Rosol, & Gianelly, 1976; Firouz et al., 1992; Hubbard et al., 1994; Poulton, 1967; Ülger et al., 2006). In combined headgears distalization in first molars is reported to be from 2.3 mm up to 4.5 mm, and 1.2 mm up to 3.6 mm in cervical headgears

(Armstrong, 1971; Badell, 1976; Bernstein et al., 1976; Haydar & Üner, 2000; Hubbard et al., 1994; Taner et al., 2003; Ülger et al., 2006).

Reported distalization amounts for conventional intra-oral methods in various studies are; 2.1 – 4.2 mm for magnets, 2.6 – 3 mm for Wilson biometric arches, 3.8 mm for Ni-Ti coil springs, 2.08 – 2.8 for the Jones Jig, 3.2 mm for the Distal Jet, 4 – 4.8 mm for the First Class Appliance, 5.23 mm for the Intra-oral Bodily Molar Distalizer (Bolla et al., 2002; Bondemark & Kurol, 1992; Erverdi et al., 1997; Fortini et al., 2004; Fortini et al., 1999; Ghosh & Nanda, 1996a; Gianelly et al., 1991; Gulati et al., 1998; Haydar & Üner, 2000; Hilgers, 1992; Itoh, 1991; Keles & Sayinsu, 2000; Küçükkeleş & Doğanay, 1994; Muse et al., 1993; Taner et al., 2003). Unwanted side effects as mesialization and protusion in premolars and incisors from 4.3 to 4.7 mm have been observed. Although the distalization time was as short as 2-4 months, a severe anchorage loss was problematic.

Implant-supported intra-oral distalization studies for pendulum appliances have shown 4 – 6.4 mm distalization in first molars, 3.1 – 4.85 mm distal movement in premolars, distalization in all posterior teeth along with insignificant retrusion in anterior teeth (Escobar et al., 2007; Kircelli et al., 2006; Önçağ et al., 2007). In implant-supported modified transpalatal arch applications, reported molar distalization has been 3.90 – 3.95 mm and 0.48 – 0.52 mm of protrusion in incisors (Gelgör et al., 2004; Gelgör et al., 2007). In studies of buccal segment distalization with mini-screws, reported distal movement has been 1.50 mm in second molars, 1.64 mm in first molars, 1.20 mm in premolars, 0.85 mm in incisors (H.-S. Park et al., 2005). In buccal segment distalization studies with zygomatic anchorage, molar distalization by 3.78 mm at crown level has been achieved (Sugawara et al., 2006). Compared with other implant-supported distalization systems, less distalization amounts were achieved in buccal segment distalization assisted by mini-screws (H.-S. Park et al., 2004; H.-S. Park et al., 2005). An explanation to this is that mini-screws are often placed between molar and premolar roots, limiting the amount of distalization that can be achieved, and patients with full unit Class II relationships not being included in these studies. The distalization time in studies of implant-supported systems varies between 4.6 – 19 months. Although distalization times are longer in these systems compared with the standard intra-oral systems, not losing anchorage but also gain some distalization and retrusion in premolars and incisors, are superior advantages that shorten the overall treatment time. All in all, it has been reported that the mean distalization amounts in the sagittal direction after distalization are 3.34 mm with tooth-borne intraoral distalization methods and 5.10 mm with skeletal anchorage (da Costa Grec et al., 2013).

