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EVALUATION OF THE INFLUENCE OF THIRD MOLAR ERUPTION ON CONTACT TIGHTNESS AND INCISOR ALIGNMENT IN THE LOWER DENTAL ARCH

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II) CONTENTS

III) ABBREVIATIONS and SYMBOLS

I.I Irregularity Index

I.P.F Interproximal force

mm milimeters

N Newton

° degrees

1. SUMMARY:

Age related changes in the dental arches have long been known by dental professionalists. These changes occur especially in the lower dental arch. Literature data is available about the effects of late mandibular growth and mandibular growth rotation, changes in occlusal relations, soft tissue maturation, periodontal forces and anterior component of the occlusal force. Mesially directed force from lower third molars is also discussed as a contributing factor, but there is an on-going debate about its effects. The aim of this study was to investigate the effects of lower third molar teeth on the mandibular dental arch. Thus, volunteers among dental school residents were included, and two groups of patients with bilateral genesis of lower third molars and bilateral agenesis of lower third molars were examined. Model analysis, cephalometric and panoramic x-ray evaluation, and interproximal force measurements were carried out for 12 months, to investigate dental and skeletal changes, and changes in interproximal force. As a result, it is found out that the effect of lower third molars on the lower dental arch and interproximal force is insignificant.

Key words: Agenesis, interproximal force, Little's irregularity index, lower incisor crowding, lower third molar teeth.

2. ÖZET:

Üçüncü büyükazı dişlerinin alt çene arkında keser dişlerin dizilimi ve kontakt sıkılıkları üzerine etkilerinin değerlendirilmesi

Dental arkların yaşla beraber değiştiği uzun zamandır bilinmektedir. Bu değişim özellikle alt çene arkında kendini göstermekte, ark boyunun zamanla azalması, interkanin, interpremolar ve intermolar mesafenin de azalarak dental arkın zaman içinde daha dar bir hal almasıyla ortaya çıkmaktadır. Bu güne kadar erişkin bireyler üzerinde yapılan araştırmalar göstermiştir ki, mandibulada erişkinlik döneminde görülen büyüme, oklüzal ilişkilerdeki değişiklikler, yumuşak dokulardaki değişiklikler, periodontal kuvvetler ve oklüzal kuvvetin meziyal vektörü geç dönem alt keser çapraşıklığının ortaya çıkmasında etkili olmaktadır. Alt üçüncü büyük azı dişlerinin sürmesi sırasında alt arka etki eden meziyal yönlü kuvvetin de alt keser çapraşıklığında etkisi olduğu düşünülmektedir, ancak liteatürde bu konuda bir görüş birliği yoktur. Bu çalışmanın amacı, yirmi yaş dişlerinin alt diş arkına ve dişler arası kuvvete etkilerini araştırmaktır. Bu amaçla çift taraflı alt yirmi yaş dişi eksikliği bulunan ve her iki alt yirmi yaş dişi de var olan diş hekimliği fakültesi öğrencisi gönüllülerden iki grup oluşturulmuş, bireylerdeki dental ark değişiklikleri, dişlerin pozisyon değişiklikleri, iskeletsel değişiklikler ve dişler arası kuvvette meydana gelen değişiklikler model analizi, sefalometrik ve panoramik röntgenlerin analizi ve dişler arası kuvvetin ölçümü ile 12 ay boyunca incelenmiştir. Araştırma sonucunda alt yirmi yaş dişlerinin varlığının alt dental arktaki değişiklikler üzerindeki etkilerinin anlamsız olduğu görülmüştür.

Anahtar kelimeler: Agenez, alt keser çapraşıklığı, dişler arası kuvvet, Little'ın düzensizlik indeksi, üçüncü büyük azı dişleri.

