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ASSESMENT OF CHANGES IN OCCLUSAL CONTACT AREAS AFTER ORTHODONTIC TREATMENT IN PATIENTS WITH DIFFERENT VERTICAL GROWTH PATTERN

DOCTOR OF PHILOSOPHY THESIS

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DECLARATION

I hereby declare that this thesis is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person nor material which has been accepted for the award of any other degree except where due acknowledgment has been made in the text.

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LIST OF ABBREVIATIONS AND SYMBOLS

2D	: two-dimensional
3D	: three-dimensional
ANS	: anterior nasal spine
EMG	: electromyography
Gn	: gnathion
Go	: gonion
Me	: menton
MVGF	: maximum voluntary bite force
N	: nasion
PAR	: peer assessment rating
S	: sella
TMJ	: temporomandibular joint

ABSTRACT

Doğan, HB. (2022). Prospective Evaluation of Changes in Occlusal Contact Areas After Orthodontic Treatment in Patients with Different Vertical Growth Pattern. Yeditepe University, Institute of Health Science, Department of Orthodontics, PhD Thesis, İstanbul.

The aim of this prospective study was to investigate the changes in posterior occlusal contact areas during the 1-year retention period in individuals with different vertical growth patterns. Within the scope of this study, 30 low angle and 30 high angle patients who received fixed orthodontic treatment without tooth extraction at Yeditepe University Faculty of Dentistry, Department of Orthodontics were enrolled in the study groups. The control group consisted of 30 individuals with normal growth pattern who did not receive orthodontic treatment. All the patients had maxillary and mandibular canine to canine bonded lingual retainers. After the treatment (T1), 6 months later (T2) and at the end of the 1-year retention period (T3), all patients were scanned with a three-dimensional intraoral laser scanner (Cerec, Omnicam). Occlusal contact areas were measured in mm^2 using image analysis software (ImageJ) on digital models. Statistical analysis was performed. A statistically significant difference was observed between the initial mean occlusal contact area of the control, and low and high angle groups ($p<0.001$). The mean occlusal contact area of the control group at T1, T2, T3 was statistically significantly higher than the low angle and high angle groups ($p<0.001$). No statistically significant difference was observed between the mean occlusal contact area of the low angle and high angle groups at the time of T1 ($p>0.05$) whereas mean occlusal contact area of the low angle group was statistically significantly higher than the high angle group at T2 and T3 ($p<0.001$). The changes in the occlusal contact areas were significantly higher in low angle group compared to high angle group from T1 to T2 ($p<0.001$), with significantly greater changes in the first 6 months compared to the second 6 months of the retention period in both groups ($p<0.001$). As a conclusion, a significant occlusal settling occurred in the first year after orthodontic treatment but it differed between high and low angle patients. Low angle patients exhibited greater occlusal contact areas at each period and the increase in contact areas was higher compared to the high angle patients in the first 6 months.

Keywords: Occlusal Contact Area, Occlusal settling, Growth Pattern, Retention, Stability

ÖZET

Doğan, HB. (2022). Farklı Vertikal Yüz Tiplerine Sahip Hastalarda Ortodontik Tedavi Sonrasındaki Oklüzal Temas Yüzeylerinin Değişimlerinin Prospektif İncelenmesi. Yeditepe Üniversitesi, Sağlık Bilimleri Enstitüsü, Ortodonti ABD., Doktora Tezi, İstanbul.

Bu prospektif çalışmanın amacı farklı vertikal büyüme paterni olan bireylerde 1 yıllık retansiyon döneminde posterior oklüzal temas alanlarındaki değişiklikleri araştırmaktır. Çalışma gruplarını, Yeditepe Üniversitesi Diş hekimliği Fakültesi Ortodonti Anabilim Dalı'nda çekimsiz sabit ortodontik tedavi görmüş 30 brakifasiyal, 30 dolikofasiyal hasta oluşturmuştur. Kontrol grubu ise ortodontik tedavi görmemiş, normal dik yöne sahip 30 bireyden oluşturulmuştur. Tüm hastalara tedavi sonrası alt ve üst çenede kanin-kanin arası sabit pekiştirme apareyi uygulanmıştırr. Tedavi sonrası (T1), 6 ay (T2) ve 1 senelik retansiyon periyodu sonunda (T3) tüm hastaların alt ve üst dental taramaları ve kapanış kayıtları üç boyutlu ağıziçi lazer tarayıcı (Cerec, Omnicam) ile alınmıştır. Oklüzal temas alanları, dijital modeller üzerinde görüntü analiz yazılımı (ImageJ) kullanılarak mm^2 cinsinden ölçülmüştür. İstatistiksel analizler sonucunda, kontrol grubu ile brakifasiyal ve dolikofasiyal gruplar arasında başlangıç ortalama oklüzal temas alanı açısından istatistiksel olarak anlamlı bir fark gözlenmiştir ($p<0.001$). T1,T2 ve T3'te kontrol grubunun ortalama oklüzal temas alanı, brakifasiyal ve dolikofasiyal gruplara göre istatistiksel olarak anlamlı derecede yüksek bulunmuştur ($p<0.001$). T1'de brakifasiyal ve dolikofasiyal gruplarının ortalama oklüzal temas alanları arasında istatistiksel olarak anlamlı bir fark gözlenmezken ($p>0.05$), T2 ve T3'te brakifasiyal grubunun ortalama oklüzal temas alanı, dolikofasiyal grubuna göre istatistiksel olarak anlamlı derecede yüksekti ($p<0.001$). T1-T2 döneminde oklüzal temas alanlarındaki değişim brakifasiyal grupta dolikofasiyal gruba göre anlamlı derecede daha fazlaydı ($p<0.001$) ve her iki grupta da retansiyon döneminin ilk 6 ayındaki değişiklikler ikinci 6 aya kıyasla önemli ölçüde daha fazlaydı ($p<0.001$). Sonuç olarak, ortodontik tedaviyi takiben ilk bir yıl içinde posterior oklüzal temaslarda belirgin bir artış meydana gelmiştir ancak bu brakifasiyal ve dolikofasiyal hastalar arasında farklılık göstermiştir. Brakifasiyal hastaların her dönemdeki oklüzal temas alanları ve ilk 6 aydaki oklüzal temas alanlarındaki artış dolikofasiyal hastalara göre yüksek bulunmuştur.

Anahtar Kelimeler: Oklüzal kontak alanı, Okluzal Yerleşim, Büyüme Paterni, Retansiyon, Stabilite.

1. INTRODUCTION AND PURPOSE

Various occlusal changes occur after the active phase of orthodontic treatment as shown by long term studies (1,2). These changes sometimes lead to undesirable situations and can sometimes be beneficial. Undesirable changes can be considered as relapse, or may be useful and desirable, such as improved interdigitation of the teeth (3).

The British Standards Institute defined relapse as the return of original malocclusion characteristics following orthodontic correction (4). For prevention of relapse, the retention phase after the end of orthodontic treatment is essential to ensure the rearrangement of periodontal fibers, to minimize changes in dental position due to growth, and to provide neuromuscular adaptation to the new occlusal condition (5). After end of the active phase of orthodontic treatment, retention appliances are used to retain aligning of teeth and arch dimensions. It is also expected to allow a better tubercle-fossa relationship by allowing physiological movements of the teeth after treatment.[3] Settling, which can be defined as improving the occlusal relationship more suitable for posterior teeth, is the natural horizontal and vertical movement of the teeth towards functionally stable interocclusal contacts following orthodontic treatment (6).

Occlusion stability affects stomatognathic system health and may prevent relapse after active treatment (7,8). Many studies have found that the number of occlusal contacts increases during the retention period (9). It has been reported that balanced occlusal contact areas could be obtained during and after retention mainly due to the settling of the molars that had been discluded by the active orthodontic treatment (9). The settling of occlusion may continue approximately two years after orthodontic treatment (10). The choice of retention appliances may also affect the occlusal settling (9,11–13). In the literature, a variety of retention appliances have been used, but there is no definite judgment about their effects on settling, and which appliance is more successful is still controversial (3,13–15). In general, it was reported that retention appliances such as Hawley plate or fixed lingual retainers, which allows vertical movement posteriorly, provide better settling whereas Essix retainers do not gives permission for relative vertical movement of the posterior teeth since they cover the occlusal surfaces (12,15,16). A recent study showed an increase in number of occlusal contacts and maximum voluntary bite forces during retention period, with lower occlusal settling with Essix retainers on both jaws compared to maxillary Essix and mandibular fixed retainer combination, or wrap around retainers. In addition, the increase in biting forces does not coincide with the increase in occlusal contacts; instead, forces grow more slowly. (17). On the other hand, bonded retainers as noncompliance retention appliances only attached to anterior teeth, allow a significant increase in terms of occlusal force distribution in the posterior dental arch. Moreover, posterior occlusal changes occur faster with bonded retainers compared to vacuum formed and Hawley retainers (18).

Normal facial growth is a process that occurs due to the close morphogenetic relationship between growing, changing and functioning facial soft and hard tissue units. It is known that no part can grow as a single, independent unit. Regional imbalances are compensated by neighboring structures in order to achieve balance in the whole craniofacial structure. Depending on the degree to which this compensation occurs, different growth patterns may occur (14). In the literature, it is widely accepted that the morphology of bone structures and size and activities of facial muscles are related. In a study conducted in 1870, there was an accepted hypothesis in the field of biodynamics. In this study, it was argued that the size and activity of skeletal muscles are effective on the morphology of bone structures in the regions of origin and attachment (19). A similar mechanism is thought to direct the relationship between the activity of the masticatory muscles and the development of the craniofacial structures (20,21). It is known that if the size and activities of the muscles in the craniofacial structure are less than normal, the vertical dimensions of the face will be affected by these adverse conditions. It has been informed that muscle size and activity decrease in individuals with diseases such as congenital atrophy of the jaw muscles or myotonic dystrophy, and the vertical development of the face is markedly increased. It is an important indicator that the development of the vertical direction of the face will be affected in case of any disruption of the muscular balance (22–24). Researchers argued that masseter muscle was the most effective on facial morphology (25–27). In addition, temporal, digastric, lateral pterygoid, medial pterygoid muscles which have different activities and dimensions, are effective on facial morphology (28–30). Therefore, the relationship between the vertical structure of the face and chewing function has been a subject of debate for many years. Hyperdivergent structure was generally associated with low muscle activity and decreased muscle strength (31–34,35,36).

There may also be an indirect relationship between craniofacial dimensions and occlusal contact areas. There is a relationship between occlusal contact areas and bite force which can be summarized as greater the bite force, greater the occlusal contacts

(37). Furthermore, it has been reported that the bite force may be affected by the craniofacial morphology since, as mentioned earlier, the masticatory muscles of dolicofacial subjects are less efficient in generating bite force (38). Adults with increased mandibular plane angle were found to be at risk of having low bite force (39). Lower masticatory muscle activity has been linked to a smaller occlusal contact area, implying an indirect link between vertical growth pattern and occlusal contact area (40). From this perspective, the settling by an increase in occlusal contact areas after orthodontic treatment may also vary in patients with different craniofacial morphology and masticatory function. No study has evaluated the relationship between settling and vertical growth pattern, as far as we are aware.

Therefore, the aim of our study was to investigate the changes in posterior occlusal contact areas during retention period in individuals with different vertical growth pattern. The null hypothesis was that there was no difference between the changes in occlusal contact area of low angle and high angle patients after orthodontic treatment.

2. LITERATURE REVIEW

2.1. Orthodontic Treatment and Occlusion

The purpose of orthodontic treatment is to provide not only aesthetics but also good occlusal function. Orthodontists should make an effort to achieve charmful, healthy, stable and functionally effective occlusion (41).

There is a cause-and-effect relationship between the function, health and even dentition stability and the quality of the posterior occlusion. It has been shown that masticatory efficiency is affected by many occlusal characteristics, involving the size of the occlusal contacts, the number of occlusal contacts, the surface area of the posterior teeth, and the Angle classification of the dentition (42,43). Orthodontic treatment can make a significant contribution to the treatment of periodontal disease (44–46). Some researchers also have suggested that the guided eruption of permanent dentition and coordinated facial growth are supported by the intercuspal relationship (47). Ostyn et al. (48) concluded that interdigitation is an important factor in the control of anteroposterior and vertical facial development and in jaw relationships. As a result, it was proposed that orthodontic treatment should be finished with good occlusal contacts and intercuspation for a stable orthodontic outcome (49–52).

Maintaining the occlusal stability at the end of the active treatment is one of the most important challenges in the field of orthodontics (53). The teeth which changed their position by the application of force with orthodontic treatment tend to return to their original position after treatment. Therefore, retention is required to maintain the results obtained at the end of treatment. It is not a realistic approach to keep the entire dentition stable and to prevent relapse completely with the necessity of meeting the aesthetic expectations of the patients. Better interdigitation after treatment can be achieved by vertical displacement of the teeth. The relative vertical movements of the posterior teeth after orthodontic treatment are known as settling (54). The different removable and fixed retainers used for retention retain the tooth after orthodontic treatment. They may also affect the occlusion positively or negatively.

2.2. Vertical Growth Pattern and Etiology

Vertical anomalies of the face are common skeletal problems in the craniofacial region. These anomalies may occur due to different etiologic factors during the growth period. These factors can be listed as the growth direction of condyle, growth differences of jaws, growth differences in dentoalveolar structures and environmental factors (55,56).

2.2.1. Growth Direction of Condyle

The mandibular condyle grows upward, forward and backward depending on the direction of growth of the individual (57–59). Upward and forward overgrowth of the condyle leads to more horizontal movement of the mandible. Anterior facial height decreases and malocclusion is often associated with deep bite. Maxillary and mandibular teeth move mesialy and mandibular incisors tilt forward. This can result in crowding. If the condyle grows more in the posterior direction, mandible moves more in the vertical direction, lower face height increases and high angle growth pattern occurs. When the effect of growth pattern on teeth is observed, posterior teeth are extruded in the vertical direction and anterior teeth are inclined in the lingual direction.

The vertical growth pattern is related to the development of anterior and posterior facial heights as well as the direction of growth of the condyle. These facial height differences cause mandibular rotation and positional changes that affect the chin. Posterior height development is closely related to the vertical growth of the temporomandibular fossa and condyles. If the vertical condylar growth exceeds the dentoalveolar growth, the mandible rotates forward, if the dentoalveolar growth exceeds the vertical condylar growth, the mandible rotates backward (60).

Anterior facial height shows a more complex structure. Skeletal factor such as downward movement of the maxilla due to sutural activities, eruption of maxillary and mandibular teeth and soft tissues are also effective in the development of anterior facial height (61)

Isaacson et al. (62) stated that the growth direction of the face is in the direction of the junction of the horizontal and vertical growth vectors relative to the cranium. The regions with the greatest amount of facial growth are; mandibular condyle, maxillary alveolar processes and facial sutures. Mandibular rotation will not occur if the condylar vertical growth is equal to the maxillary sutural-alveolar growth, this balanced vertical growth will result in translation of the mandible. If the condylar vertical growth is greater than the maxillary sutural-alveolar growth, the mandible will rotate (counterclockwise) forward and upward, whereas in the contrary, if the sutural-alveolar growth is excessive, the mandible will rotate downward and backwards (clockwise).

2.2.2. Dentoalveolar Structures and Vertical Growth Pattern

Alveolar structures have a compensatory role in establishing the sagittal and vertical relationship between the jaws (63,64). Vertical direction differences between dentoalveolar morphology and skeletal structure may cause deep bite and open bite.[65] Excessive vertical facial development is closely related to the vertical development of the posterior dentoalveolar region (58,62,66) One of the most common symptoms of high angle growth pattern is increased posterior dentoalveolar height (66,67)

Moreover, some studies (68–70) have shown an increase in maxillary anterior dentoalveolar dimensions in hyperdivergent subjects, but no difference has been found in other studies. Nahoum et al. (70) stated that the development of maxillary dentoalveolar structures was not inadequate at open bite, while Sassouni and Nanda (71), and Subtelny and Sakuda (72) stated that there was excessive development in maxillary dentoalveolar structures.

Another factor related to open bite is the excessive eruption of mandibular molar teeth. However, while Subtelny and Sakuda (72) did not find any differences between the open bite and control groups, the researchers Sassouni and Nanda and Nahoum et al. (70,71) found that there was a reduction in the distance that existed between the mandibular plane and the mandibular molars.

Kuitert et al. (73) stated that the factor determining overbite was lower facial height in long-faced individuals and mandibular dentoalveolar structures in short-faced individuals.

2.2.3. The Relationship Between Vertical Growth Pattern and Dental Eruption

The growth of the mandible occurs by moving away from the maxilla and creating space for tooth eruption. The eruption direction of the maxillary teeth is downward and forward. In the normal growth pattern, the maxilla rotates slightly forward and partially backward. Forward rotation causes the anterior incisors to procline and increase the overjet (74).