For unilateral maxillary molar distalization in the ZGA study (Kilkis et al., 2016), the maxillary first molar moved 5.31 ± 2.46 mm in 0.45 ± 0.12 years, showing a 0.98-mm distalization rate per month. The results from this study are very close to our findings (5.84 ± 1.37 mm, mean: 0.58 ±0.92 years). This rate was higher than those of Miresmaeili et al. (Miresmaeili, Sajedi, Moghimbeigi, & Farhadian, 2015) (0.4 mm per month), Nalcaci et al. (Nalçaci, Biçakçi, & Ozan, 2010) (3.95 ± 1.35 mm in 9.61 ± 2.1 months; about 0.4 mm per month), and Yamada et al. (Yamada et al., 2009) (2.8 ± 1.6 mm in 8.4 ± 4.2 months; about 0.33 mm per month), whereas it was close to the findings of Gelgor et al. (Gelgör et al., 2004) (3.9 mm in 4.6 months; about 0.85 mm per month), Escobar et al. (Escobar et al., 2007) (6.0 ± 2.27 mm in 7.8 months; 0.77 mm per month), and Oberti et al. (Oberti et al., 2009) (1.18 mm per month) using miniscrew-supported distalization appliances. The differences for the amounts of distalization that we obtained and those of the previous studies might be due to differences in patient selection and the materials used during distalization. Kaya et al. (Kaya et al., 2009) reported 5.03 ± 0.30 and 4.63 ± 0.35 mm of distalization for the first molar and premolar, respectively, in 9.03 ± 0.62 months using the zygomatic anchorage system. The reason for the increased movement of the maxillary first premolar might be because the buccal segment was completely distalized in their study, agreeing with our premolar movement results (Table-3). The rate of molar distalization was reported to be 0.84 mm per month with the ZGA for bilateral distalization (Nur et al., 2011).

In addition, several of the mentioned studies (Kaya et al., 2009; Kaya et al., 2012; Kilkis et al., 2016; Nur et al., 2011) found that the maxillary molar was slightly tipped distally and intruded using the zygoma anchor.

Teeth in both jaws but specially the maxillary teeth were assessed in terms of not only distalization; but also any extrusion, intrusion and tipping movements that might have occurred during distalization. Mean distalization amounts in maxillary anterior and posterior teeth are displayed in table 3,4 and 5. Values were found significant at $p<0.05$ statistically. Non-bonded teeth are thought to have retruded or distalized due to transseptal fibers.

There are studies reporting the more distalization amount, the more distal tipping (Dermaut, Kleutghen, & De Clerck, 1986). Distal tipping of the first molars is an expected reaction after distalization treatment (G. S. Kinzinger, Eren, & Diedrich, 2008). It is reported in the literature that the molars have distal tipping varying from 3 to 12 after distalization with skeletal anchorage (da Costa Grec et al., 2013).

The distal tipping movements in upper central, first premolar, second premolar and first molar were evaluated by their preop-postop angular changes according to the Sella-Nasion plane. The distal tipping results were statistically significant for upper centrals (-3.5° ± 4.95°), first premolars (-4.58° ± 4.27°) and molars at $p<0.05$. The tipping movement in molars was measured by two parallel parameters in our study marked as molar angulation and molar mesial root angulation. Both parameters showed very similar results; -4.25° ± 2.92° and -4.75° ± 3.6° respectively. This indicates the reliability of both measurement parameters to assess tipping in molars on cephalometric radiographs.

According to an opinion in this regard, the whole force is delivered to the tooth on which the force is applied because of the stability of the skeletal anchorage unit during distalization with skeletal anchorage methods. However, the pressure caused by the force on the tooth is reduced by the potential anchorage losses (mesial movement of premolars and anterior teeth) in intra-oral or other tissue-supported distalization methods. This, in turn, results in greater tipping of the molars in skeletal anchorage methods (Fudalej & Antoszewska, 2011).

It has been reported that when distalization forces pass under the center of resistance for upper first molars, this causes a distal crown tipping (Armstrong, 1971; Barton, 1972; Jacobson, 1979; Melsen, 1978; Nanda & Goldin, 1980). Although even when forces pass horizontally through the center of resistance, it is stated that distalization without some tipping is unavoidable (Armstrong, 1971; Greenspan, 1970). The ideal placement and configuration of the miniplates in our study group, together with the horizontal force application perpendicular to the roots, made it possible to distalize in a more controlled manner. Since first premolars were bonded and involved in our design unit, it was expected to get some more tipping in these teeth, compared with non-bonded second premolars that had free distal drifting. Another important element is that the distalization force comes with a balancing moment as part of the force laws, in our case applying a forward and counter-clockwise force on the arch wire leading to some mesial tipping movement in premolars.