3. **INTRODUCTION and AIM:**

Incisor crowding is one of the main concerns of orthodontic patients to seek for treatment. This crowding can be successfully eliminated by means of orthodontic therapy, but tends to relapse after completion of active treatment. Additionally, crowding, especially lower anterior crowding, tends to increase within time - weather the patient is treated orthodontic ally or not. Taking this tendency into consideration, understanding the reasons causing incisor irregularity to increase in time, and taking precautions are of great interest in the current orthodontic concept.

In previous researches many authors concluded that, several factors responsible for late lower anterior crowding may act together or alone at different stages of the adult life (70, 81, 87, 92, 93, 94, 106). These factors can be classified as follows:

1- Skeletal structure, complex growth patterns and late mandibular growth
2- Occlusal factors
3- Soft tissue maturation
4- Periodontal forces
5- Anterior component of the occlusal force
6- Presence of third molars

One of the most blamed reasons for lower incisor irregularity is the presence of erupting or impacted lower third molars. Literally, mesially directed force from an erupting lower third molar, by causing the posterior dentition to drift mesially, provides necessary space for the erupting tooth. However, mesial migration of the lower posterior teeth diminishes lower arch length, thus, is believed to be increasing the lower incisor malalignment.

Interproximal force (I.P.F) between the teeth was first measured by Osborn in 1961. He stated that interproximal forces of the dentition is related to interdental dynamic frictional forces, within the formula *I.P.F (Interproximal force)= F (frictional force) / 2u (coefficient of dynamic friction)* (62). In 1991, inspiring Osborn, Southard, Southard and Weeda (95) introduced a specific technique to quantify the mesially directed force from lower third molar teeth, and measured the changes in mesially directed force levels after surgical removal of lower third molar teeth. Later on, in 2000, Fuhrman, Grave and Diedrich (35) used the same technique to interrogate their hypothesis on mesially directed force.

Southard et al. (95) stated in their study that mesially directed force from an erupting third molar does not cease after surgical removal of the tooth, thus extraction of all third molars to prevent late lower anterior crowding or post retention relapse is unwarranted. On the contrary, Fuhrman et al. claimed that mesially directed force from third molars decrease significantly after removal of these teeth. (35, 36)

Taking these contradictory data on lower third molars into account, it can be stated that studies on both sides of the debate lack in considering the influence of interproximal force on the increase of late lower anterior crowding. In regard, our aim was to measure the changes in interproximal force between lower posterior teeth during eruption of lower third molars, to measure the amount of crowding, to identify the changes in lower arch dimensions, and to investigate the possible correlation between late lower anterior crowding and interproximal force.

4. LITERATURE REVİEW:

4.1. Lower Incisor Alignment

Alignment of the teeth is known to be dynamic in all steps of dentition, by means of the living periodontium which binds the teeth to their supporting alveolar bone, and which provides an adaptation to the new equilibrium. As a result, lower incisor alignment changes throughout life, as the individual grows and matures. These changes are classified in three steps of dentition.

1- Primary dentition
2- Mixed dentition
3- Permanent dentition

4. 1. 1 Primary dentition

The dates of eruption of primary lower incisors are relatively variable, but usually central incisors erupt first. Lower primary dentition is completed approximately at 24 to 30th month. Interdental spacing is the characteristics of the primary dentition but is most noticeable in two locations, called primate spaces. For maxilla this space is in between lateral incisors and canines, whereas in mandible it is located between canines and first molars. According to some authors, primate spaces securing proper alignment of the permanent teeth present from the time the teeth erupt, but become somewhat larger as the child grows and alveolar processes expand, which create an arch length increase. But some other researchers found an arch length decrease even at age 3, right after the completion of primary dentition (55).