In the mandible, the eruption direction of the teeth is upward and forward. The forward rotation of the mandible affects the position of the incisors and allows them to be positioned behind. Internal rotation makes the anterior incisors in an upright position. The molars become more mesialized and this migration reduces the arc length (74).

This relationship between maxillomandibular rotations and teeth affects both the vertical and anteroposterior position of the incisors in short and long-faced individuals (75). In short-faced individuals, the upright position of the incisors and lingual inclination cause crowding, while overbite increases. In long-faced individuals, the incisors are overproclined and open bite or bimaxillary protrusion may occur (74).

2.2.4. Environmental Factors and Vertical Growth Pattern

The structure of the face is affected by genetic factors as well as soft tissues and posture (76). The shape and volume of facial bones during the growth process are determined by resorption and remodeling processes on periosteal and endosteal bone surfaces, sutures and cartilages. Bone-associated soft tissues and functional requirements had significant effects on remodeling (14,77).

The vertical growth pattern is determined by the balance between tongue, lips, cheeks and teeth. This balance in the biological system is closely related to the duration of the force rather than the amount of force (78). During ingestion, the masticatory muscles produce heavy, but intermittent forces. Occlusal forces provide continuity of the vertical balance (79).

Parafunctional habits such as clenching, grinding, hyperactivity of masticatory muscles have a potential impact on vertical balance. These factors cause insufficient eruption of the posterior teeth, so the vertical development of posterior maxillary and mandibular alveolar processes decreases and anterior overbite increases (58).

It is known that individuals with brachyfacial structure have high bite force and dolichofacial ones have weak bite force (31,80). In dolichofacial individuals, the bite force is reduced, resulting in greater eruption of the posterior teeth and consequently rotating the mandible backwards (31,81).

Weijs and Hillen (29) and van Spronsen et al. (82) argued that temporal and masseter muscles have a positive relationship with facial width, jaw muscles affect the facial growth and determine adult facial dimensions.

Based on the principle that non-antagonist teeth continue to erupt until contact is achieved, Lowe (83) states that if the tongue is positioned in front, the teeth do not have complete eruption and consequently open bite develops. Fields et al. (84) reported that nasal airway capacity and respiratory type also affect vertical dentofacial morphology.

Proffit and Fields (31) stated that there are effects of discrete forces on the speed of eruption during swallowing and speech activities, but that the resting pressures and positions of the tongue and lips are effective in the development of malocclusion, rather than the pressure of muscular structures during swallowing and speech.

Mouth breathing due to nasal obstruction causes the posterior teeth to overeruption and increase the lower face height because the mouth remains open. A minimal increase in eruption of the posterior teeth has a large effect on the anterior vertical dimension (85).

Differences in the mandibular rest position are effective in vertical facial growth. Enlarged adenoid and tonsils, septum deviation, large concha and allergic problems are common in high angle cases. These factors influence the posture of the mandible, causing more of the posterior teeth to erupt as a result. After patients' adenoids and tonsils removed, Woodside et al. (86) observed a decrease in the patient's anterior face height as well as the angle of the mandibular plane.

2.2.5. Classification of Vertical Malocclusion

Determining the face type is very important for orthodontic planning and diagnosis. Because the muscle and skeletal form of each face type creates different results in orthodontic treatment and affects the treatment results positively or negatively (87).

Vertical malocclusions have been named by different researchers as follows considering the most important clinical indicators and possible etiological factors:

- Hyperdivergent, normodivergent, hypodivergent
- Brachyfacial, mesofacial, dolichofacial (88)
- Long, normal and short face type (89)
- Anterior and posterior rotation pattern (90)
- Skeletal open bite and deep bite (91)

In the orthodontic literature, Schudy (92) has defined the terms hyperdivergent and hypodivergent. Schudy used these terms to describe vertical directional changes in facial morphology using the SN-GoGn angle. Cases with an SN-GoGn angle of 28 ° or less are considered hypodivergent and cases with an angle of 36 ° or more are considered hyperdivergent.

Proportion of the face was defined by total face height. Total face height is divided into three equal parts as upper face (Tr-Gl), middle face (Gl-Sn) and lower face (Sn-Gn). The ratio of upper, middle and lower face heights to total face height was found to be 0.30, 0.35 and 0.35 in normal individuals (93). Aesthetically accepted faces generally have in common features that they have balanced face ratios rather than norm values. An ideal face should be divided into three equal parts in the vertical direction by the horizontal lines through the trichion, the base of the nose and the menton.

Siriwat and Jarabak (94) used the face height ratio (Jarabak ratio) to describe changes in facial morphology. This ratio is obtained by dividing the height of the posterior face by the height of the anterior face and accordingly three basic growth models have been identified.

1. Hyperdivergent growth model (face height ratio <59%) with downward and backward rotation of the face
2. Neutral growth model (face height ratio = 59-63%) with downward and forward growth along the Y axis
3. Hypodivergent growth model (face height >63%) is characterized by upward and forward rotation of the face

Another method used to determine the vertical growth pattern is facial analysis on photography. In a study, Martins et al. (87) used facial photographs of individuals to determine vertical growth pattern. Lateral cephalograms and facial photographs were taken from 64 subjects aged between 18 and 38 years. Ricketts' Vert index was used to determine facial types on cephalometry whereas facial index was used on facial photographs. In this study, when comparing the photometric method and cephalometric method used to determine vertical facial type, photometric method was found to be very reliable (87). Another advantage of this method is that it is a less invasive procedure for the patient in the selection of scientific studies samples. In this way, when a study involving data on different facial types is performed, no additional radiation dose is required to determine the face types.

2.3. Masticatory Muscles

Skeletal muscles are embryologically derived from the mesoderm. The formation of muscle tissue is controlled by the connective tissue from which myoblasts migrate during the embryological period. Connective tissue arises from somatic mesoderm in extremity muscles and neural crest in the first branchial arch in cranial muscles (95).

Masticatory function occurs as a result of voluntary contraction and relaxation of the masticatory muscles during speech, resting and swallowing. Muscle contraction is very complex and includes units in the same area but with different functions. Muscles responsible for the movement of the mandible are temporal, masseter, digastric muscles, medial pterygoid and lateral pterygoid muscles. In addition, the mylohyoid and geniohyoid muscles may also be part of mastication (96).

2.3.1. Masticatory Function and Vertical Morphology

Mastication occurs as a result of the coordinated movements of the masticatory muscles, TMJ, tongue, lips, in relation with the teeth, palate and salivary glands. Mastication involves a series of jaw movements to prepare nutrients by grinding in the mouth and ready to swallow. It is an autonomic movement with acquired neuromuscular reflexes.

The function of the chewing is to crush the food by shredding, grinding and preparing it for digestion by mixing with saliva (97).

There are mainly three factors that affect mastication; maximum bite force, occlusal contact area affecting occlusal forces and lateral movements during chewing (98).

In adults, mastication is directly proportional to the contact surfaces of the teeth in the occlusion. This is due to the fact that the amount of disintegration and grinding of the food in the chewing cycle is directly related to the contact points or surfaces of the teeth in the occlusion (99). In a study by English et al. (98) it was reported that patients with Class III malocclusion had the greatest difficulty in chewing compared to subjects with normal occlusion. This was followed by patients with Class II malocclusion, and lastly, mastication of patients with Class I malocclusion were reported to be closest to the that of individuals with normal occlusion.

Craniofacial morphology and craniocervical relationship are also affected by chewing and respiratory functions. The masticatory muscles and bite force were reported to affect the transversal and vertical dimensions of the face. Accordingly, there are many studies that demonstrate the relationship between muscle force and craniofacial morphology (81,100). Proffit et al. (81) reported that individuals with vertically increased facial height had lower occlusal forces than normal individuals during maximum biting, chewing and swallowing. In the study of Throckmorton et al. (34), no relationship was found between anteroposterior dental relationships and maximum bite forces of adults.

The maximum bite force differs between male and female adults, with higher force in men (101). The forces generated by the muscles closing the jaw are the main forces used during chewing, and the maximum bite force is not observed during routine chewing. The chewing force applied to a single tooth when chewing hard foods such as carrots and cooked meat was reported to be 70-150 N, while the average chewing force of all teeth in contact was reported to be 190-260 N. The maximum bite force is 500- 700 N on average and it reaches 1200-1500 N in individuals with muscle hypertrophy due to parafunctional activity. In contrast to these forces, the force applied during the jaw opening does not exceed 150 N (48).

In a study by Verulkar (102), the activity and thickness of the masseter, orbicularis, mentalis and temporalis muscles were correlated with cases with different growth patterns (low angle, high angle, normal angle). Ultrasonography and electromyography were used in this study because they are noninvasive, easily accessible, and have no known harmful biological side effects. When the thickness of the masseter muscle was examined, the muscle thickness was found to be less in high angle cases and higher in low angle cases compared to normal angle cases. When the activity of masseter muscle was examined, it was revealed that its activity was greater in low angle cases whereas lesser in high angle cases compared to the normal growers.

In a study with 77 people, the relationship between facial muscles and facial growth pattern was evaluated. Muscle strength measurements were made by electromyography. The sample was divided into 3 groups; horizontal facial pattern group, vertical facial pattern group and normal facial pattern group. The Bjork sum was used to calculate the facial growth pattern. According to the study's findings, the activity of perioral and masticatory muscles may play a role in the direction of facial growth. (103).

Quiudini et al. (104) evaluated the difference between bite force in dolichofacial and brachifacial individuals. 190 patients were used in the study. They classified these patients according to VERT index and face height ratio. The maximum bite force in brachyfacial individuals was found to be greater than in dolichofacial individuals.

2.3.2. Interaction of Skeletal Structures with Mimic Muscles of the Face and Masticatory Muscles

During chewing and grinding, the mastication muscles strongly contract but the duration of the contraction is short. On the other hand, it is known that the chewing muscles are continuously active, even weakly, to maintain the position of the mandible. These weak but continuous muscle forces have a significant impact on the development of craniofacial structures. Temporal and masseter muscles play a main role in the etiology of dental and skeletal irregularities therefore should be taken into consideration when planning the treatment planning and retention (95).

Variations in the vertical dimension of the face reflect the characteristics of the facial structure more than the sagittal direction (105). Reduction in the size and activity of the masticatory muscles and low maximum bite force were determined in individuals with hyperdivergent facial structure (33,34,81). In his study examining the relationship between gonial angle and masticatory muscle force, Ahlgren (106) found that the increase in gonial angle was associated with decreased masseter and temporal muscle activity during mastication. In 1985, the same researcher (107) emphasized that the posterior part of the temporal muscle was the muscle responsible for the shape and position of the mandible that provided the posture of the mandible.

Karlsen (108) investigated the effects of the vertical dimension of the face on the temporal muscle. It was stated that the increase in the vertical dimension occurred due to a decrease in postural activity.

Ueda et al. (32) found a close relationship between the activity of masticatory muscles and vertical craniofacial morphology in adults. Other studies examining this relationship found a negative correlation between the activity of mandibular elevator muscles and vertical dimensions of the face (32).

Uslu et al. (109) Evaluated electromyographic activities of masticatory muscles in individuals with different vertical facial structures. Records were obtained during swallowing, mastication and maximum intercuspation from 31 individuals with skeletal deepbite and open bite. According to the findings of the study, masseter muscle activity increased from open bite to deepbite, while anterior temporal muscle activity showed a significant decrease. During maximum intercuspation, muscle activity values of deepbite cases were higher than that of open bite cases.

The relationship between the size and location of the tongue and craniofacial morphology has also been investigated in the literature. It has been suggested that chewing muscle activity is also affected by tongue position. It was found that superior positioning of the tongue increased anterior temporal muscle activity and did not change masseter muscle activity (110). It was reported that inferior positioning reduces anterior temporal muscle activity. Anterior position of the tongue has been reported to cause an increase in masseter muscle activity. As a result of EMG studies, it was determined that the activities of lip, tongue and masticatory muscles during chewing were concurrent and could affect each other (111).

Depending on the vertical characteristics of the craniofacial system, the orientation of the masticatory muscles is also changing. The masticatory muscles are oblique in dolicofacial individuals and vertically located in brachifacial individuals (112). There are other researchers suggesting that there is a relationship between the orientation of the masticatory muscles and the growth direction of the mandible. For example, Takada et al. (111) reported that the superficial portion of the masseter muscle is generally inclined towards the anterior, and the attachment site of the muscle is located higher in the mandible in individuals with a large gonial angle, increased mandibular plane angle, and short posterior face height.

Not only the location of the masticatory muscles, but also the fibril structure varies according to the vertical morphology of the craniofacial structure. Rowlerson et al. (113) according to the results of their study on masseter muscle fibril type in different facial morphologies, Type 1 fibril (slow contracting) is more common in individuals with open bite and Type II fibril (fast contracting) is more common in individuals with deepbite.

Muscle thickness is another factor affecting craniofacial morphology. The thickness of the masseter muscle was mostly associated with the facial morphology by researchers. Kiliaridis et al. (114) found a negative relationship between masseter muscle thickness and anterior face height. They stated that long-faced individuals had thin and narrow chewing muscles while short-faced individuals had large and thick chewing muscles.

In 1984, Weijs and Hiljen (29) measured the cross-sectional area of the masseter muscles by computed tomography. According to the findings of the study, the masseter muscle was thicker in short-faced individuals with brachicephalic skull structure.

Lione et al. (115) showed that, at rest and function, thickness and cross-sectional area of the masseter muscle were higher in brachifacial individuals compared to the dolicofacial and mesofacial individuals. Ariji et al. (116), in 2000, reported that the masseter muscles of individuals with mandibular prognathism were thinner than those with normal facial morphology.

There are also studies investigating the relationship between temporal, medial pterygoid, lateral pterygoid and digastric muscles and facial morphology(28). Mouth opening forces were associated with craniofacial morphology; it is stated that digastric muscle, which is one of the muscles that open mouth, is stronger and thicker in individuals with long face type than normal face type. The results of the study conducted by Van Sprousen et al. (80) indicated that there was a weak correlation between anterior digastric muscle thickness and craniofacial morphology.

2.3.3. Bite Force and Dental Occlusion

Bite force is the amount of force exerted by the masticatory muscles during dental occlusion. For orthodontic treatment planning and progression, in-depth knowledge and comprehension of masticatory muscles and their relationship to various facial morphologies are indispensable. The occlusal bite force is used to evaluate the functional status of the chewing mechanism (117). Age, sex, periodontium, craniofacial morphology, temporomandibular joint diseases and dental status are factors affecting the bite force (118,119).

Craniofacial morphology and occlusal relationships are important determinants of the bite force. Short-faced individuals show stronger bite force values, whereas long-faced craniofacial morphology is associated with smaller bite force (120). The maximum bite force is found in individuals with normal occlusion. This is followed by Class I, Class II and Class III malocclusion, respectively. It has been reported that children who have unilateral posterior cross-bite have a lower maximum bite force and fewer occlusal contacts than children who have ideal occlusion. This is in comparison to children who have ideal occlusion (121). On the other hand, Sathyanarayana et al. (122) found that vertical morphology affected maximum voluntary bite force whereas the sagittal morphology did not significantly affect it.

The large occlusal table, contact areas and the number of teeth loaded while biting action create more bite force in the posterior arch (123).In addition to the craniofacial morphology, the age is also another factor affecting the bite force. It was shown that bite force decreases with age (124). Weak periodontium causes a decrease in the threshold value of mechanoreceptors and may cause changes in bite force (125).

The relationship between the bite force and orthodontic treatment was also investigated. Changing occlusal relationships during orthodontic treatment, pain and discomfort associated with orthodontic appliances cause a decrease in bite force. Alomari et al. (126) stated that the bite force decreased in the first period of active orthodontic treatment, but that the bite force reached pre-treatment levels in the following period. It was also reported that occlusal bite force improved as a after treatment. Winocur et al. (127) reported that neuromuscular adaptation began a few minutes after the brackets were debonded. In the retention period of 3 months, a second stage of muscular adaptation occurs. These findings showed that muscle adjustments occur immediately after orthodontic treatment. In patients treated with crossbite, regeneration was noted for at least 6 months after treatment to restore and strengthen occlusal functions (128).

Sonnesen et al. (119) analyzed the correlations between craniofacial dimensions, bite force, head posture, and temporomandibular disorder symptoms and signs. The sample includes 96 children. On plaster casts, dental arch widths were measured, and bite forces were measured at the first molars on each side using a pressure transducer. The maximal unilateral bite force of each subject was measured to assess the strength of the mandibular elevator muscles. During 1-2 seconds of maximal clenching, the first mandibular molars on each side were recorded using a pressure transducer. The relationship between muscle tenderness and a long face type of craniofacial morphology and a lower bite force was established.