A common thought for second molars in this regard is; as the archwire at the posterior level is not affected by this above-mentioned moment, involved teeth not being supported at the distal end on the archwire might exhibit a greater tendency to distal tipping. However, our results show a significant mean distalization amount for second molars (Right: 4,57 ±1,28 mm, Left: 4,73±1,49 mm) at $p<0.05$, yet no significant unwanted rotational changes in either reference plane (Table 8 and 10).

Studies on conventional intra-oral distalization methods have shown up to 22° of distal tipping in molars and up to 9.47° and 6.3° mesial tipping and protrusion in premolars and incisors (Bolla et al., 2002; Bondemark & Kurol, 1992; Bussick & McNamara, 2000; Byloff & Darendeliler, 1997; Erverdi et al., 1997; Fortini et al., 2004; Ghosh & Nanda, 1996a; Gulati et al., 1998; Itoh, 1991; Keles & Sayinsu, 2000; Muse et al., 1993; Pieringer et al., 1997; Runge, Martin, & Bukai, 1999). These methods are known to cause significant amounts of anchorage loss in molars and premolars, resulting in more tipping than actual distalization in molars.

Evaluating implant-supported intra-oral distalization systems; up to 9.05° distal tipping in molars and 3.15° and 1.08° proclination in premolars and incisors have been reported for modified transpalatal arches (Gelgör et al., 2004; Gelgör et al., 2007). For pendulum appliances distal tipping up to 14.4 ° in molars, 16.3° in premolars and 2.50° in incisors have been observed (Escobar et al., 2007; Kircelli et al., 2006; Önçağ et al., 2007). In mini-screw supported buccal segment distalization studies; distal tipping and retroclination up to 2.06° in second molars, 0.31° in first molars, 0.06° in first premolars and 3.13° in anterior teeth have been reported (H.-S. Park et al., 2005). Based on these study results, it can be stated that friction-oriented sliding mechanics combined with mini-screws for buccal segment distalization, result in a more controlled distalization without significant tipping.

It should be underlined that a distalization with crown tipping can have less resistance to the movement, resulting in less treatment time, but can also be heading for greater anchorage requirements during the subsequent phase of fixed appliances therapy and major risk of relapse.

The distal movements of the posterior teeth and the backward movements of the anterior teeth that were observed in varying amounts can contribute to the correction of anterior crowding; therefore, this is likely to shorten the treatment with fixed orthodontic appliances, the second stage of treatment (Table-3, 4, 5). Cornelis et al. (Cornelis & De Clerck, 2007) reported that simultaneous distal movement of the maxillary canines and reduction of anterior crowding and overjet occurred in patients who had no contact between the maxillary and mandibular incisors. However, in patients with tight interdigitation or occlusal interference with the mandibular teeth, spontaneous drift appeared more restricted.

A meta-analysis revealed that a spontaneous distal movement of the premolars with no incisor protrusion could only be observed using direct skeletal anchorage because of stretching of the interseptal fibers (da Costa Grec et al., 2013). Conversely, both the conventional intraoral distalization appliances and the indirect skeletal anchorage appliances showed significant amounts of anchorage loss characterized by mesialization of the premolars, protrusion of the incisors, and increased overjet. In Kilkis et al. (Kilkis et al., 2016), the maxillary premolars moved distally (1.63 ± 1.90 mm) with tipping of 4.05° ± 3.47° , and the maxillary incisors were retroclined (1.59° ±1.45°) resulting a decrease in overjet (-0.29 ± 0.62 mm). Retrusion of the maxillary incisors (-0.60 mm) and decrease of overjet (-0.50 mm) were also reported by Nur et al. (Nur et al., 2011) for the ZGA when used for bilateral maxillary molar distalization. No anchorage loss was found by Kaya et al. (Kaya et al., 2009; Kaya et al., 2012) who used zygoma anchors for the distalization of maxillary buccal segments.