4 .1. 2 Mixed dentition

Permanent lower incisors begin to emerge in the mandibular arch at age 6. Most commonly, central incisors are the first to erupt, being also the pioneer of whole permanent dentition. When the mandibular central incisors erupt, they usually use all the excess space found in the mandible. At age 7.5, mandibular lateral incisors follow central incisors and the space condition becomes tight. From that time until the eruption of mandibular canines at age 10 to 12, there is a latent period of tooth eruption in the mandible. In this period between 8 to 12, crowding decreases in mandibular incisor region. This situation of incisor crowding is compensated by dentoalveolar changes, since no skeletal growth takes place in the anterior region of mandible at that time interval (12, 81, 92, and 93).**.** The extra space providing proper incisor alignment comes from three sources:

1- When the mandibular canine teeth erupt, they go not only upward but also slightly outward. This slight buccal movement of tooth germs contributes resolution of crowding by increasing the arch width at canine region.

2- Mandibular deciduous incisors are located buccal to their successors. As the permanent incisors erupt, they move labially, expanding the dentoalveolar process and creating extra space for alignment.

3- As the permanent incisors erupt, they push the canine teeth slightly back into the primate space, causing an increase in intercanine width since the arch is wider at posterior, and provides extra space for permanent incisors.

Regardingly, Knott reported an increase of mandibular intercanine arc width at 5 to years, after the completion of deciduous dentition to full eruption of mandibular incisor teeth (45). Bishara et al. (13) also reported an increase in mandibular arch width between 5 to 8 and 8 to 13 years, in primary dentition and in mixed dentition years; which supports the idea that natural compensation mechanism works in behalf of the alignment of recently emerging permanent incisors. However, there is also evidence that mandibular arch width decreases even in mixed dentition period, as Richardson (81) reported a 1 mm decrease in lower incisor crowding from 8 to 12,5 years.

4.1.2 Permanent dentition

Changes in permanent dentition measurements such as intercanine width, intermolar width, arch perimeter, incisor irregularity, tooth size-arch length discrepancy have long been examined by different investigators, since these changes are directly related with the stability of incisor alignment, and understanding the mechanisms underlying these changes are of great importance.

Vego (106), in 1962, announced the results of a longitudinal study on mandibular arch perimeter. In this article, he compared two groups of untreated individuals with good occlusions and facial proportions, 25 of whom had missing 3rd molars and 40 of whom had 3rd molars. He followed the cases between 13 and 18 years. At the end of the observation period, he found out a significant arch length decrease in both missing 3rd molar and 3rd molar groups, 1,7 mm and 2,5 mm respectively. Every case in this study presented an arch length decrease.

In 1964, Mills (54) examined 230 Caucasian navy men aged 17-21 years and reported that crowding or malalignment increased significantly as the arc width, especially 2nd premolar width, decreased.

Knott (45), in 1972, presented a longitudinal study on development of mandibular arch width during deciduous, mixed, permanent dentitions and young adult years. According to the results, mandibular intercanine width increased 3,5 mms as permanent incisors erupt and remained relatively stable after full eruption of mandibular laterals. According to this study, there was a small decrease in mandibular intercanine width in between mixed dentition - permanent dentition and permanent dentition – young adult years, but a significant reduce in mandibular interlateral width was reported between permanent dentition- young adult years.

Sinclair and Little (93), in their longitudinal study carried out among 65 untreated individuals, reported that mandibular arch length and mandibular intercanine width decreased both in mixed dentition between 9- 13 years of age and in permanent dentition between 13-20 years of age, whilst mandibular incisor irregularity increased only between 13-20 years.

In a longitudinal study on untreated subjects, Bishara et al. (12) reported that segmental (anterior region of mandible) and total arch length decreased in mandible from 13 to 26 years and decrease was more in male subjects. In another study of Bishara, he reported that mandibular intercanine width and mandibular arch length continued to decrease and mandibular anterior tooth size-arch length discrepancy increased in adulthood from 26 to 45 years, being significant in both male and female subjects (11, 13). Regarding to these studies on the same population, he reported an increase of 2,7 mms crowding in males and 2,0 mm in females from 13 to 45 years. (11)

Carter and McNamara (22) in their longitudinal study reported that mandibular intercanine width and mandibular arch perimeter decreased and mandibular incisor irregularity increased from 14 to 17 years and from 17 to 48 years.