Garcia et al. (36) investigated the relationship between maximum bite force and masticatory muscle electromyography (EMG) activity in children with vertical growth patterns and craniofacial morphology and mechanical advantage. A unidirectional transducer was placed between the upper and lower right first molars to measure bite force. To protect the teeth, the metal arms of the transducer were wrapped in polypropylene tubing. It is concluded that, regardless of chronological age, children with larger faces have larger moment arms and require less muscle activity to achieve a given force, and that greater hyperdivergence is associated with a lower mechanical advantage and maximum bite force. These findings corroborate the correlations between biting force, muscular strength, and morphology in children, similar to those described for adults.

2.4. Retention Period after Orthodontic Treatment

After fixed orthodontic treatment, the retention phase aims to maintain the teeth in their corrected positions. There is a tendency for the teeth to return to their initial positions, which occurs due to the tension in the periodontal fibers of the teeth, particularly the cervical portions of the teeth (inter-dental and dento-gingival fibers). The compliance and quality of the occlusion at the end of the treatment affects the stability of the orthodontic outcome. Undesirable occlusal contacts cause negative changes in the tooth position.

Minimization of orthodontic relapse can be achieved by a good treatment plan and the achievement of appropriate occlusal and soft tissue treatment goals. In addition, after the debonding of fixed orthodontic appliances, the likelihood of relapse increases if an appropriate retention appliance is not applied. Unfortunately, as orthodontic treatment progresses, patient compliance frequently decreases. In addition, poor compliance with retention appliance during the post-treatment period may undermine the result (129).

In a study in which the retention appliances were not used after orthodontic treatment, significant deterioration in corrected tooth rotations, overjet and lower incisions were found within the first 4 weeks (130).

Even in patients who have not received orthodontic treatment, normal aging can result in undesirable dental migrations. This deterioration in tooth alignment is caused by changes in the pressures of soft tissues, such as the cheeks and tongue, and skeletal structures, such as the mandible and alveolar crest surrounding the teeth. Soft tissue changes and minor ongoing growth, which are part of the aging process, are unpredictable. The use of retainers is not only due to prevent unwanted movements in the teeth after orthodontic treatment, but also to prevent physiological changes that may occur with age by long-term use (131).

In most orthodontic treatments, retainers are an important part of treatment, the retainer to be applied should be included in the planning at the beginning of the treatment.

There is no evidence that the retention protocol to be used in adolescent and adult patients should be different, providing the periodontal supporting tissues are normal. When the post-retention results between adults and adolescents were examined, it was found that they were stable with each other in terms of midline alignment, incisor alignment, molar relationship, overbite and overjet (132,133).

In one study, it was stated that there were some conditions that did not require retention after some orthodontic treatments. For example, retention protocol is not necessary in patients with corrected anterior and posterior cross-bite if the occlusion resulting from the treatment can well protect overbite and posterior interdigitation (134).

Patients should be informed about the retention period at the beginning of the treatment when obtaining informed consent, and should be aware of the need for retention as well as orthodontic limitations. Since relapse is unpredictable, patients should request retention protocol to be applied after orthodontic treatment and treatment should be started if it can. The patient should be informed of the long-term responsibilities during the retention phase and should be taken a written text that the patient accepts these responsibilities (131).

When the occlusion is evaluated, there are few studies examining the relationship between a well-finished treatment and long-term retention, although it is stated that the best and aesthetic occlusal outcome will be beneficial for retention (131,135). Recent studies suggest that good occlusal outcome does not mean that it will be a good retention process. In these studies, it was found that well-treated cases tend to deteriorate and poorly treated cases tend to improve during retention (136,137). Freitas et al. (138) examined the effect of the quality of the finished occlusion on post-retention occlusal stability. They found that in patients with class 1 malocclusion with four premolar extractions, the amount of relapse decreased at the post-retention stage as the quality of occlusion improved after orthodontic treatment.

The retention period after orthodontic treatment should be such as to allow for the reorganization of periodontal fibers, and also to reduce physiological tooth movements due to growth and to provide neuromuscular adaptation to the new occlusal condition (5).

There is no definite conclusion as to how long the retention period will be. Although many books and studies have indicated that the average time for reorganization of periodontal and gingival fibers is 232 days, relapse may occur even during this period (139,140). Therefore, some orthodontists extend the retention time and even prefer a lifetime retention (141). In addition to many undesirable effects, the positive movement of the teeth during the retention helps occlusal settling and provides better chewing function and interdigitation (54). In previous studies, it was found that the increase in occlusal contacts during retention and the preference of retention devices affect occlusal settling. (9,13,141).

The wrap around appliances is advantageous because it allows the occlusal surfaces of the teeth to contact each other; the disadvantage is that the wire can be deformed and disturb the patient. When we look at Essix retainers, it is more easily accepted by the patient because of its aesthetics, affordability and size. But it cannot allow the occlusion to settle because the contact surfaces of the teeth are covered with acrylic (142). Fixed retainers attached to the back surfaces of the front teeth are smaller than removable retainers and are more easily accepted by the patient. Accidental removal of adhesives varies between 6% and 20%, depending on the bonding technique of the retainer and the duration of the retention period (143)

The ideal centric contacts conduct the force vertically parallel to the long axes of the teeth, so that the maximum level of the occlusion in which the teeth are in contact reduces the pressure on the periodontal tissues and the teeth to a minimum (7). Therefore, occlusal treatment prevents the occurrence of periodontal disease and even helps to treat it (10).

During fixed orthodontic treatment, orthodontic appliances may interfere with the settling of functional occlusion because the teeth are connected to each other by wires. After removal of the orthodontic appliances, slow tooth movements occur with the function of the teeth. These tooth movements occur due to the balance between the oral musculoskeletal system. Changes in posterior teeth are more pronounced; this improves chewing performance and efficiency (17).

The maximum voluntary bite force (MVBF) indicates the functional state and health of the chewing system (118). The force values differ according to the measurement location (highest at 1st molar and lowest at incisors) (144). MVBF is affected by physiological and morphological factors. Force changes with age; It reaches its peak at the age of 12, stabilizes after the age of 14, and then decreases after the age of 25 for women and 45 for men. In general, MVBF is higher in men than in women (101).

Other factors affecting MVBF; the number of teeth and the number of occlusal contacts (118). Individuals with horizontal craniofacial growth have a high MVBF value, and in individuals with vertical growth, this value is lower than those with average growth

(74). There was no difference between MVBF values in the study between long-faced and normal growth pattern children (31).

In another study to measure the stability of orthodontic treatment; fixed retainers were applied to the mandible and maxilla, and 8-year post-retention period was examined for any relapse of the jaws. In this study by Steinnes et al. (145), fixed retainer was found to be very effective in maintaining the alignment of the teeth in the lower jaw, but it was concluded that the fixed retainer in the upper jaw does not make any difference in the long term.

2.5. Occlusal Contact Area Changes after Orthodontic Treatment and During Retention Period

During the retention period, after finishing the active phase of orthodontic treatment, measures are taken to maintain dental arch dimensions and alignment, while teeth are allowed to settle. Occlusal settling, also known as a positive form of relapse, is defined as desirable vertical tooth movement that occurs after active orthodontic treatment. This type of tooth movement is considered to be beneficial (6,12). Following removal of fixed orthodontic appliances, the teeth start to move slightly until they reach a balanced position in the oral environment, guided by the occlusion, muscles and retention appliances. By occlusal settling, it is expected to have an increase in the occlusal contact areas with positive contribution to function. So, Settling of occlusion during retention therapy may be considered as a useful form of relapse (12). This is characterized by alterations in occlusion that increase the number of occlusal contacts between the jaws. The best retention appliance will be a system that allows an increase in interdigitation but prevents relapse (54).

Haydar et al.(146), in their study in which 20 patients were included, investigated occlusal contact changes with the silicone bite recording method after three-month retention period. The contact changes seen with the retention appliances were compared with a control group of 10 individuals of the same age group who were not treated. Hawley appliances was used in the lower and upper jaw in 10 of the patients in the treatment group and positioner appliances was used in 10 of them, and a significant increase was found in the total number of contacts with both appliances. There was an increase from 21.20 to 22.40 in the Hawley group and from 24.80 to 27.00 in the Positioner group, but there was no statistical difference between appliances.

Sauget et al. (12), compared Hawley and Essix retainer appliances. They received occlusal recordings 3 times at regular intervals. Among the patients included in the study, there are cases treated with and without extraction and cases with congenital missing teeth. The change in the number of occlusal contacts they obtained with the 3-month retention period was found to be statistically insignificant in the Essix retainer group, while significant increases were observed in the total number of contacts in the Hawley group. The authors reported that the Hawley appliance allows vertical movement of the posterior teeth, but that the Essix appliance does not allow interdigitation by keeping the teeth fixed in their position.

Gazit et al.(147), examined occlusal contact changes after fixed orthodontic treatment in 12 patients. They received occlusal recordings three times, at the end of treatment, one month later and one year later. They told the patients not to use their appliances at least 3 months before the last recording, but in this study, it was not specified which retention appliance was used. In this study, in which bite records were used to determine the number of contacts, the authors stated that the total number of contacts increased from 11.2 to 17.4, on average, 56% at the end of the 1-year retention period. The results obtained in this study show that there are settlings in the occlusion at the end of the 1-year retention period.

Durbin and Sadowsky (3) obtained post-treatment and post-retention silicone bite records to examine occlusal changes of 38 patients at the end of the 3-month retention period. At the end of the study, they stated that the significant increase in the total number of contacts in all samples was due to the changes in the premolar and molar regions.

Razdolsky et al. (10) studied the effect of Hawley and Positioner appliances on occlusal contacts in a patient group of 40 people. 29 of the patients used Hawley on the upper jaw and fixed retainer appliance on the lower jaw. 8 of them used Hawley appliance on the upper and lower jaws. Hawley appliance was used in 3 patients after using the positioner. At the end of the 21-month retention period, silicone bite records were used to examine contact number changes. According to the results, it was reported that the total number of contacts increased from 36.6 to 58.2 and the number of posterior contacts from 30.4 to 49.0. It was stated that the significant change seen in the total contact number was due to the increase in the contacts in the posterior teeth and the close contacts in the anterior teeth.

Başçiftçi et al. (54) examined the effect of modified Hawley plate and Jensen plate on occlusal contacts in a study group consisting of 40 patients and compared it with a control group of 20 untreated patients. Patients who received treatment with and without extraction were included in the study group. Twenty patients used Hawley plates in the lower and upper jaw, 20 patients used fixed retainer appliances in the lower jaw, Jensen plate on the upper jaw for 6 months full-time and 6 months part-time for a 1-year retention period. Occlusal contact changes were examined through bite recordings taken with a silicone-based impression material, and a significant increase was found in the total and posterior region with both retention appliances.

Sarı et al. (148), investigated the effects of fixed retainer appliance and Hawley appliance on occlusal contact change in their study in which 50 patients were included with similar study methods and compared them with a control group of 20 patients. Patients who received treatment with and without extraction were included in the study group. 1-year retention follow-up has been carried out. According to the results of the study, occlusal contacts showed a significant increase in the posterior region with both retention appliances, and a greater increase was observed in the posterior region in the fixed retainer group. However, in the study groups of Sarı et al., Fixed retainer appliances were extended to premolars in patients who were treated with extraction, since they did not differentiate patients who received treatment with and without extraction.

Dinçer et al. (149), investigated the effect of Hawley appliance on occlusal contacts at the end of the 9-month retention period. 20 patients used the Hawley appliance for the first 6 months full-time and part-time for the following 3 months for the lower and upper jaw after treatment. Results were compared with 20 untreated individuals with ideal occlusion. The determination of occlusal contact change was made with a silicone bite recording. The authors stated that the number of contacts in the posterior region increased from 11.45 to 19 at the end of the retention period, and they interpreted this significant contact increase as an important sign of occlusal stability.

Aslan et al. (150) evaluated the results of previous studies investigating the effect of the Essix appliance on occlusal contacts and compared the effect of the modified Essix appliance, which does not cover the occlusal surfaces in the posterior region, and the Essix appliance that covers all surfaces on occlusal contacts. The modified Essix appliance is designed to expose half of the facial and lingual surfaces of posterior teeth and the entire occlusal surfaces. In the study, 18 patients were taken to the Essix appliance and 18 patients to the modified Essix appliance for 6 months full time and 3 months part time retention period. Bite records with silicone impression material were taken after treatment, 6 months and 9 months. With the modified Essix appliance, which is expected to allow vertical movements of the posterior teeth, a statistically significant increase was found in the posterior and occlusal contacts only in the last 3 months of part-time use (between T2 and T3). Essix appliance did not allow any increase in interdigitation during the 9-month retention period. When we look at the results of the studies using essix appliances in the retention period, it is understood that these appliances reduce (15) or slow down the occlusal contact.

Parkinson et al. (41), followed up 49 patients for an average of 14 years after treatment. In the study where the authors did not specify which retention appliances were used, they looked at the change in contact areas before treatment, after treatment, and after retention in Class I and Class II malocclusion. The silicon bite records taken on the models transferred to the articulator were scanned with a scanner and transferred to the digital media in the form of photographs, and the corresponding pixel density in 256 gray scale was calculated automatically with the Image Tool program according to the thickness of the impression material. Accordingly, the researchers calculated the values 50 μm and below as the real contact area, and the values 300 μm and below as the near contact area. The results showed that occlusal contact areas were reduced during treatment and there was no statistical increase in the retention period. The method of this study enabled other studies to be conducted.

Horton et al.(151), based on the method of the previous study, investigated the effect of Hawley and Perfector / Spring Aligner retention appliances on occlusal contact areas with approximately 2 months of follow-up in 50 patients. Using the 256 grays scale, the areas remaining 300 μm and below were measured as the contact area. There was a statistically significant increase from 6.71 mm2 to 10.97 mm2 in the Hawley group and from 8.44 mm2 to 12.95 mm2 in the Perfector / Spring Aligner group.

Aszkler et al. (152) assessed long-term posttreatment changes in all criteria of the American Board of Orthodontics' (ABO) model rating system. In the study, the records of 30 patients at the final and posttreatment were taken for a period of 22 years and plaster models were used. At the end of the treatment, scores for occlusal contacts and marginal ridges were higher; however, these scores and the overall scores for the 30 subjects improved during the postretention phase.

Using the American Board of Orthodontics discrepancy index, Hoybjerg et al (6) evaluated a total of 90 patients. These individuals were evenly assigned to one of three retention protocols: upper Hawley/lower bonded, upper Essix/lower bonded, or upper Hawley/lower Hawley. The patients were then divided into equal groups according to extraction versus non-extraction treatment and case complexity. Plaster model and radiograph records were taken from the patients before the treatment, after the treatment, and 1 year later. The initial complexity of the case has been reported to have a significant impact on posttreatment occlusal settling. The more difficult and complex the treatment, the less occlusion settling during the retention process. According to the cast and radiography evaluations, at the end of 1 year, improvement in occlusal contacts is observed in all 3 retention appliances. In addition, the changes that occur as a result of retention do not differ in cases treated with and without extraction in the study.

Varga et al.(17) investigated changes in the retention period of occlusal contacts and bite force. In their study of 176 people, they divided them into four different groups: wrap-around, essix and fixed retainer appliances for use in the lower and upper jaws. They were divided into groups of 30; 86 with normal occlusion were not treated. The number of occlusal contacts and maximum voluntary bite force were measured at the end of orthodontic treatment, 6 weeks and 10 weeks later. As a result, it was observed that the increase in the number of occlusal contacts increased more than the increase in bite force. Occlusal settling in patients using wraparound retainers was better than in patients using essix retainers. In addition, the improvement in men was greater than in women. It was stated that the values of the study group nearly reached the values of the control group.

Kara et al.(15) investigated the changes in occlusal contact area and cast-radiogragh evaluation score after a 1-year retention period in patients with 3 different retention protocols. All the dental models and panoramic radiographs were measured according to American Board of Orthodontic's CRE including all 8 criteria: rotation and alignment, occlusal relationship, overjet, buccolingual inclination, occlusal contacts, interproximal contacts, marginal ridges, and root angulation. In the study, 90 people were evaluated and divided into 3 groups: upper fixed retainer and Hawley or lower fixed retainer (Hawley group); upper fixed retainer and lower Essix or fixed retainer (Essix group); and upper fixed retainer and lower fixed retainer. The dental casts were digitized with maximum intercuspation relationship by using 3Shape R900 3-dimensional laser scanner. While both the Hawley and bonded retainer groups allowed occlusal settling during the retention period, Essix retainers did not allow relative vertical movement of the posterior teeth.

Alkan et al.(18) used T-Scan III to examine changes in occlusal surface area and occlusal force distribution. Three different retention appliances were used: Vacuum-formed, Hawley and Bonded retainers. Evaluation during the retention period was made at 3 different times: 2 hours after debonding orthodontic appliances, 3 months and 6 months. According to the evaluation results, the fastest increase in occlusal area occurs in the bonded retainer group.