Vertical changes in upper maxillary teeth were evaluated for each tooth according to the occlusal plane, as seen in table 3,4 and 5. Kaya et al. (Kaya et al., 2009) reported some intrusion in molars, differing from our results showing some extrusion instead. Extrusion in anterior teeth can be explained as a geometric result of the retroclination movement.

Numerous studies have reported that cervical headgear application results in extrusion in upper first molars (Armstrong, 1971; Cangialosi et al., 1988; Hubbard et al., 1994; Kim & Muhl, 2001; Melsen, 1978; O'Reilly, Nanda, & Close, 1993; Ülger et al., 2006). There are also other studies claiming the opposite, that cervical headgears do not cause extrusion in molars (Baumrind et al., 1983; Cook, Sellke, & BeGole, 1994).

Studies on conventional intra-oral methods report intrusion in molars (Bussick & McNamara, 2000; Byloff & Darendeliler, 1997; Ghosh & Nanda, 1996a; Pieringer et al., 1997). Others on the contrary, claim extrusion in molars (Gulati et al., 1998; Haydar & Üner, 2000). Extrusion was observed in premolars as they were incorporated in the anchorage unit (Bussick & McNamara, 2000; Ghosh & Nanda, 1996a; Keles & Sayinsu, 2000).

As for the implant-supported intra-oral distalization systems, no vertical changes were noticed for molars and premolars in the pendulum appliance, about 1 mm of extrusion was seen in anterior teeth (Escobar et al., 2007; Kircelli et al., 2006). No significant vertical changes in teeth were observed in mini-screw supported buccal segment distalization studies (H.-S. Park et al., 2005).

Significant amounts of transversal rotations have been detected for only first molars in the sagittal plane (Table-8), and for both first molars and second premolars in the coronal plane (Table-10). Significant increase of maxillary inter-canine and inter-molar distance has also been registered (Table-12).

Only a couple authors have investigated the rotational changes of all teeth over the maxillary arch during distalization besides our study and Duran et al. (Duran et al., 2016). They report to have measured 3D rotations in degrees; we have equivalent measurements in mm.

The rotational changes in first premolars can be connected to the configuration design involving bonded premolars, however results were not found to be significant in our sample. On the contrary, rotations in second premolars were found to be significant in the coronal plane (Table-10) that could be linked to the free distal drifting. Molars consisting of three roots resist distalization more and undergo a disto-buccal rotation around the palatal root; explaining the disto-buccal rotation of molars. The movements of the second molars after distalization are also based on factors such as morphology, locations, and spongious bone (G. S. Kinzinger et al., 2009).

The higher the distalization amount, the more the resistance there will be forcing teeth into tipping and rotation. The force vector being applied towards the posterior from the buccal can explain the increase in maxillary arch width.

The increases in inter-canine and inter-molar widths can partially be explained because these teeth were moved along the alveolar ridge; this tends to widen to the distal. However, the line of force from the skeletal anchorage units is oriented buccally and therefore is also responsible for part of the expansion observed. With the distalization force from the anchor unit directly pushing the buccal tube of the molar distally, mesio-buccal molar rotation is easily corrected, perhaps because the second premolars were not bonded and a light archwire was used.

Studies on cervical headgears report significant increase in the inter-canine and inter-molar width (Kirjavainen, Kirjavainen, & Haavikko, 1997). Conventional intra-oral distalization systems show significant numbers of disto-buccal rotation in molars (Erverdi et al., 1997; Gulati et al., 1998; Itoh, 1991). Implant-supported intra-oral distalization studies state arch width increase at the molar area in pendulum appliances, while no changes in mini-screw supported buccal segment distalization systems (Kircelli et al., 2006; H.-S. Park et al., 2005). Molar disto-buccal rotation on the other hand, was not seen in implant-supported modified transpalatal arch applications, but registered in implant-supported pendulum systems (Gelgör et al., 2004; Gelgör et al., 2007; Kircelli et al., 2006).

The change in overjet was significant by 0.92 ±0.80 at $p<0.05$ level, this finding coincides with results of similar studies (Cornelis & De Clerck, 2007; Kaya et al., 2009). As molars and premolars distalized, some crowing in the anterior was resolved in many patients. Based on retrusion in anterior teeth, the overjet had a following decrease.