In another study, Richardson reported that from 13 to 18 years mandibular crowding increased 2,3 mms and first molars moved forward 2,0mm significantly. From 18 to 21 years mandibular incisor and 1st molar position proved to be relatively stable. From 21 to 28 years mandibular incisor crowding reported to be increasing significantly by 0,2 mm. And from 18 to 50 years, mandibular incisor crowding reported to be increasing continuously, ranging from 0,2 to 2,5 mms. According to her report, the greatest amount of crowding occurred during the teenage years between 13 and 18. (81)

All the data collected by various investigators imply that mandibular intercanine width and mandibular arch length decreases, whilst mandibular tooth size-arch length discrepancy and anterior crowding continuously increases after completion of permanent dentition. Some authors state that mandibular 3rd molars may have an important role, while the others claim that late mandibular growth and accompanying mandibular rotation or complex growth patterns, causing continuous reduction of mandibular intercanine arch width and mandibular arch perimeter is responsible for the phenomenon. In the next section, regarding to the evidence based data available in the literature, possible causes of late lower incisor crowding will be defined.

4.2 Factors Influencing Late Lower Incisor Crowding

Factors responsible for reduction in arch dimensions after completion of permanent dentition may vary from one person to another, and several factors, acting together or at different stages of development, may contribute to lower arch crowding in a person. These factors can be classified as follows: (87)

1-Skeletal structure, complex growth patterns and late mandibular growth
2-Occlusal factors
3-Soft tissue maturation
4-Periodontal forces
5-Anterior component of the occlusal force
6-Presence and eruption of third molars

4.2.1 Skeletal structure, complex growth patterns and late mandibular growth

Various researchers imply late mandibular growth as the potential cause of late mandibular anterior crowding, since it may result in increased pressure at the front of the mouth, and tendency of upper and lower teeth to keep their contact may cause positional changes of the upper and lower incisors.

In a pioneering study on late mandibular growth, Lande (46) searched the existence and amount of late mandibular growth, and found out that point B changed less than gnathion in horizontal direction, suggesting that alveolar growth does not keep pace with mandibular skeletal growth. As a conclusion, he underlined that, compared to mandibular basal bone; the inadequate late growth pace of dentoalveolar bone may not support the lower incisor teeth properly in a yet growing mandible, and may cause an increase in lower incisors.

Chang, Kinoshita and Kawamato (24) et al. carried out a research among 80 young adults and 80 children in a Japanese population and, confirming the statements of Lande, found out that, in puberty mandible grows more than maxilla, thus lower face grows downward and forward compared to middle face, and profile straightens in adulthood.

As reported by Richardson (87), in an implant study, Björk and Palling (15) showed that mandibular prognatism increases relative to maxillary prognatism in male subjects between the age of 12 and 20 years, resulting in straightening of the profile. They also found 1.7 degrees of retroclination of lower incisors on average. As a result, they suggested that this relative increase in mandibular prognatism causes a packing effect in lower incisors, causing them to retrocline and to come in a more crowded situation.