Alkan et al.(153) evaluated force distribution, individual force and occlusal surface area in their study using hawley and essix appliances. In the study conducted with 35 people, T-Scan analysis was performed at the time of debonding of orthodontic appliances, 3 months and 6 months later. Occlusal force distribution and individual force distribution did not change during the use of hawley and essix appliances, while the occlusal surface area increased.

2.6. Digital Orthodontic Models

With the help of developing technology, orthodontic records, radiographs and photographs of the patients can be stored as digital documents in electronic form, thus creating an alternative to the plaster models. Thus, a new industry has been developed for the digital models and digital analysis that can be performed in 3D.

Plaster models have a proven track record as a standard dental recording material and have been the gold standard for dental analysis for decades. However, plaster models have a number of disadvantages, including labor-intensive requirements, the need for physical storage, fragility, deterioration, and potential loss issues during transfer. (154).

Digital working models provide a trustworthy alternative to conventional plaster models. Advantages in orthodontic diagnosis and treatment planning include simple and rapid electronic transfer of data, instant access and low storage requirements (155). Digital models can be incorporated into a variety of patient management systems and digital recordings, in addition to digital photographs, radiographs, and clinical notes. Arch form, crowding or gap size, and type of malocclusion can be analyzed using digital models. It is possible to perform measurements such as overjet, overbite, tooth size, arc length, transversal dimensions, and Bolton analysis. It permits the user to create digital configurations and simulate treatment plans, bracket placement, and indirect bonding (156).

Digital models were introduced in 1999 by OrthoCAD (Cadent, Carlstadt, NJ, USA) with the introduction of the first 3D orthodontic scanner system. Following this, many scanning technologies and different devices were produced (157). A recent study published in the Journal of Clinical Orthodontics found that the use of digital models for pre-treatment diagnosis and treatment increased significantly from 6.6% in 2002 to 18.0% in 2008. (158).

Based on the studies showing that measurements with digital models can be made with precision of 0.27 mm, it can be said that measurements made with digital models are as sensitive as plaster models (159). There are also studies showing that there is no clinically significant difference between measurements made on digital orthodontic models and plaster models (160,161)A study in this area focused on the reliability of digital models and dental study models used in orthodontics and reported that the reliability of the two methods was comparable. (156).

In a study (162), to compare traditional and digital impression techniques; patient preferences and treatment comfort were evaluated. Digital impressions and bite scans were taken with the 3D CEREC Omnicam. In this study, Yuzbasioglu et al. (162) found that digital impression technique was better than traditional ones in terms of time spent. In addition, patients prefer digital technique because they are comfortable and effective.

Zimmerman et al.(163) compared the sensitivity of guided digital scanning procedures with conventional impression techniques in vivo. Records were taken with Cerec Omnicam Ortho and Ormco Lythos intraoral scanning devices, and compared with the traditional impression technique: using irreversible hydrocolloid material (alginate). The intraoral scanning procedure showed statistically significantly higher results than the conventional impression technique.

3. SUBJECTS AND METHODS

This prospective study was approved by Yeditepe University Clinical Research Ethics Committee (Decision no: 910, Date:25/10/2018). The individuals who were willing to be involved, signed the Informed Consent Form after receiving information about the study.

3.1. Subjects

In the study groups of this prospective controlled clinical trial, 68 patients meeting the inclusion criteria were initially enrolled, but the study was completed with 60 people due to transportation problems of 8 patients. Finally, study groups consisted of 60 patients who were treated between 2015-2019 at Yeditepe University, Faculty of Dentistry, Department of Orthodontics. All patients underwent fixed orthodontic treatment with straight-wire technique without tooth extraction and had fixed lingual retainers bonded between right and left canines in the maxillary and mandibular dental arches.

Inclusion criteria of the study groups:

- Having high or low angle growth pattern
- Presence of all the permanent teeth except for third molars
- Treated with nonextraction orthodontic therapy
- Having ideal overjet and overbite relationship, Class I canine and molar relationships with good interdigitation, PAR index <10 at the end of the treatment
- Application of a similar retention protocol (fixed lingual retainers bonded to maxillary and mandibular anterior teeth)
- Attending control appointments
- No occlusal restorations

Exclusion criteria of the study groups:

- Patients without Class I molar and canine relationship
- Patients with occlusal restorations
- Patients with tooth agenesis (except for third molars)
- Patients in primary/mixed dentition

- Patients treated with extraction, rapid maxillary expansion or orthognathic surgery
- Patients having Hawley or Essix retainers or fixed lingual retainers extending to the premolars

The patients with decreased lower facial height were enrolled in the low angle study group whereas the patients with increased lower facial height were enrolled in the high angle study group. At the beginning of retention period, the mean age of the low angle group was 16.90±2.17 years (Table 3.1.). Low angle group was composed of 12 male and 18 female patients (Table 3.2.). The mean age of the high angle group was 17.20±2.24 years (Table 3.1.). High angle group was composed of 18 male and 12 female patients (Table 3.2).

The control group consisted of 30 individuals (15 males and 15 females) with a mean age of 17.33±2.28 years at the beginning of the observation period (Table 3.1. and Table 3.2.).

Inclusion criteria of the control group:

- Having normal vertical growth pattern
- No previous history of orthodontic treatment
- Presence of all the permanent teeth except for third molars
- Having ideal overjet and overbite relationship, Class I canine and molar relationships with good interdigitation, minor anterior crowding
- No occlusal restorations

Exclusion criteria of the control group:

- Not having Class I molar and canine relationship
- Having occlusal restorations, tooth agenesis (except for third molars)
- Primary/mixed dentition
- Previous history of orthodontic treatment

Table 3.1. Mean ages of the groups

	Control Group	Low Angle Group	High Angle Group
Age (years)	17.33±2.28	16.90±2.17	17.20±2.24

Table 3.2. Gender distribution of the groups

Gender	Control Group		Low Angle Group		High Angle Group	
	n	Percentage	n	Percentage	n	Percentage
Male	15	50.00%	12	40.00%	18	60.00%
Female	15	50.00%	18	60.00%	12	40.00%

3.2. Material Collection and Evaluation

3.2.1. Determining the vertical facial type

In our study, we used cephalometric radiographs of the patients in the study groups and the frontal facial photographs of the subjects in the control group to determine the vertical facial dimension. Cephalometric radiographs were obtained from the patients using (Morita, Veraviewpocs 2D, Japan). Extraoral photographs were taken at a 1 m distance from the subject, at natural head position with a digital camera (Canon EOS 550D)

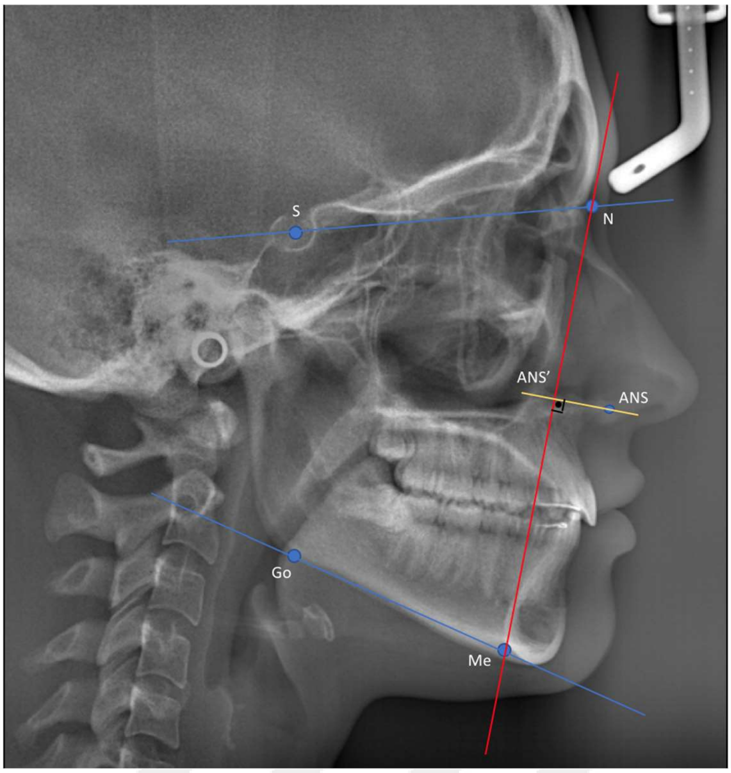
In study groups, the vertical growth pattern of the patients was determined using following cephalometric measurements (Figure 3.1.):

1- ANS-Me/ Na-Me: Ratio of the lower facial height to anterior facial height (164). If this ratio is more than %55, it indicates an increased facial vertical height. If it is less than %55 it indicates a low facial vertical height,

2- S-N/Go-Me angle: The angle is between sella-nasion line and gonion-menton line. If this angle is less than 27^0, it indicates low facial angle. If it is more than 37^0, it indicates high facial height. (164,165).

The patient was assigned to high angle or low angle group when these two cephalometric measurements indicated the same group. In the high angle group, the mean

ANS-Me/Na-Me was 57.6%, and the mean SN/Go-Me angle was 39,5 ^{0}. In the low angle group, the mean ANS-Me/Na-Me was 53.2% and the mean SN/Go-Me angle was 24,8^{0}.



ANS'-Me/Na-Me: It is the ratio of the height of the lower face to the total face height.

S-N/Go- Me angle: It is the angle between the SN line and the Go-Me line.

Figure 3.1. Cephalometric measurement

In the control group, vertical facial type of the subjects was determined by measuring facial index on the facial photographs as described by Daruge (166) (Figure 3.2.).

The Facial Index were: (166)

1. Anterior facial height (N'-Me '): The distance in soft tissue that exists between the nasion point and the chin.
2. Facial width (Zid'- Zie '): The distance in soft tissue between the left and right Zigium points that correspond to the lateral portion of the zygomatic process.

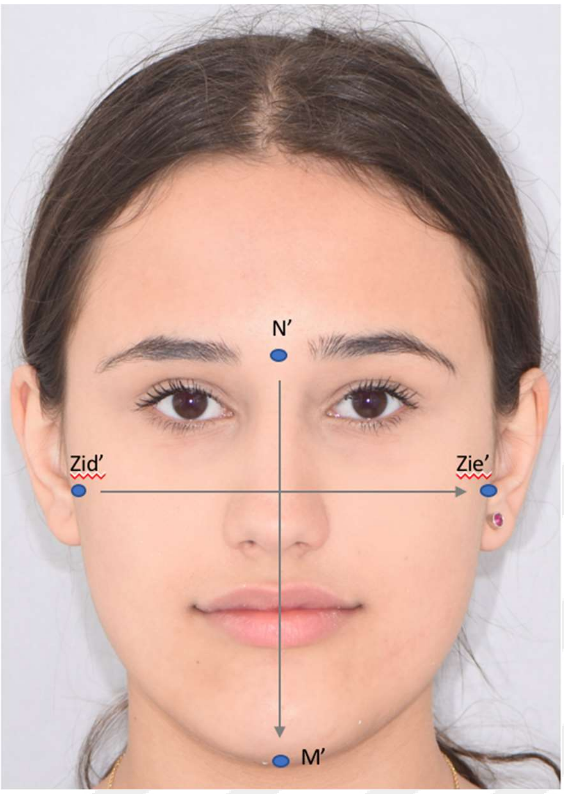
The face type determined by the face index is calculated as follows:

(N '- Me' x 100 / Zid '- Zie')

The following comments can be made according to this equation (166):

- Brachyfacial: smaller than 80.0 to 84.9%

- Mesofacial: 85.0 to 89.9%
- Dolichofacial: 90.0 to 95% or greater



Facial Index: (N'-Me') x 100/Zid'-Zie'

Figure 3.2. Frontal Photos

In the control group, the mean facial index value was 86.6%.

3.2.2. Intraoral Records

Intraoral scans of the patients in the study groups were taken after the removal of the orthodontic appliances at the end of the treatment (T1) whereas intraoral scanning of the control group was performed at the beginning of the observation period (T1) using a dental CAD-CAM system, Cerec OMNICAM Ortho (Cerec OMNICAM, Sirona Dental GmBH, Wals Bei Salzburg, Austria) (Figure 3.3.)(163). Subjects in both groups were recalled at 6th (T2) and 12th months (T3) of the observation period for intraoral scanning. All digital scanning procedures were performed by the same operator in accordance with the manufacturer's instructions (H.B.D.)

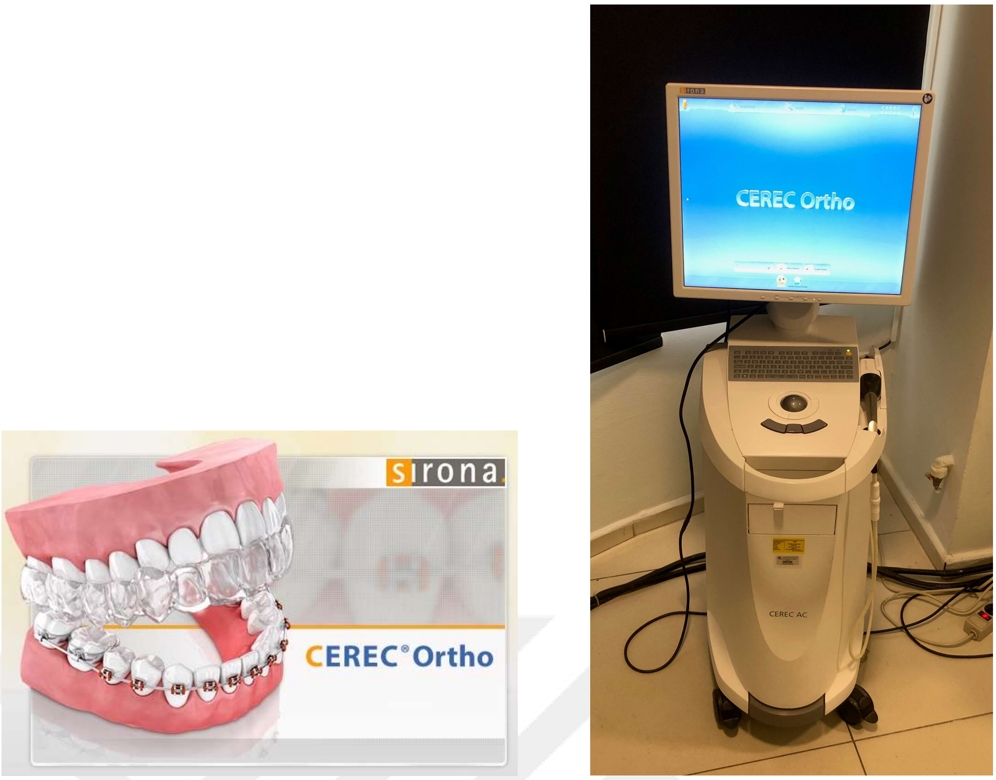


Figure 3.3. Cerec Ortho and Cerec Omnicam

3.2.2.1. Scanning Steps

3.2.2.1.1. Lower jaw

1. Scan lingual right: (Figure 3.4.)
    1. Position over right terminal tooth (occlusal), hold for timer
    2. Rotate to lingual, scan lingual of quadrant distal to mesial
    3. Hold at midline (lingual) for timer
2. Scan occlusal right: (Figure 3.5.)
    1. Start on right terminal tooth (occlusal)
    2. Scan occlusal of quadrant distal to mesial
    3. Scan ends automatically at midline
3. Scan vestibular right: (Figure 3.6.)
    1. Start on right terminal tooth
    2. Rotate to buccal, scan vestibular of quadrant distal to mesial
    3. Scan ends automatically at midline
4. Scan transversal right: (Figure 3.7.)

    1. Start on lingual of rights anteriors (shown in model at right)
    2. Scan across arch to vestibular
    3. Scan ends automatically when marked target is reached
5. Scan lingual left: (Figure 3.8.)
    1. Position over left terminal tooth (occlusal), hold for timer
    2. Rotate to lingual, scan lingual of quadrant distal to mesial
    3. Scan ends automatically at midline
6. Scan occlusal left: (Figure 3.9.)
    1. Start on left terminal tooth (occlusal)
    2. Scan occlusal of quadrant distal to mesial
    3. Scan ends automatically at midline
7. Scan vestibular left: (Figure 3.10.)
    1. Start on left terminal tooth (occlusal)
    2. Rotate to buccal, scan vestibular of quadrant distal to mesial
    3. Scan ends automatically at midline
8. Scan transversal left: (Figure 3.11.)
    1. Start on lingual of left anteriors (shown in model at right)
    2. Scan across arch to vestibular
    3. Scan ends automatically when marked target is reached

- Define border: To expedite model reconstruction and increase accuracy, remove unnecessary or mobile anatomy from the scan. Edit the crop line accordingly before clicking OK. (Figure 3.12.)