In studies where extra-oral appliances used alone or combined with an intra-oral appliance, a decrease in overjet by 2 mm was obtained (Battagel & Ryan, 1998; Caldwell et al., 1984; Odom, 1983; Orton, Battagel, Ferguson, & Ferman, 1996; Ricketts, 1960). Some cervical headgear studies report up to 4.9 mm of decrease in overjet (Kim & Muhl, 2001; Ülger et al., 2006). Significant anchorage loss in anterior teeth thus protrusion, seen in many conventional intra-oral distalization studies, show a significant increase in overjet (Bondemark & Kurol, 1992; Byloff et al., 1997; Ghosh & Nanda, 1996a; Haydar & Üner, 2000; Itoh, 1991; Runge et al., 1999). No significant changes in overjet values were seen in implant supported distalization methods (Gelgör et al., 2004; Gelgör et al., 2007; Karaman et al., 2002; Kircelli et al., 2006).

No significant changes in overbite were found (Table-11), in agreement with the zygoma group in Kaya et al. (Kaya et al., 2009). Cornelis et al. (Cornelis & De Clerck, 2007) reported a slight reduction in overbite.

Kim and Muhl (Kim & Muhl, 2001) have reported significant decrease in overbite post application of cervical headgear, Ülger et al. (Ülger et al., 2006) on the other hand, have registered no change in overbite. Conventional intra-oral distalization studies have indicated a significant decrease in overbite (Byloff & Darendeliler, 1997; Erverdi et al., 1997; Ghosh & Nanda, 1996a). In implant-supported intra-oral distalization studies, no significant changes in overbite were noticed (Gelgör et al., 2004; Gelgör et al., 2007; Haydar & Üner, 2000; Kircelli et al., 2006).

Changes in mandibular teeth were also evaluated according to the same reference planes used for maxillary teeth (Table-6, 7). No significant changes were found in either of the mandibular measurements, agreeing with findings for mandibular teeth in implant-supported intra-oral distalization systems (Gelgör et al., 2004; Gelgör et al., 2007; Önçağ et al., 2007) and similar miniplate studies (Cornelis & De Clerck, 2007; Kaya et al., 2009).

Evaluating the soft-tissue measurements, no significant changes were observed in the nasio-labial angle or in lip positions (Table-16). Although changes in the nasio-labial angle could be expected post distalization, soft-tissue points as the nasal tip and soft-tissue pogonion easily affect such angles.

In cervical headgear studies, significant retrusion in upper and lower lip together with increase in the nasio-labial and labio-mental angles, hence straightening in the lower facial soft-tissue profile has been reported (Hubbard et al., 1994). A great number of studies on implant-supported intra-oral distalization systems show no significant changes in the lips (Gelgör et al., 2004; Gelgör et al., 2007; Kircelli et al., 2006; Önçağ et al., 2007). In mini-screw supported buccal segment distalization results reveal 2.04 mm retrusion in upper lips, 0.86 mm retrusion in lower lips (H.-S. Park et al., 2005).

Cozzani et al. (Cozzani et al., 2016) compared dento-alveolar maxillary measurements post distalization traced by the CBS (cranial base superimposition) to MS (maxillary superimposition), aiming to eliminate measurement bias. No significant differences in vertical and angular measurements were detected. Only a slight difference in horizontal movements relative to the molar and premolar was noted, so that CBS could underestimate the amount of molar distalization and overestimate the premolar anchorage loss, but these changes were not clinically significant. In our study this could have an implication on the cephalometric tipping measurements only, that values might be slightly overestimated than the actual tipping occurred.

When all parameters evaluated, significant dento-alveolar advantages were gained with the zygomatic anchorage. The results are similar to those obtained by cervical headgears and superior in some aspects; offering an easier application and use, being more comfortable and esthetic for the patient.