In a later article, Björk (16) defined the pathways of mandibular rotation and their clinical implications. According to his implant studies, he showed that growth in length of the mandible in man occurs essentially at the condyles. The growth at the condyles usually does not occur in the direction of the ramus, but slightly forward. Individual variations in this direction are large, and in adolescent period, have been found to vary by almost 45 degrees. He stated that mandible can rotate forward or backward according to the type of growth at the mandibular condyles. *Forward rotation* can occur in 3 ways. In *Type I*, center of rotation of mandible is in the condyles. In this type of rotation, deep bite occurs, lower dental arch is pressed into the upper. In *Type II,* growth rotation of mandible is located about the incisal edges of lower anterior teeth. Both posterior and anterior face heights increase in this type . *Type III* takes place in the case of large maxillary or mandibular overjet. In this case, center of mandibular growth rotation is located at the level of lower premolar teeth. The inclination of the teeth is greatly influenced by forward growth rotation of mandible. The interincisal angle undergoes a smaller change than the mandibular growth, the eruption of incisors and the posterior teeth are guided mesially, which may create a tendency towards crowding in the anterior segment. *Backward rotation*, however, may take place in 2 ways. When there is a flattening of the cranial base or an incomplete development in the height of the middle cranial fossa, *Type I* backward rotation of mandible takes place, with overdevelopment of anterior face height, and an openbite usually accompanies. In *Type* II, growth takes place usually in the sagittal direction of mandibular condyle, and backward growth rotation occurs about the most distal occluding molars. Symphysis is swung backwards, basal openbite develops and a difficulty in closing the lips occurs. Lower incisors tend to retrocline in order to decrease the alveolar prognatism and to reach the functional contacts with the upper incisors. In this type of backward rotation, the interpremolar and intermolar angles become small, which means that they are inclined mesially in relation to the maxillary premolars and molars. As a result, he emphasized that mandibular growth pattern, thus type of mandibular rotation may have great influence on lower incisor irregularity.

In 1974, Siatkowski (94) defined a method for measuring anterior arch circumference, by means of a mathematical model using arch depth and width. He tested his mathematical model for calculating the anterior arch circumferences of Skillman's case series, and found decreases in all arch circumference measurements. He stated that small increments in arch depth and width result in relatively large changes in arch circumference. In his own case series, he found an increase in interincisal angle between 13 and 18 years, being more in males, and a decrease in maxillary and mandibular anterior arch circumferences in majority of subjects. He claimed that uprighting of incisors can fully account for decreases in anterior arch depth and, therefore decreases in anterior arch circumference. For his opinion, this arch length decrease resulting from incisor uprighting will produce late anterior crowding.

Gormely and Richardson (42) found that maxillary and mandibular length, upper and lower face height increased significantly in a group of 47 subjects, between 18-28 years. In their sample, lower incisors proclined significantly in females and retroclined insignificantly in males between 18-21 years, and did not exhibit a significant change between 21-28 years. They also found that upper incisors retroclined significantly only in females between 18-21 years. Although intersexual differences existed, incisor positions did not changed significantly in their pooled sample. Regarding to these results, opposing Björk and Pauling, Siatkowski, Chang, and Lande, they supported that skeletal and dental relationships tend to remain constant while face height and jaw length dimensions continue to increase; thus, such changes are unlikely to have much influence on late lower anterior crowding in mature adults.

Unlike Gormely and Richardson, Richardson (77), in her research carried out through 22 males and 29 females between the age of 13 and 18 years, found that no relationship exists between facial type and increase in lower anterior crowding. She also found an increase in mandibular length, ramus height, lower face height and a decrease in maxillary plane to mandibular plane angle, showing the anterior rotation of mandible. Interincisal angle, ii-Pog/ Go-

Me angle and Ar-Pog/ Go-Me angle also increased significantly, indicating an average forward direction of eruption and vertical direction of mandibular growth. According to her data, lower anterior crowding increased significantly between 13 and 18 years. Statistics stated that there is a negative correlation between changes in lower anterior crowding and changes in maxillary occlusal plane/mandibular occlusal plane angle, and in lower face height in males. In females changes in N-S-Gn angle found to be positively correlated with the changes in lower anterior crowding. Taking these correlations into consideration, she indicated that a downward direction of growth or treatment change in mandible in young adolescents may result in an increase in lower anterior crowding.

In a later study of Richardson (84) carried out among untreated dental students during their residency, she stated that mandible continued to grow in this period from 18 to 21 years, and rotated backward significantly. She reported that although mandible did rotate, mandibular incisor alignment remained stable and there was no change in lower incisor angulations from 18 to 21 years. Thus, she claimed that late mandibular growth in young adults does not have serious effects on lower incisor position. However, she did not preclude the possibility that, cumulative yet small increments of late mandibular growth may have an influence on lower incisor crowding later in life.