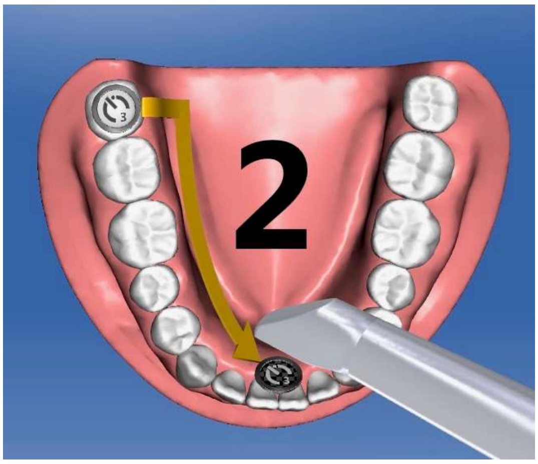


Figure 3.4. Scan lingual right

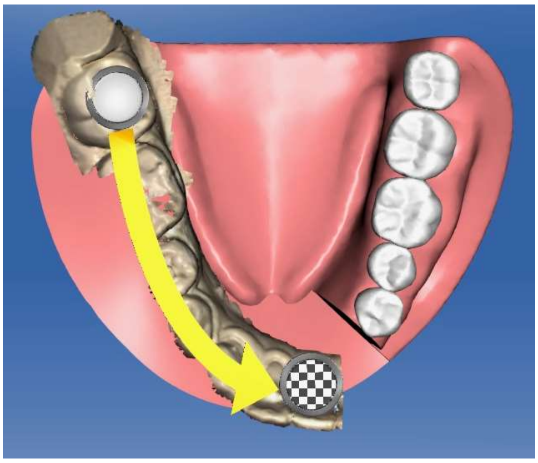


Figure 3.5. Scan occlusal right

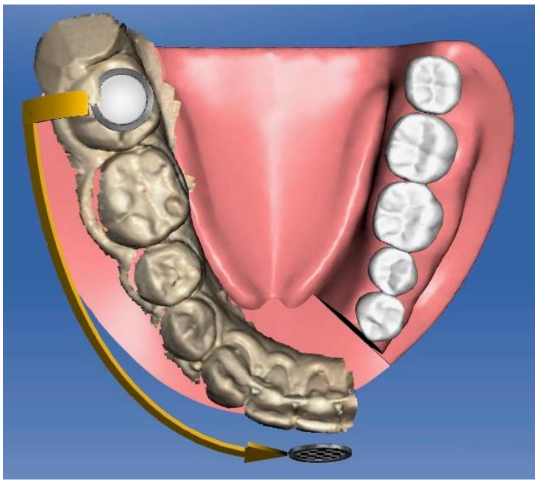


Figure 3.6. Scan vestibular right

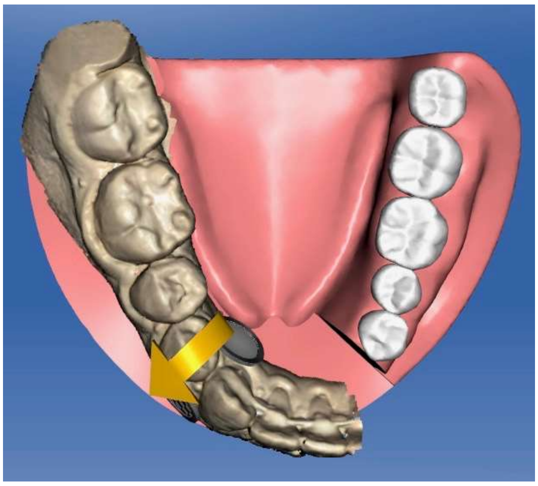


Figure 3.7. Scan transversal right

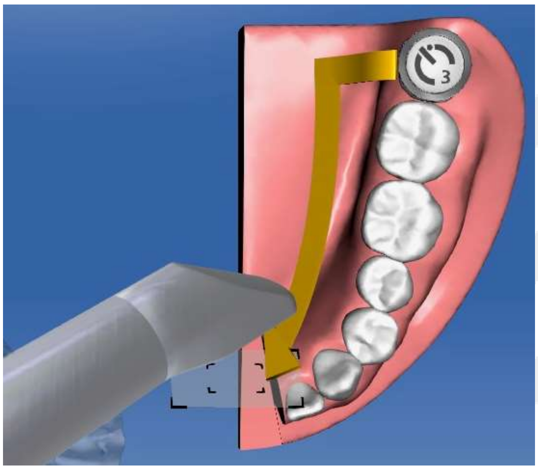


Figure 3.8. Scan lingual left

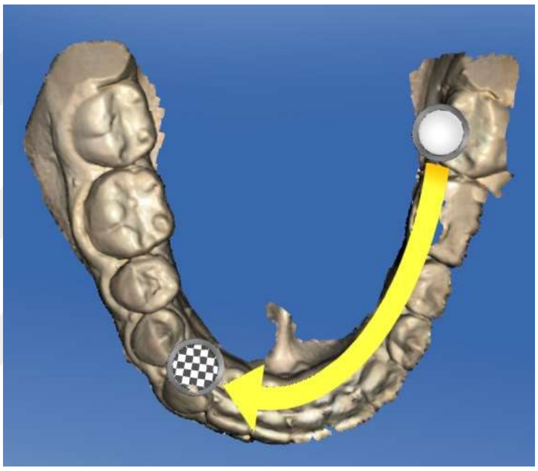


Figure 3.9. Scan occlusal left

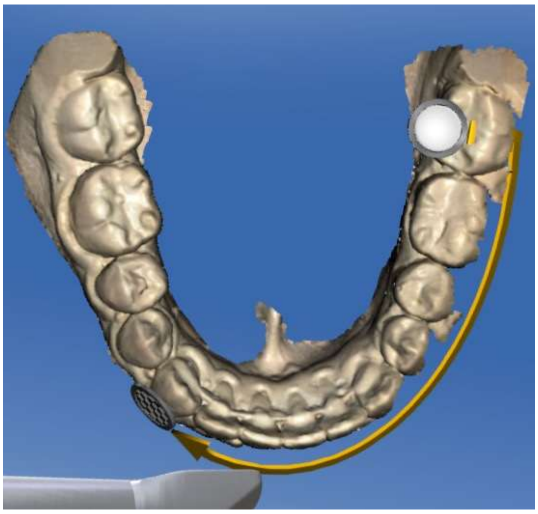


Figure 3.10. Scan vestibular left

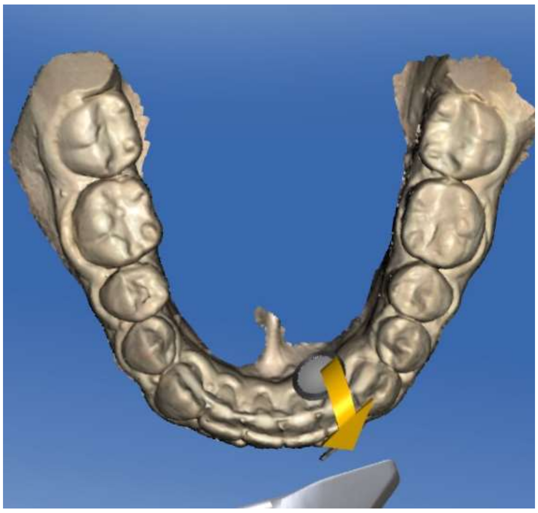


Figure 3.11. Scan transversal left

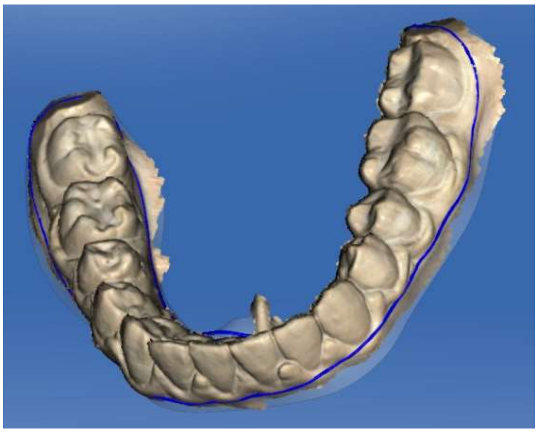


Figure 3.12. Define border

3.2.2.1.2. Upper jaw

1. Scan palatal right: (Figure 3.13.)
    1. Position over right terminal tooth (occlusal), hold for timer
    2. Rotate to palatal, scan palatal of quadrant distal to mesial
    3. Hold at midline (palatal) for timer
2. Scan occlusal right: (Figure 3.14.)
    1. Start on right terminal tooth (occlusal)
    2. Scan occlusal of quadrant distal to mesial
    3. Scan ends automatically at midline
3. Scan vestibular right: (Figure 3.15.)
    1. Start on right terminal tooth
    2. Rotate to buccal, scan vestibular of quadrant distal to mesial
    3. Scan ends automatically at midline
4. Scan transversal right: (Figure 3.16.)
    1. Start on palatal of rights anteriors (shown in model at right)
    2. Scan across arch to vestibular
    3. Scan ends automatically when marked target is reached
5. Scan palatal left: (Figure 3.17.)
    1. Position over left terminal tooth (occlusal), hold for timer
    2. Rotate to palatal, scan palatal of quadrant distal to mesial
    3. Scan ends automatically at midline
6. Scan occlusal left: (Figure 3.18.)

    1. Start on left terminal tooth (occlusal)
    2. Scan occlusal of quadrant distal to mesial
    3. Scan ends automatically at midline
7. Scan vestibular left: (Figure 3.19.)
    2.1.Start on left terminal tooth (occlusal)
    3.1.Rotate to buccal, scan vestibular of quadrant distal to mesial
    4.1.Scan ends automatically at midline
8. Scan transversal left: (Figure 3.20.)
    1. Start on palatal of left anteriors (shown in model at right)
    2. Scan across arch to vestibular
    3. Scan ends automatically when marked target is reached
9. Scan palate: (Figure 3.21.)

    If palate scan is required: Scan along the bone structure toward the posterior as far as possible.

- Define border: To expedite model reconstruction and increase accuracy, remove unnecessary or mobile anatomy from the scan. Edit the crop line accordingly before clicking OK. (Figure 3.22.)

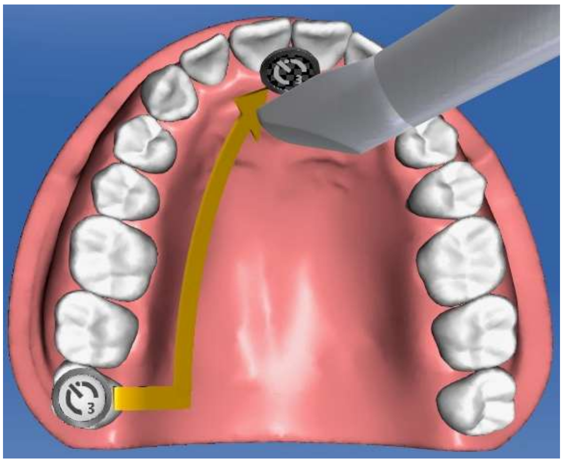


Figure 3.13. Scan palatal right

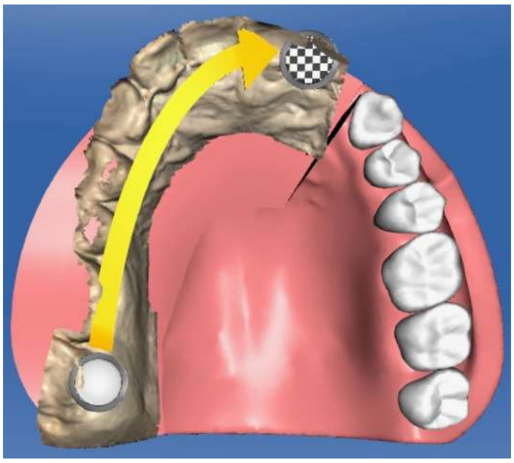


Figure 3.14. Scan occlusal right

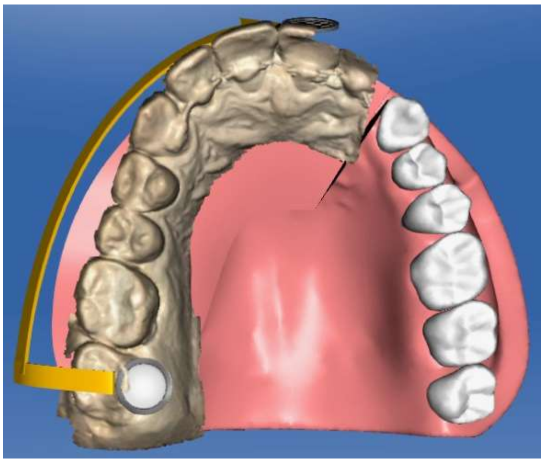


Figure 3.15. Scan vestibular right

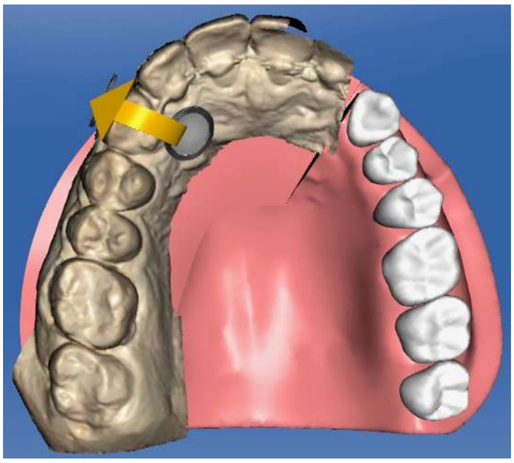


Figure 3.16. Scan transversal right

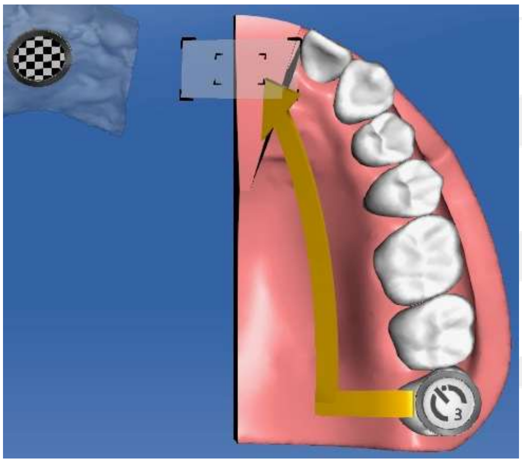


Figure 3.17. Scan palatal left

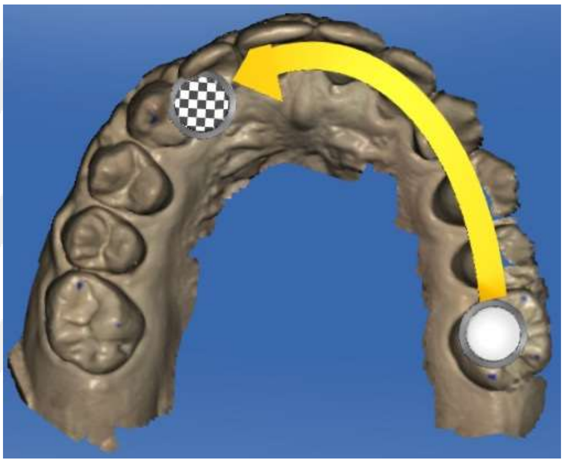


Figure 3.18. Scan occlusal left

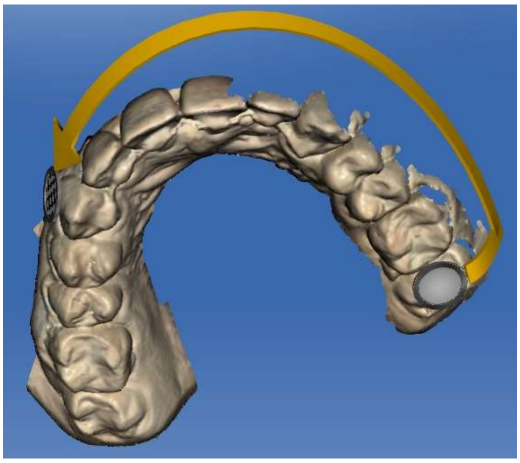


Figure 3.19. Scan vestibular left

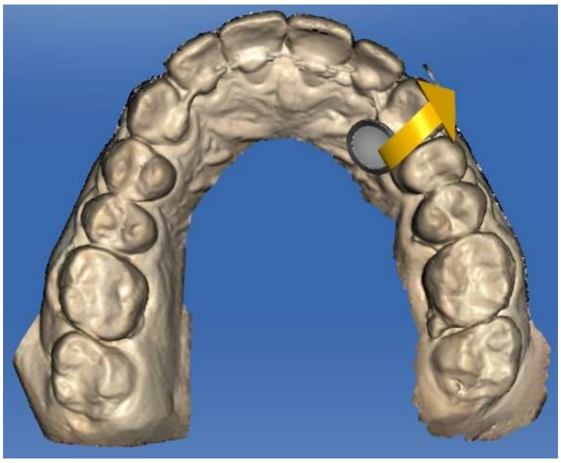


Figure 3.20. Scan transversal left

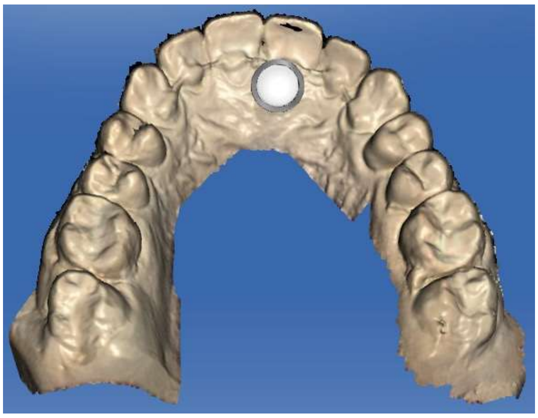


Figure 3.21. Scan palate

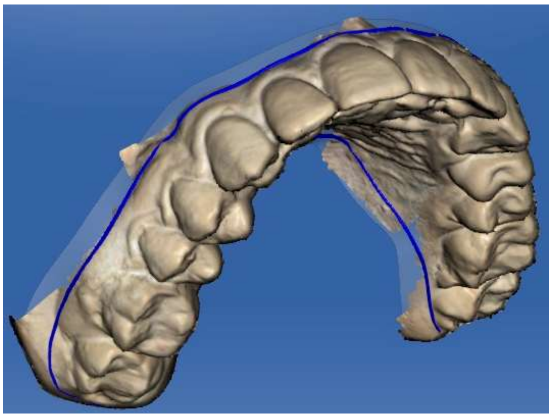


Figure 3.22. Define border

3.2.2.1.3. Checking the upper and lower jaw

The image of the lower and upper jaws obtained after all the steps are completed. (Figure 3.23. and Figure 3.24.)