The zygomatic anchorage system involving a minor surgical procedure, requiring a multi-disciplinary approach, thus being a bit complicated treatment can be considered as a disadvantage. However, this minor surgery does not cause any severe trauma or edema other than a mild swelling 4-5 days post operatively. On the other hand, it has superior advantages to buccal segment distalization systems that last long, or headgears that impair esthetics and life quality for the patient. They have therefore easier acceptance rates by patients in general (Cornelis et al., 2008).

Statistical and clinical results obtained from this study group, show beneficial features of the zygomatic anchorage in particular for buccal segment distalization where indicated, especially suitable for post peak or adult patients who can maintain good oral hygiene. The zygomatic anchorage can also serve as a valid alternative to use of extra-oral distalization appliances.

9. CONCLUSIONS

In our study group where we aimed to evaluate the skeletal, dento-alveolar and soft tissue changes post molar distalization with zygomatic anchorage, obtained significant results are as follows:

- This treatment protocol is an ideal cooperation- independent modality.
- Significant distalization was achieved in all maxillary posterior teeth with skeletal anchorage, correcting a Class II dental relationship into an overcorrected Class I relationship.
- Mild level of distal tipping was registered in molars and first premolars.
- Significant rotational changes were observed in maxillary molars and second premolars.
- Maxillary anterior teeth were retruded causing a decrease in overjet.
- The A point slightly retruded post distalization.
- The occlusal, palatal and mandibular plane showed no significant changes post operatively.
- None of the soft-tissue changes were found to be significant.
- Pre-study aim being to evaluate molar distalization with zygomatic anchorage, has been achieved proving significant results.

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Sağlık Bilimleri Enstitüsü
Etik Kurulu

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PROJE YÜRÜTÜCÜSÜ: Prof.Dr. Nejat ERVERDİ
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Prof. Dr. Göksel ŞENER
Komisyon Başkanı

Yrd.Doç.Dr. Pınar MEGA TİBER

Prof. Dr. Serap AKYÜZ

Prof. Dr. Hülya AŞÇI

Prof. Dr. Ufuk YURDALAN

Prof. Dr. Dilşad SAVE

Doç. Dr. Nefise BAHÇECİK

Doç. Dr. Tolga GÜVEN

Doç. Dr. Hakkı ARIKAN

Yrd. Doç.Dr. Ümit UĞURLU

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11. Biography:

Personal Information:

Name:	Nor	**Surname:**	Shahab
Birth place:	Iraq	**Birthdate:**	16/12/1982
Citizen:	Norway	**ID Card number:**	TCKN:99601346402
Email:	nor.shahab7@gmail.com	**Contact number:**	+9053739187 +4740865908

Education Level:

	Institution	**Graduation Year**
Postgrad. Orthodontics	Marmara University, Turkey	2013-2017
Fellowship in AEGD	UCLA, USA	2011
License, Masters	University of Oslo (Norway)	2003-2008
High School	Skien VGS School, Skien, Norway	2003

Work Experience:

	Institution	**Year**
General Practitioner	Tannhelsetjenesten i Akershus, Norway	2008-2011
Clinic Coordinator	Ås Tannklinikk, Norway	2009-2010

Language Competency:

Foreign Languages	**Comprehension**	**Speaking**	**Writing**
English	Excellent	Excellent	Excellent
Turkish	Excellent	Excellent	Excellent
Norwegian	Excellent	Excellent	Excellent
Arabic	Intermediate	Intermediate	Intermediate

* Evaluated as Excellent, Well, Intermediate, Invalid

Foreign Language Competency								
KPDS	ÜDS	IELTS	TOEFL IBT	TOEFL PBT	TOEFL CBT	FCE	CAE	CPE

*it is to be written all the successful examinations

KPDS: Kamu Personeli Yabancı Dil Sınavı; **ÜDS:** Interuniversity Board Foreign Language Examination ; **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.

Computer Knowledge:

Program	**Ability to use**
Microsoft Office	Excellent

*Evaluate as Excellent, Well, Intermediate, Invalid

Memberberships:

Turkish Orthodontic Society	American Orthodontic Association
European Orthodontic Society	World Orthodontic Association