Bondevik (18) carried out a research among 164 Norwegian citizens between 22 and 33 years of age, and found out that both anterior and posterior facial height increases throughout the third decade of life, the increase being more prominent in anterior face, dimension of the lower face increasing more compared to the upper face. He also found significant retroclination of lower incisors and insignificant retroclination of upper incisors, which support the results of other researches.

In his study in a group of patients between 8 years and 22 years, Brodie (20) found that late stages of growth are accompanied by a continuing forward and downward movement of anterior nasal spine and of pogonion, while the dental arch and its supporting bone tends to move more slowly and thus drop behind. However, such behavior of the mandible and alveolar bone does not necessarily accompanied by the uprighting of the incisors. According to his results, these teeth may either become less proclined or more proclined, or remain at their original axial inclination, varying interindividually.

In his study among 49 Swedish adults between the ages 24 and 34 years, Forsberg (30) showed that facial height increases significantly, being related to an increase in the lower face height, since no change was recorded in the upper face height. Mandible rotates backwards as a result of the increase in lower face height. As a response to the posterior rotation of mandible, upper incisors are extruded and lower incisors are extruded and proclined to maintain their functional contact points. Both upper and lower lips are retruded. Debating with the findings of a group of researchers, Forsberg's study demonstrates a backward mandibular rotation and lower incisor proclination, and this proclination of incisors fails to explain an increase in late lower anterior crowding, which was not mentioned in this work.

Bishara et al. (11) in a research among 30 subjects between the ages 25 and 46, found that mandibular and maxillary length, anterior and posterior face heights increased, soft tissue convexity decreased, and upper and lower lips become retruded compared to nose and chin, significantly. They also found out that both maxillary and mandibular intercanine and interincisor widths decreased, and mandibular tooth size- arch length difference (TSALD) increased significantly. As a result, they concluded that age related changes of craniofacial complex continue throughout life at a significantly slower rate, so that their clinical relevance is limited. They also stated that even uncrowded dentitions should expect various amounts of lower anterior crowding later in life, which is a part of the normal ‘‘maturation’’ process.

4.2.2 Occlusal factors

The phenomenon of continuing tooth eruption throughout life is due to a purpose to keep the upper and lower dentitions in occlusion. Alterations in functional occlusion may produce a different pattern of masticatory forces or an occlusion with premature contacts, which may cause a positional change of upper and lower teeth.

Brodie (19), in 1939, suggested that with each stroke of mastication, the upper incisors receive a separating impulse, whereas the lower ones tend to come into closer contact. This implies retroclination of lower incisors, which has already been discussed. The principle may also be applied to individual teeth coming into premature contact, being displaced by the force of occlusion, and allowing adjacent teeth to move toward each other, thus creating a crowded situation.

Fastlich (28) and Lombardi (52) suggested that canine guidance in lateral excursion may cause a lingually directed force on lower canines, with a reduction of intercanine width, thus increasing the incidence of late lower arch crowding.

There is evidence that changes in occlusal relationships via orthodontic treatment of upper dental arch may have an effect on the lower arch. Owman, Bjerklin and Kurol (64) showed that Class II div I cases treated by upper first premolar extractions experience significantly greater lower anterior crowding, compared to untreated children. They suggested that, with reduction of overjet and establishment of incisor contact, occlusal forces and/or soft tissue pressures may be transmitted through the upper incisors to the lower incisors, causing them to become retroclined and crowded.

4.2.3 Soft tissue maturation

It is generally accepted that dentoalveolar structures are responsive to soft tissue pressures and adapt to a position of balance between the muscles of lips, cheeks and tongue.