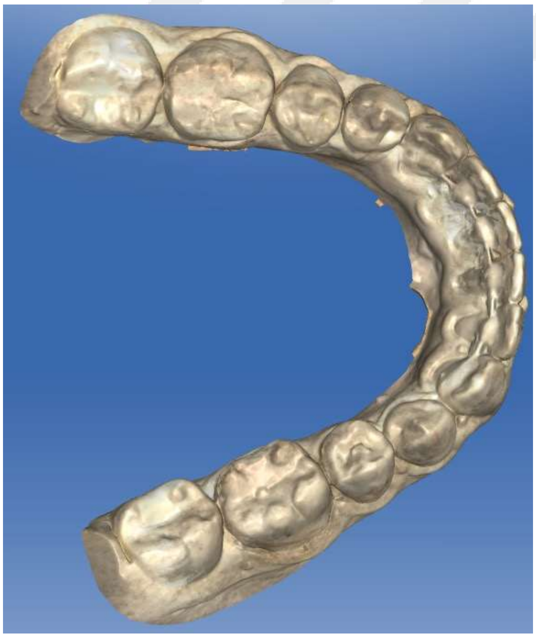


Figure 3.23. Lower jaw

Figure 3.24. Upper jaw

3.2.2.1.4. Scanning the Bite

As the last step, bite recording was also taken from the patient. The patient is scanned from the right and left sides with maximum intercuspation (Figure 3.25. and Figure 3.26.).

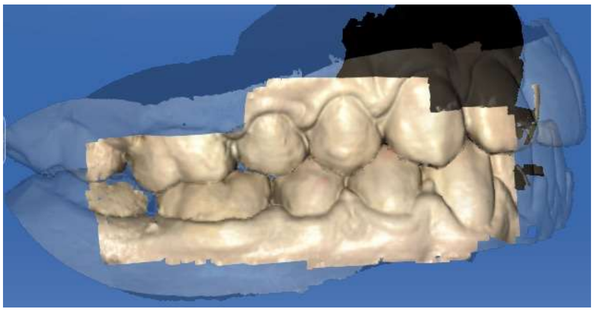


Figure 3.25. Right Side

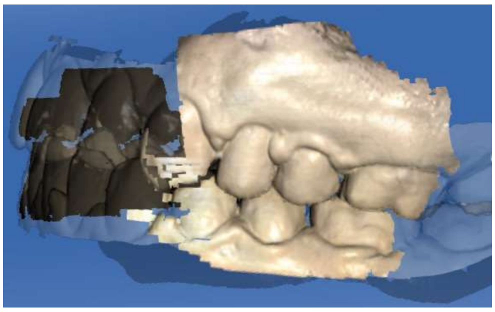


Figure 3.26. Left Side

3.2.2.1.5. Adding Base

After the scanning process is over, we can get a virtual image of the patient's lower and upper jaw (Figure 3.27.).

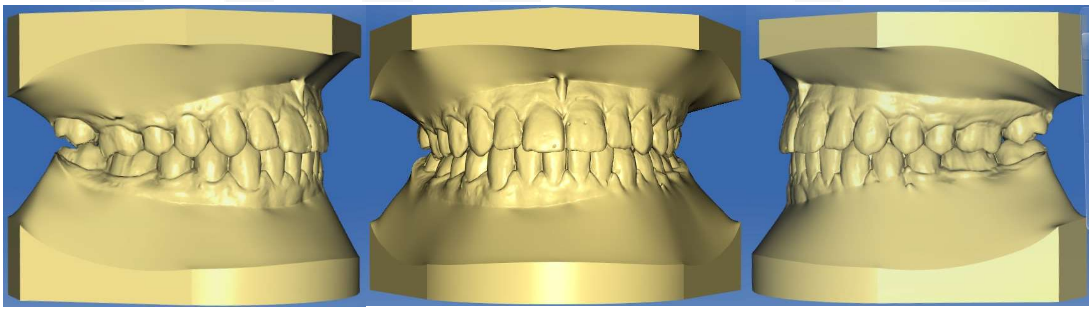


Figure 3.27. Virtual Image of the Patient

3.2.2.2. Measurement of the Contact Areas

The scanned samples were displayed with the "Model Contacts" feature in the Cerec Ortho (Dentsply Sirona, Germany). The regions that are in contact in the closing bite and are in the close contact area with 0.5 mm differences are determined with different color distribution. In Cerec Ortho, contact surfaces cannot be measured. Therefore, the necessity of using another program for the measurement of the contact areas has arisen.

The digital intraoral scans whose contact areas were determined in Cerec Ortho were transferred to ImageJ (Version 1.52a for Macintosh, , Bethesda, National Institutes of Health, Maryland, ABD) software in jpeg (Joint Photographic Experts Group) format by taking a screenshot. ImageJ is an open source image analysis software (https://imagej.nih.gov/ij/). It was designed by Rasband and Schneider in 1997 for use in all operating systems (Windows, Mac OS X and Linux), all scientific image analysis including biological and medical imaging (167).

While taking screenshots of 3D digital images, attention was paid to record the contact areas for each tooth to be measured with an optimum viewing angle of approximately 90°. For the calibration of the images transferred to the ImageJ software, a two-point measurement in mm was made on the digital image, and this measurement value was entered into the ImageJ software as a two-point value (Figure 3.28.). Then, using the “analyze - measurement” feature, the measurement values were determined in mm^2 and set to perform area measurement. This software can calculate surface area defined by the user’s selections. Accordingly, the boundaries of the contact areas determined with red, yellow, green and dark blue colors on the teeth were monitored by using the freehand preselection tool with the computer mouse. The posterior contact areas were calculated automatically in mm^2 by the software (Figure 3.29.). This procedure was repeated three times and the average value was recorded. All images were evaluated with a 27-inch screen computer.

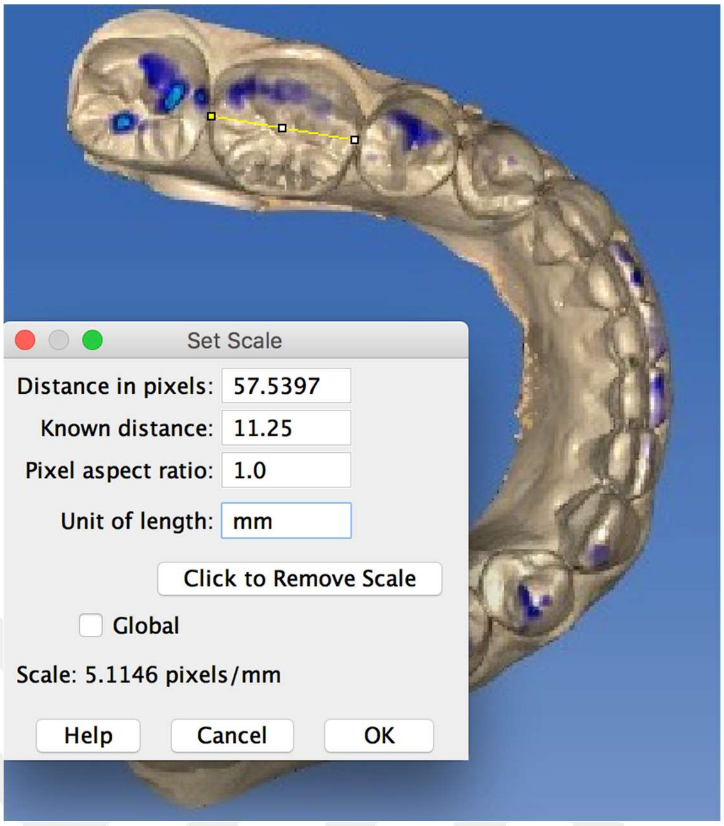


Figure 3.28. Calibration of images imported into ImageJ software.

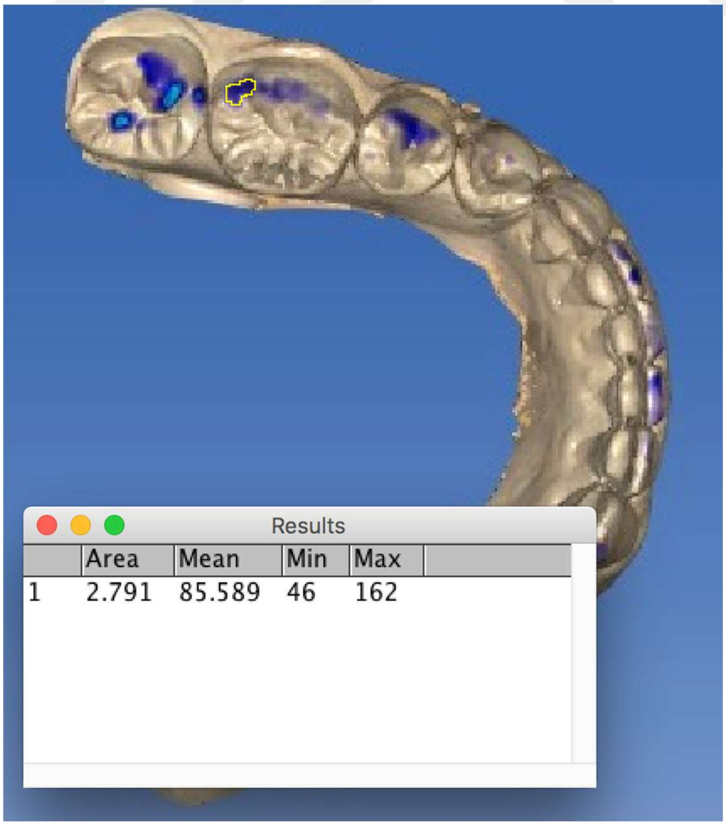


Figure 3.29. Contact area measurements in ImageJ software.

3.3. Retention Protocol

Fixed lingual retainers were fabricated by the same technician in the laboratory from 0.0215-inch 5-coiled stainless steel wire (PentaOne, Masel Orthodontics, Carlsbad, CA, USA) were applied to the patients included in the study. These retainers were bonded to all anterior teeth in the maxillary and mandibular dental arch (Figure 3.30.). No additional removable retention appliance was used.

Figure 3.30. Maxillary and mandibular fixed lingual retainers

3.4. Statistical Method

In this study, statistical analyses were performed with the NCSS (Number Cruncher Statistical System) 2007 Statistical Software (Utah, USA) package program.

In the evaluation of the data, besides descriptive statistical methods (mean, standard deviation, median, interquartil range), the distribution of the variables was examined with the Shapiro-Wilk normality test, and One-Way Analysis of Variance were used in time comparisons of the variables with normal distribution. Newman Keuls multiple comparison test was used for subgroup comparisons, one-way analysis of variance for intergroup comparisons, Tukey multiple comparison test for subgroup comparisons, chi-square test for qualitative data comparisons. The results were evaluated at the significance level of $P<0.05$.

To test the reliability of the measurement, the same researcher (H.B.D.) repeated the calibration and measurements of randomly selected 15 subjects from all groups 2 months later for T1, T2 and T3 records. intraclass correlation test and 95% confidence interval to determine the reliability of the measurements. Intraclass correlation coefficients and 95% confidence intervals were calculated for the measurement reliability of surface area measurements.

Using the G * power 3.1 program, experimental statistical power analyses were performed to determine the study's power based on the observed effect sizes (Heinrich Heine Universitat, Dusseldorf, Germany). The sample size in the study group was calculated as 0.24, the effect size of the occlusal contact surfaces of the second molar (148). Accordingly, 60 patients who were included in the study group were divided into 2 groups with 30 patients in each group.

4. RESULTS

In this study, the changes in occlusal contact surface areas during retention period in individuals with different vertical growth pattern were evaluated.

4.1. Evaluation of Method Error

Intraclass correlation coefficients (ICC) were found above the desired limit value of 0.700 in repeated measurements. When intraclass correlation coefficients are over 0.700, they are evaluated as reliable (168). Intraclass correlation coefficient for T1 measurements was 0.996 (0.991-0.998), ICC for T2 measurements was 0.995 (0.990-0.998), ICC for T3 measurements was 0.987 (0.974-0.994) (Table 4.1.)

Table 4.1. Intraclass correlation coefficient for posterior contact area measurement

	Intraclass Corelation Coefficient	%95 Confidence Interval
T1	0.996	0.991-0.998
T2	0.995	0.990-0.998
T3	0.987	0.974-0.994

T1:Beginning of observation period, T2:6th month, T3:12th month

4.2. Comparison of Demographic Characteristics of Groups

The comparison of mean ages and the gender distribution of the groups revealed no statistically significant differences (p>0.05), showing homogeneity of the groups in terms of age and gender (Table 4.2. and Table 4.3.).

Table 4.2. Comparison of the mean ages of the groups by One-Way Analysis of Variance

	Control Group	Low Angle Group	High Angle Group	p
Age (years)	17.33±2.28	16.90±2.17	17.20±2.24	0.750

Table 4.3. Comparison of gender distribution of the groups by chi square test

Gender	Control Group		Low Angle Group		High Angle Group		p
	n	Percentage	n	Percentage	n	Percentage	
Male	15	50.00%	12	40.00%	18	60.00%	0.301
Female	15	50.00%	18	60.00%	12	40.00%	

4.3. Contact Area Changes

One-way analysis of variance was used to evaluate the changes between posterior occlusal contact surface areas at different time intervals after treatment (Table 4.4. and Table 4.5.). A statistically significant difference was observed between the initial mean occlusal contact area of the control, low angle and high angle groups ($p<0.001$). At T1, the mean occlusal contact area of the control group was found to be statistically significantly higher than that of the low angle and high angle groups ($p<0.001$). No statistically significant difference was observed between the mean occlusal contact area of the low angle and high angle groups ($p>0.05$).

At T2, a statistically significant difference was observed between mean occlusal contact area of the control, low angle and high angle groups ($p<0.001$). The mean occlusal contact area of the control group was statistically significantly higher than that of the low angle and high angle groups ($p<0.001$). Mean occlusal contact area of the low angle group were statistically significantly higher than that of the high angle group ($p<0.001$).

At T3, a statistically significant difference was found between mean occlusal contact area of the control, low angle and high angle groups ($p<0.001$). The mean occlusal contact area of the control group was statistically significantly higher than that of the low angle and high angle groups ($p<0.001$). Mean occlusal contact area of the low angle group were statistically significantly higher than that of the high angle group ($p<0.001$).

Within each group, a significant difference was also found in occlusal contact areas in different observation periods ($p<0.001$) (Table 4.4.).

Table 4.4. Comparison of posterior occlusal contact area (in mm2) within and between groups at different time periods by One-Way Analysis of Variance and Paired One-Way Analysis of Variance

Posterior occlusal contact area (mm^2) / Time period	Control Group Mean±SD	Low Angle Group Mean±SD	High Angle Group Mean±SD	p†
T1	31.27±0.99	15.31±0.75	14.82±1.14	**0.0001*** **
T2	32.07±1.04	22.71±0.96	20.11±1.03	**0.0001*** **
T3	32.33±0.88	25.50±0.84	22.74±0.84	**0.0001*** **
pǂ	**0.0001*** **	**0.0001*** **	**0.0001*** **	

T1: Beginning of observation period, T2: 6th month, T3: 12th month, (†) One-Way Analysis of Variance, (ǂ) Paired One-Way Analysis of Variance, (***) p<0.001

Table 4.5. Tukey multiple comparison test

	T1	T2	T3
Control Group / Low Angle Group	**0.0001*** **	**0.0001*** **	**0.0001*** **
Control Group / High Angle Group	**0.0001*** **	**0.0001*** **	**0.0001*** **
Low Angle Group / High Angle Group	0.125	**0.0001*** **	**0.0001*** **

T1: Beginning of observation period, T2: 6th month, T3: 12th month, (***) p<0.001

Table 4.6. and Figure 4.1. show the changes in occlusal contact area of the groups at different time periods. At T2-T1 period, a statistically significant difference was found in occlusal contact area changes between groups (p<0.001). The changes in the control group were significantly lower than the changes in low angle and high angle groups (p<0.001). The changes in the high angle group were significantly lower than the changes in the low angle group (p<0.001). To summarize, in terms of the changes at T2-T1; low angle group > high angle group > control group (Table 4.7.).

At T3-T2 period, a statistically significant difference was found in occlusal contact area changes between groups ($p<0.001$). The changes in the control group were significantly lower than the changes in low angle and high angle groups ($p<0.001$) whereas there was no significant difference between low and high angle groups ($p>0.05$). To summarize, in terms of the changes at T3-T2; low angle group = high angle group > control group (Table 4.7.).

At T3-T1 period, a statistically significant difference was found in occlusal contact area changes between groups ($p<0.001$). The changes in the control group were significantly lower than the changes in low angle and high angle groups ($p<0.001$). The changes in the high angle group were significantly lower than the changes in the low angle group ($p<0.001$). To summarize, in terms of the changes at T3-T1; low angle group > high angle group > control group (Table 4.7.).

In the control group, the changes in occlusal contact areas were significantly different between time periods ($p<0.001$), without any difference between T2-T1 and T3-T2. In the high and low angle groups, the changes in occlusal contact areas were significantly different between time periods ($p<0.001$), with significantly greater changes at T2-T1 compared to T3-T2 ($p<0.001$) (Tables 4.6. and 4.8.).

Table 4.6. Comparison of the changes in posterior occlusal contact area (in mm^2) within and between groups at different time periods by Kruskal Wallis test

Change in Posterior occlusal contact area (mm^2) / Time period	**Control Group Mean±SD**	**Low Angle Group Mean±SD**	**High Angle Group Mean±SD**	**p**
T2-T1	0.80±0.50	7.40±1.22	5.30±1.45	**0.0001*** **
T3-T2	0.25±0.67	2.79±1.14	2.63±0.63	**0.0001*** **
T3-T1	1.05±0.83	10.18±1.12	7.93±1.41	**0.0001*** **
p	**0.0001*** **	**0.0001*** **	**0.0001*** **	

T1: Beginning of observation period, T2: 6th month, T3: 12th month (***) $p<0.001$

Table 4.7. Dunn's Multiple Comparison Test

	T2-T1	**T3-T2**	**T3-T1**
Control Group / Low Angle Group	0.0001***	0.0001***	0.0001***
Control Group / High Angle Group	0.0001***	0.0001***	0.0001***
Low Angle Group / High Angle Group	0.0001***	0.374	0.0001***

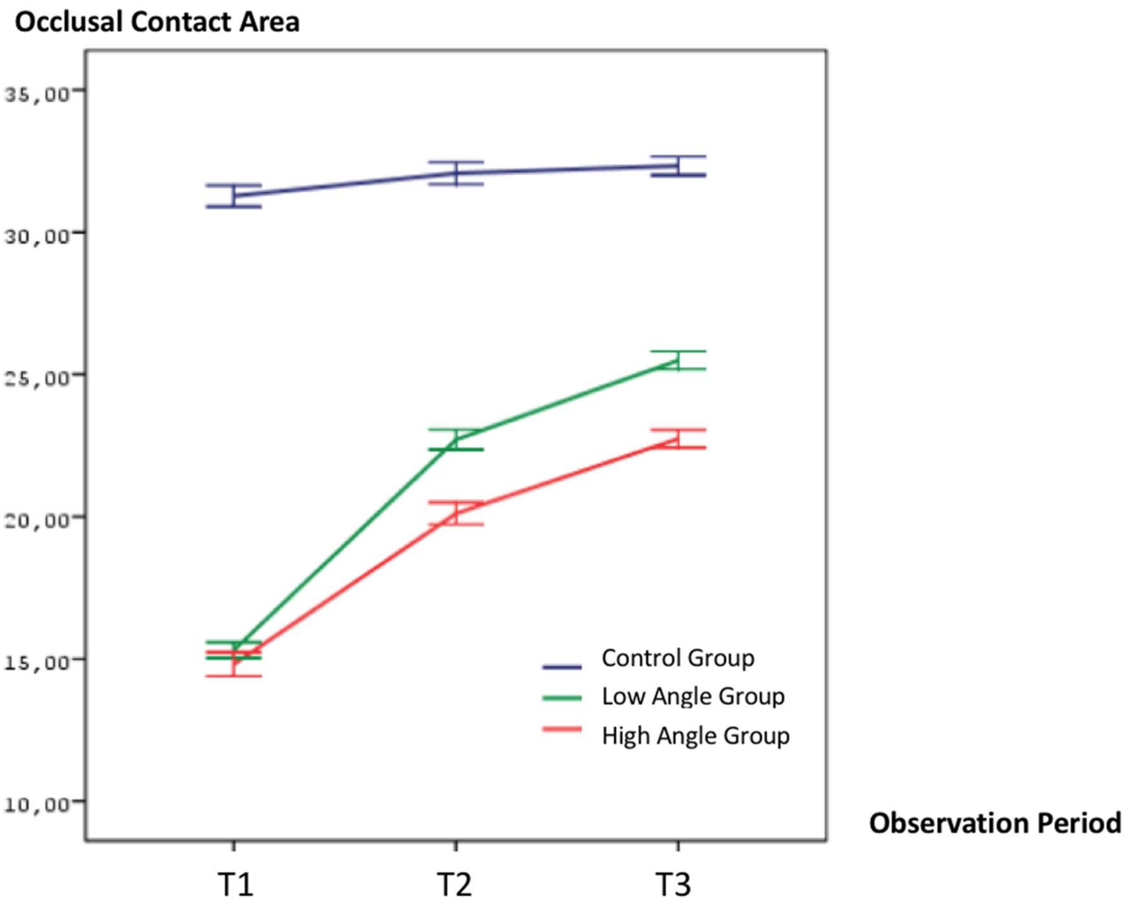
T1: Beginning of observation period, T2: 6th month, T3: 12th month, (***) $p<0.001$

Table 4.8. Dunn's Multiple Comparison Test

	Control Group	**Low Angle Group**	**High Angle Group**
T2-T1/ T3-T2	0.190	**0.0001*** **	**0.0001*** **
T2-T1/ T3-T1	**0.002** **	**0.0001*** **	**0.0001*** **
T3-T1/T3-T2	**0.0001*** **	**0.0001*** **	**0.0001*** **

T1: Beginning of observation period, T2: 6th month, T3: 12th month, (**) $p<0.01$, (***) $p<0.001$

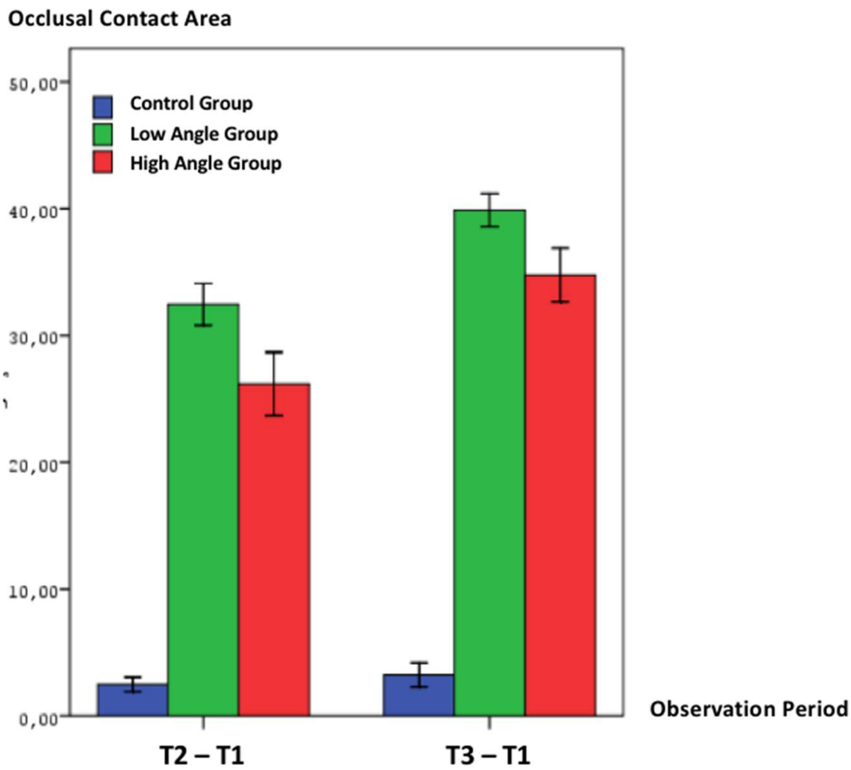
Graph 4.1. Graphic illustration of occlusal contact area changes of control, low angle and high angle groups during 1 year of observation period



The percentage of occlusal contact area changes in the control, low angle and high angle groups at T2-T1 and at T3-T1 is shown in Table 4.9. and Figure 4.2. The percentage was calculated using this formula: ((T2-T1)/T1 x 100). In the first 6 months (T2-T1), the increase in occlusal contact areas was 2.48 % in the control group, 32.45 % in the low angle group, 26.18 % in the high angle group. In one year observation period (T3-T1), the increase in occlusal contact area was 3.24 % in the control group, 39.88 % in the low angle group, 34.77 % in the high angle group.

Table 4.9. Percentage of occlusal contact area changes in each group at different time periods

Percentage of occlusal contact area changes		Control Group	Low Angle Group	High Angle Group
T2-T1	Mean±SD	2.48±1.53	32.45±4.42	26.18±6.69
	Median (IQR)	2.14 (1.25-3.73)	32.40 (29.85-35.50)	27.18 (21.10-29.38)
T3-T1	Mean±SD	3.24±2.54	39.88±3.51	34.77±5.67
	Median (IQR)	3.58 (0.95-4.82)	39.33 (37.85-41.64)	34.78 (31.93-37.92)



Graph 4.2. Graphical illustration of percentage of occlusal contact area changes in control, low angle and high angle groups during 1 year of observation period

5. DISCUSSION

5.1. Discussion of Purpose and Methods

Retention period is a passive phase following active orthodontic treatment, which aims to maintain the occlusal relationships. Positive vertical occlusal changes seen in this period are called settling of the occlusion. Many studies have shown an increase in occlusal contact areas between teeth and occlusal forces after orthodontic treatment (15,18,153). Due to the importance of occlusal contacts in calculating the maximum bite force and masticatory performance, occlusal settling is regarded as a beneficial form of relapse. On the other hand, it was shown that the bite force is related with both occlusal contacts (37) and craniofacial morphology of the individuals (38). It has been indicated that the masticatory muscles of dolichofacial subjects are less effective than those of brachyfacial subjects at generating bite force at a specific point on the lever arm due to reduced mechanics (35,36). In addition, research has shown that a smaller occlusal contact area is associated with lower levels of activity in the masticatory muscles (40). Considering the interrelationship between the occlusal contact areas, bite force and craniofacial morphology, one can speculate that there might be differences in the settling process of patients with different vertical facial dimensions. Higher masticatory forces seen in brachyfacial subjects might lead to increased settling activity when compared to dolichofacial subjects with reduced bite force. Therefore, the aim of our study was to investigate the changes in posterior occlusal contact surface areas during retention period in individuals with different vertical growth pattern.

After the ending of orthodontic treatment, a retention period is generally required. A certain period of time is needed for the trabecular structure to return to normal in the alveolar bone, adaptation of the function to the new morphological structure and the formation of a balanced and stable occlusion (5). On the other hand, the necessity, duration and method of use of retention therapy are still controversial issues and there is no one correct application method that fits every situation. Considering the literature from the past to the present, the situations which do not need retention and do require retention for lifetime are depicted. Jacson (169) was the first to talk about the idea of fixed retention, saying that situations that do not need retention after treatment are rare. Angle (170) stated that when ideal occlusion is achieved, there is no need for long-term retention, but also mentioned the need for reorganization of gingival structures and consideration of habits. It has been stated that the time required for collagen fibrils and alveolar bone of the periodontal ligament is 2-3 months, for the apical area fibers 83 days, for the fibers in the middle region 147 days, and for the fibrils close to the gingival region (supraalveolar fibrils), irregularities are seen even after 232 days and reorganization can take up to 1 year (171). Due to the late reorganization of gingival fibrils, especially in adults, it is recommended that the retention treatment last at least 12 months (172). The duration of use of the retention appliances should be the first 3-4 months of the 12-month retention period according to Proffit, and the first 6 months according to Salzmann, all day except meals (173). Regarding the retention period, Kingsley (174) argues that retention should last 2-3 years, while Rathbone (175) should not be less than 6 months, and Lischer (176) states that a period of 3 weeks to 7 years is needed. Since changes occurring during the retention period are not dependent on a single factor, it is difficult to give an exact time for the retention. In addition to the treatment period, many factors such as initial malocclusion, treatment approach and duration, the width and compatibility of dental arches, new positions and inclinations of incisors at the end of treatment, adaptation of hard and soft tissues, occlusal contacts, patient motivation should be taken into consideration when planning retention period and appliance (8,177). In our study, we included patients who were treated with fixed appliances, without extraction, rapid maxillary expansion or orthognathic surgery and who received only maxillary and mandibular fixed retainers (bonded to all anterior teeth) but no other removable retention appliances such as Essix or Hawley appliance, to be able to purely evaluate posterior settling. In the literature, the influence of different retention appliances on the occlusal contacts was thoroughly evaluated (148). The findings indicated that Essix retainers do not allow to posterior settling because of the occlusal coverage compared to Hawley appliance and bonded retainers (12,15). A recent study by Kara and Yılmaz (15) revealed that bonded retainers, Hawley and Essix retention appliances resulted in different occlusal changes during 1 year retention period when occlusal contact, occlusal relationship, alignment, rotation, overjet, marginal ridge and buccolingual relationships were evaluated together. Because different retention protocols have different impact on the occlusion, a single protocol was adopted in our study to eliminate the confounding effects. In our clinic, all the patients routinely receive maxillary and mandibular fixed lingual retainers at the end of active orthodontic treatment with some exceptions. The reason for excluding above mentioned patients was the need of extra retention protocols in addition to lingual fixed retainers for those particular patients. Patients treated with first premolar extraction receive fixed lingual retainers bonded to the second premolars to eliminate the risk of space opening at the extraction site. On the other hand, since our aim was to evaluate the posterior occlusal settling, the engagement of the second premolar to the fixed retainer would interfere with the vertical settling movement of this particular tooth. Furthermore, pooling the extraction and nonextraction cases would lead to differences in occlusal contact areas because contact area of the extracted premolar would be missing (146). Patients undergoing orthognathic surgery were also excluded because of the need of extended time periods for muscular adaptation to the skeletal changes.

In our study, we only evaluated the posterior occlusal changes for two reasons. The first one is that we evaluated the patients during retention phase where all patients had bonded retainers holding the anterior teeth whereas the posterior teeth were free to move. The second reason is that many studies have reported that the improvement in the occlusal contacts were wholly due to increase in posterior contacts (3,12). Furthermore, Kara and Yılmaz (15) also showed that the changes in occlusal contact areas were mainly due to the changes in the premolar and molar regions and they did not report any significant changes in the incisor section.

The patients included in our study were postadolescents who had already terminated pubertal growth spur by the end of the treatment to be able to eliminate the occlusal changes induced by growth. An age matched control group with normodivergent vertical facial pattern was composed to differentiate the occlusal contact area changes which may physiologically occur during 1 year of observation period. The vertical facial morphology of the patients was evaluated using cephalometric analysis since posttreatment cephalometric radiographs are routinely obtained from each patient to evaluate treatment changes. However, the vertical facial dimensions of the control subjects were evaluated on frontal facial photographs since lateral cephalometric radiographs could not had been obtained due to ethical reasons. Martins et al. (87), conducted a study to promote the use of anthropometric analysis in orthodontic diagnosis and to revealing a particular circumstance for the application of one of its indexes. They found a connection between the facial analysis determined through the use of photographs and the measurements obtained through the use of cephalometry. They discovered that the photometric method (Facial Index) for determining facial type was more reliable than cephalometry (assessed by the Vert Index). Furthermore, we also conducted a pilot study where we compared the cephalometric measurements on lateral cephalometric radiographs and facial index measurements on facial photographs of 31 patients who had both cephalometric radiographs and frontal facial photographs. The fact that all the facial index results were equal to the results of the cephalometric measurements confirmed the findings of the previous research showing that the facial index was reliable to determine the vertical growth pattern of the patients. Therefore we adopted Facial index analysis to evaluate vertical facial pattern of the control subjects.