Thüer, Grunder and Ingervall (102), in their research on pressure from the lips on teeth, showed that maximum pressure during speech is highest at the modiolus, whilst the pressure at rest and the speech posture pressure are the highest at lower midline. They found that the speech posture pressure and the pressure at rest recorded at the modiolus are closely related with the ones recorded at the lower midline. They claimed that the forces acting over a period of time, like speech posture pressure, are probably more important than the maximal pressure, since they could possibly influence the tooth position due to their duration. They also stated that resting pressure influences the positions of the teeth, as is evident from the results of lip bumper researches of Bjerregaard, Bundgaard and Melsen (14), Nevant, Buschang, Alexander and Steffen (58), Osborn, Nanda and Currier (63), and Grossen and Ingervall (43).

Fröchlich, Thüer and Ingervall (33) worked on the pressure of the tongue in the rest position and during swallowing and chewing. They found out a negative pressure at rest at the upper incisors in 20 of 25 subjects, and at lower incisors in 14 of 25 subjects. Pressure at rest and during chewing is significantly lower at the upper incisors than at the lower incisors. This negative pressure at rest position is a striking result, since it is mentioned positive in Thüer et al.'s researches. Some authors like Proffit**,** McGlone and Baret (69) have, however, reported zero resting pressure at the upper and lower incisors. Many authors claim that there is no balance between the forces on the teeth from the tongue and from the orofacial musculature, the forces from the tongue being larger (67). The authors claimed that their results suggest a very well balance between the outer and the inner forces to teeth at rest position, and they added that the previous results would have been partially affected by the testing method used.

Harradine and Kirschen (38) investigated the relationship between perioral muscular activity and tooth position on 41 untreated subjects, and found out that the effects of perioral muscular activity are determined by the presence or absence of the lip competence. According to their results, resting forces have an influence on incisor position in subjects with competent lips, but the intermittent activity from chewing, speaking and swallowing have not. No clinical indicators of the level of perioral activity were found.

Cheng, Peng, Chiou and Tsai (25) examined 112 untreated adults between the ages of 20 to 26 years to understand the role of the tongue in the development of occlusion. They found out that the movements of the tongue during swallowing are related to dentofacial forms, as though the mandibular length increases, motion magnitude of the early final phase of the swallowing action increases and the duration of the swallowing prolongs. Additionally, they found out that those who have longer duration of swallowing tend to have increased gonial angles, step mandibular planes, and opened occlusal planes. However they found no relationship between arch width and tongue movement, but they saw that as arch length increases, the duration of the swallowing lengthens significantly in the late final phase. Regarding to these results, they decided that tongue movement has more effect on the vertical and sagittal development of the dentoalveolar morphology, while buccal pressure might play a more important role on a narrow arch form rather than the tongue.

Subtenly and Sakuda (101) compared 25 relapse and 25 nonrelapse cases and found out that a strong tendency for mandibular intercanine width to maintain its original dimension exists in both groups, relapse cases exhibiting a narrower intercanine arch width initially, which returns to its original dimension after the treatment. They surmised that the lip musculature did not permit the necessary intercanine expansion to maintain good alignment. They claimed that as the mandible increases in size, the lips exert greater pressures than the tongue, creating a lingually directed force counteracting by mesially directed forces, and cause crowding.

Bench (6) studied growth of the cervical vertebrae, hyoid bone, and tongue in relation to the facial skeleton and the denture. He found out that the hyoid bone and the tongue descend with age relative to surrounding structures, and continue to do so after facial growth slows down. He claimed that this was particularly true in persons with long faces and with lack of forward growth, and suggested that it could explain the development of late lower arch crowding.

Cohen and Vig (26) examined the tongue growth in 50 subjects from 2 to 4 years and found out that tongue size increases in time, relative to the intermaxillary. They examined the lip growth of the same sample and found that it continues up to 19 years and exceeds the growth of lower anterior face height (109).