In similar studies in the literature, the widely used method to examine occlusal contacts is bite recording with silicone impression materials (3,12). Few studies have used different methods such as photoocclusion technique, modern systems such as Dental Prescale System and T-Scan, and digital masurement through optical scans of bite recording (9,41,147,178). Only measuring occlusal contact numbers with polyether and silicone-based impression materials provides insufficient information about posterior contacts (3,10,54,146,149). Silicone impression materials can accurately record occlusal relationships with mild occlusal forces. Because they have little resistance to biting force and they harden quickly (179). Although it is stated that the measurements made with the light transmittance of these recordings are a reliable method for determining the total number of contacts and their sizes (10,54,147), the results obtained by accepting the translucent sections as contacts may vary depending on how the recordings are directed to the light source (17). Occlusal contacts and bite forces can be determined using modern systems such as T-Scan and the Dental Prescale System. However, these systems can prevent occlusion because patients bite on a 0.004 inch thick sensored plate, they cannot puncture the plaque, and the contacts are not directly related to the occlusal anatomy of the teeth, so the results obtained are 2-dimensional (180,181). In addition, low reproducibility of measurements made with T-Scan was also reported (182).

In the measurement of occlusal contact areas, a more objective and measurable method has been developed in which the silicone bite records are scanned and transferred to digital media and the degree of transparency varying according to the thickness of the measurement material with a 256 gray scale is converted into digital data according to the pixel density (41,183). In this method, silicone bite recordings were transferred to digital media with a scanner as 2-dimensional photographs. With the help of the Image Tool program, with the help of a 256-gray scale, areas with a thickness of 300 μm and less were calculated as contact area in mm^2. The results obtained with this method may vary with the angle of the bite record placed on the scanner. In our study, as a more recent and reliable method, occlusal contacts were determined using intraoral scanning at each observation period. With the 3-dimensional images and the bite record taken from the patient by an intraoral scanner, occlusal contacts were transferred in the digital environment and contact areas were determined with the model contacts section of Cerec Ortho. This method gives the 3-dimensional positions of occlusal contacts and the digital model method provides accurate and quantitative measurements of occlusal contacts (184,185).

Various software has been developed by the manufacturers in order to analyze the objects scanned with three-dimensional laser scanners. It is not possible to measure the surface area in the "Cerec Ortho" program developed for analysis by Dentsply Sirona. It is possible to measure the areas on these sections by taking the cross-sections of objects in various engineering programs, but since the occlusion map feature is disabled during this 3-dimensional area measurement, the color scale showing the contact areas cannot be used. Due to the morphological structure of the teeth, it was not possible to measure the contact area on separate sections. This has required the scan data to be transferred to an image analysis software that enables field measurement. For this reason, in our study, 3D images scanned with Cerec Ortho and whose contact areas were determined with the "occlusion map" feature were transferred to ImageJ program in JPEG (Joint Photographic Experts Group) format. In this way, the morphological surfaces of the teeth (tubercle crests) were reduced to 2 dimensions and the contact area was measured.

ImageJ includes a number of useful features for digital image analysis, including determination of linear and angular measurements, area calculation, particle analysis, cell counting. The reason we chose ImageJ for field measurements in this study is that it is an open source, free, user-friendly software that is regularly updated by a reliable source (167). Almasoud and Bean (186) used ImageJ program as image analysis software in their studies comparing Little Irregularity Index (LII) measurements made on photographs with measurements made on dental plaster models. The results of the study showed that good reliability and measurement accuracy can be achieved with ImageJ and can be used as an alternative to traditional manual measurement. The researchers also tested the repeatability of the measurements made on the photographs of the study model between 70° and 110° and stated that the measurements at a range of 20° were highly reproducible and the best result was obtained with photographs taken at 90°. Furthermore, in a recent study where occlusal contact areas were evaluated, researchers used to measure the contact area using Image J program, similar to our method, after scanning the models with a model scanner (15).

5.2. Discussion of Results

At the beginning of the observation period, occlusal contact areas of the orthodontically treated patients were smaller than that of the control subjects. This was evidently due to the inability of achieving a complete functional cusp-fossa relationship right after fixed orthodontic treatment although a finishing stage is followed for every patient to ensure a good interdigitation and functional occlusion. The orthodontic appliance does not totally allow for functional occlusion during active treatment and 3D control of the tooth position, since groups of teeth are tied together and fixed appliances. Parkinson (41) observed that, despite excellent treatment outcomes by conventional standards, the contact surface area of the posterior teeth decreased during active orthodontic treatment. Supporting these findings, Dinçer and Işık Aslan (187) showed that the number of ideally located contacts was less than normal values at the beginning of the retention period when patients with Class I malocclusion treated with premolar extraction were compared to nontreated Class I subjects. On the other hand, they also found that non ideally located contacts did not differ between groups. There are other studies showing that occlusal contacts are far being normal after orthodontic treatment compared to untreated subjects. Haydar et al.(146) compared the contact number change in the retention phase in their study. In the first recordings taken after orthodontic treatment, the occlusal contact number of the control group was significantly higher than the study group. Similarly, Basciftci et al.(54), in their study where the records taken from the study and control groups immediately after orthodontic treatment were compared, reported that the number of occlusal contacts was higher in the control group. While the mean number of contacts in the control group was 38.4, the number of contacts in the study groups were 13.93 and 12.36.

In our study groups, the occlusal contact areas significantly increased at 6 and 12 months after orthodontic treatment in accordance with the findings of other studies (15,146,153). It is stated that this increase in contact area was mainly due to the changes in the premolar and molar regions (3). This occlusal improvement is expected although different retention protocols may lead to different amounts of settling. Main difference seems to arise from the design of the retention appliance. Appliances with occlusal coverage such as Essix retainers seem to interfere with the settling of the occlusion whereas appliances without bite blocks (Hawley appliance, anterior fixed lingual retainers) allow vertical movement of the posterior teeth (15). Sauget et al. (12), who compared Hawley and Essix retainer appliances on cases treated with and without extraction showed that the change in the number of occlusal contacts was not significant in the Essix retainer group, while significant increases were observed in the total number of contacts in the Hawley group. Haydar et al. (146) found significant increases in the number of occlusal contact points although there was no difference between Hawley retainers and positioners in a time period of 3 months. Sarı et al. (148), investigated the effects of fixed retainer appliance and Hawley appliance on occlusal contact change in their study where they revealed that occlusal contacts showed a significant increase in the posterior region with both retention appliances, and a greater increase was observed in the posterior region in the fixed retainer group. Razdolsky (10) observed the change in the number of occlusal contacts by using Hawley appliance and positioner during the retention period and found a significant increase in the number of contacts. Basciftci et al.(54) examined the effect of the modified Hawley plate and Jensen plate on occlusal contacts, and a significant increase was found in the total and posterior region with both retention appliances. Similarly, Dincer et al.(149) studied the effect of the Hawley appliance on occlusal contacts and found a significant increase in the number of posterior contacts during the retention period, indicating this an important marker of occlusal stability. Modified appliances were also assessed in the literature. In a study by Aslan et al.(150), a statistically significant increase was found in the posterior and occlusal contacts only in the last 3 months of part-time use of a modified Essix appliance, which is expected to allow vertical movements of the posterior teeth. On the other hand, the conventional use of Essix appliance did not allow any increase in interdigitation on total contact during the 9-month retention period. In another study, Varga(17) evaluated different and combined retention appliances. Their common finding was that the values of the study groups approached the values of the control group supporting our findings showing that the occlusal contact areas of our study groups approached that of the control group. The effect of bonded retainers on the occlusal settling of the posterior teeth were recently justified by Alkan et al. (18,153) who investigated the change in occlusal surface area and occlusal force distribution after the use of Hawley, Essix and bondend retainers using T-Scan. At the end of the 6-month retention period, they observed an increase in occlusal contact areas in all retainer groups. However, the fastest increase was in the bonded retainer group. As it can be seen from the literature, different retention protocols may lead to different occlusal outcomes during retention period. In our study where all patients received bonded lingual retainer from canine to canine, occlusal settling was allowed during the retention period since no retention appliance was used to prevent interdigitation of the posterior teeth. As a result, interdigitation increased significantly in both groups.

In the control group, we noted slight but significant changes with an average increase in occlusal area of 0.8 mm^2 in the first six months, 0.26 mm^2 in the second six months, and 1.06 mm^2 at the end of 1 year. These changes may be due to physiological tooth movement and continuous vertical eruption of the teeth over this one year of observation period (188). As shown by Massaro et al.(189), many occlusal and dimensional changes occur in the dental arches of untreated subjects from adolescence to adulthood.

In our study groups, occlusal contact area increases were significantly higher than that of the control group. Moreover, in the low angle group the average changes were approximately 7.4 mm^2 between T2-T1, and 10.2 mm^2 between T3-T1, whereas in the high angle groups they were 5.3 mm^2, and 7.9 mm^2, respectively, showing a significant difference between groups except for T3-T2. Furthermore, comparison of contact area measurements at T2 and T3 showed higher contact areas in the control group, followed by the low angle and then the high angle group. In other words, both the contact areas and settling in high angle cases was lower and occurred in a slower pace compared to the low angle cases. This highly significant difference between dolichofacial and brachyfacial cases may be explained by the interrelationships between the craniofacial vertical dimensions, bite force and occlusal contact areas. Supporting this hypothesis, Gomes et al.(190), who evaluated the effect of craniofacial morphology on chewing function, occlusal contact area, and chewing muscle activity, found that masticatory efficiency was significantly higher in brachyfacial patients and lower in dolichofacial subjects. Since the masticatory muscle strengths of the brachyfacial subjects were the highest, they presented the highest occlusal contact area (mm^2), followed by the mesofacial and dolichofacial subjects (190). Therefore, reduced masticatory function was also conducted to smaller occlusal contact area (191). Lower activity of the cervical muscles has been linked to a smaller occlusal contact area in adults, indicating an indirect relationship between occlusal contact area and craniofacial dimension (40). Besides the interaction between the occlusal contacts and the masticatory function, many studies showed the correlation between the muscle activity and craniofacial morphology. Ueda et al. (192), found a significant correlation between activity of masseter and digastric muscle and craniofacial morphology in their study of the relationship between the length of daytime chewing vertical craniofacial morphology and muscle activity in children and adults. In another study, Sathyanarayana et al. (122), found that sagittal morphology had no effect on maximum voluntary bite force (MVBF) in adults with Class I normal occlusion and different malocclusions, but vertical morphology had a significant correlation. It was concluded that the bite force varied according to the vertical facial morphology, and hypodivergent subjects had a higher bite force than hyperdivergent subjects. Furthermore, muscle thickness was thought to be an indicator of muscle function. It has been reported that there is a relationship between muscle thickness and activity and facial morphology in adults, since the thickness of the masseter muscle is a direct indicator of its activity (193). Therefore, strong masticatory muscles of brachyfacial patients may lead to higher bite force at function, resulting in development of more occlusal contacts at posttreatment. Maximum molar bite forces were found to be significantly lower in dolichofacial patients during maximum effort than in mesofacial and brachyfacial subjects (81,194), which may cause lower settling activity at retention period as found in our study.

When the settling of the occlusion was evaluated in terms of percentage, we found that, in the first 6th months after debonding, the posterior occlusal contact area increased by 33% in the low angle group and 26% in the high angle group. Over one year, this increase reached 40 % in the low angle group and 35 % in the high angle group. These values are slightly lower than what was reported in the literature. Gazit et al.(147), stated that the total number of contacts increased from 11.2 to 17.4, on average, 56% at the end of the 1-year retention period. The reason for this difference may be that they evaluated number of contacts of both anterior and posterior teeth whereas in our study we only evaluated posterior occlusal contact areas.

In our study, we followed the patients for 1 year starting from the final of active orthodontic treatment and took 3 records, right at the beginning, 6th and 12th month of retention period. We revealed that the most of the occlusal settling occurred in the first 6 months compared to the second half of the observation period although significant occlusal changes took place as shown by the T2 measurements and comparison of first and second six months changes in both study groups. Similar to our findings, Bauer et al. (178), reported that the most significant change in contact area increase was seen in the first 2 months, with less change in the following 4 months, and little or no change in the last 2 months.

Another important finding of our study is that although significant changes occurred in occlusal contact areas during this 1 year posttreatment period in the high and low angle group, occlusal contact areas did not reach that of the control subjects. This may highlight the need for a prolonged time for full occlusal settling after orthodontic treatment. A study by Sultana et al. (9) which followed the orthodontically treated patients both at 2 years of retention period and one year postretention, showed that 3 years after active orthodontic treatment, the occlusal contact areas of treated patients were larger compared to untreated control subjects and close to that of subjects with normal occlusion. Following a longer postretention period, one might expect a better settling in both high and low angle cases. However, this needs further evaluation. Futhermore, a better finishing should be aimed at the final stage of the active orthodontic treatment either by using positioners or contemporary methods such as digital planning of the final occlusion and fabrication of custom made fixed appliances to ensure 3D control of the teeth.

There are several limitations of our study, which should be addressed in future studies. In our study, the contact area measurements were made at the end of the 6th month and the 1st year. Whether occlusal settling is in the late or early phase of the retention period can be investigated in more frequent periods and for a longer period.

Another limitation is not measuring the bite force in the current study. Since increase in occlusal contacts may lead to an increase in the bite force and masticatory efficiency, this interrelationship needs to be investigated in patients with different vertical growth patterns at retention phase.

Finally, in our study, the determination of occlusal contact areas was made using digital models in 3 dimensions, but the contact area measurement was performed by reducing to 2 dimensions and the morphological surfaces of the teeth were not taken into account. This may lead to smaller measurements of the actual contact areas. In future studies, more realistic results can be obtained by developing new software that makes it possible to measure 3-dimensional surface area.

Several clinical implications can be drawn from our study. First, particularly for high angle patients, it might be recommended that proper occlusal contacts should be achieved at the finishing phase of active orthodontic treatment since the increase in occlusal contact at retention period is lower than that of brachyfacial patients. On the other hand, a better settling may be expected for the brachyfacial patients after active orthodontic treatment. Secondarily, it may be recommended that the practitioner wait at least 6 months before performing occlusal equilibration since most of the occlusal settling occurs in the first 6 months, but we should also consider that although slight, some occlusal settling continues during 6 to 12 months after active orthodontic treatment. Tirdly, if a retention appliance such as Hawley or Essix retainers is indicated after the treatment, these appliances can be used a few months after the end of the treatment. Thus, a better interdigitation is provided.

6. CONCLUSION

In this prospective controlled study, the changes in posterior occlusal contact areas of patients with different vertical facial height were evaluated during one-year of retention period with bonded retainers after active orthodontic treatment. The results of this study revealed that:

- At the end of the active orthodontic treatment, posterior occlusal contacts of the treated patients were smaller than that of untreated subjects. There was no difference between high and low angle patients.
- At 6 and 12 months after orthodontic treatment, the occlusal contact areas in low angle group were significantly greater than that in high angle group.
- During the retention period, significant increases in the posterior contacts areas were found in the high and low angle groups compared to control group, however they did not reach the normal values.
- The increase in occlusal contact areas of the low angle group was higher than that of the high angle group in the first 6 months whereas the occlusal settling did not differ between both groups in the second 6 months.
- In both study groups, the increase in occlusal contact area in the first 6 months was higher than in the second 6 months.
- Occlusal contact areas increased by 40% and 35% in low and high angle patients, respectively, in the first year following orthodontic treatment when canine to canine bonded retainers were used.

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İlgili Makama (Halil Berat Doğan)

Yeditepe Üniversitesi Diş Hekimliği Fakültesi Ortodonti Bölümü Prof. Dr. Derya Çakan'ın koordinatör olduğu **"Farklı Vertikal Yüz Tiplerine Sahip Hastalarda Tedavi Sonrasındaki Oklüzal Temas Yüzeylerinin Değişimlerinin Prospektif İncelenmesi"** isimli araştırma projesine ait Klinik Araştırmalar Etik Kurulu (KAEK) Başvuru Dosyası (**1514** kayıt Numaralı KAEK Başvuru Dosyası), Yeditepe Üniversitesi Klinik Araştırmalar Etik Kurulu tarafından **24.10.2018** tarihli toplantıda incelenmiştir.

Kurul tarafından yapılan inceleme sonucu, yukarıdaki isimi belirtilen çalışmanın yapılmasının etik ve bilimsel açıdan uygun olduğuna karar verilmiştir (**KAEK Karar No: 910**).

Prof. Dr. Turgay ÇELİK

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