Verdonc, Jorissen, Carels and van Tillo (108) carried out a research on 156 subjects, to examine the interaction between soft tissues and the sagittal development of the dentition and the face. They found out that there is a significant relationship between the cross-sectional surface area of the lower lip and the sagittal position of the lower incisors, the position of the mandible and the position of maxilla. Also, the cross-sectional surface area of the lower lip was found to be related to the sagittal position and the inclination of the upper incisors only in Class I malocclusions and to the sagittal position and the inclination of the lower incisors in Class II Division I malocclusions. They concluded that within Class I the soft tissues have more influence on the position of the upper incisors than on the lower incisors since both upper and lower lips exert a pressure on upper incisors. Additionally, they claimed that in Class II Division I subjects lower lip is situated palatally of the upper incisors, and exerts a labial pressure to the upper lip and a lingual pressure to the lower lip.

Richardson (82) researched the lips and their effect on incisor crowding. Examining 46 subjects between 12,5 and 15,5 years of age, she found that lower incisor crowding increases, upper incisors retrocline significantly in girls and insignificantly in boys, lower incisors procline in boys and retrocline in girls, interincisal angle increases significantly in both genders, cross sectional area of the upper and lower lip increases, the amount of lip separation decreases significantly. However, she found no direct relationship between the soft tissue changes and increased lower arch crowding. Referring to Siatkowski's (94) findings and the results of her study , she claimed that retroclination of the upper incisors and increase in the interincisal angle are associated with the increase in lower incisor crowding, rather than the changes in positional and dimensional changes of lips and the relating soft tissues.

These contradictory data available on the perioral musculature failed to prove a direct relationship between late lower incisor crowding and muscular pattern. Thus, a number of researchers worked on the influence of a changing balance in between the tongue and the perioral musculature, hypothesizing that this change may alter the lower incisors in a more crowding position.

Frankel and Loffler (31), in a study on the effects of function regulator (FR), showed that the reduction of mandibular arch length found in an untreated control group was prevented in subjects treated with the functional regulator (FR) appliance. They claimed that the vestibular shields of the FR appliance favorably influence the sagittal development of the mandibular dental arch by eliminating the restraining forces of the external muscle environment.

In another study, Linder-Aronson and Woodside (48) showed that the lower incisors of children who were mouth breathers were more retroclined and crowded compared with controls, and proclined after adenoidectomy and a changed mode of breathing that altered the muscular environment.

These studies show that lower arch alignment can improve after the removal of adverse muscular forces and, although no direct relationship has been found between changes in soft tissue forces and increased lower arch crowding, it is likely that such changes may adversely affect arrangement of the teeth.

4.2.4 Periodontal forces

Periodontal membrane is the connective tissue which binds the teeth to alveolar bone and holds them in a stabilized, yet dynamic position. Alveolar bone, teeth and periodontal membrane together are a compound living system. Proffit (67) underlined the periodontal membrane as playing an important role in stabilizing the teeth after their terminal vertical positions are attained. He claimed that periodontal membrane is the source of force which maintains the teeth in a stable position despite an imbalance between the lips and the tongue.

Southard et al. (96) found out that periodontium exerts a continuous force on the mandibular dentition and this force acts to maintain the contacts of approximating teeth in a state of compression. They added that this force increases after occlusal loading, and this increase may help to explain late lower anterior crowding, physiologic drifting of the teeth, and maintenance of posterior dental contacts after proximal wear. In another study, they found out a significant correlation between interproximal force and mandibular anterior alignment. They concluded that periodontal forces could contribute the development of late lower anterior crowding (100).

4.2.5 Anterior component of the occlusal force

Anterior component of the occlusal force (ACF) has long been discussed as the possible cause of late lower anterior crowding. Many researchers tried to measure the amount of anterior component of the occlusal force and used strain indicators for this purpose.

Southard et al. (99) designed and developed a method to measure the anterior component of the occlusal force generated by a single tooth under a known axial load. ACF was calculated from interdental friction force (I.P.F). First, a stainless steel matrix strip was slipped between two teeth and the I.P.F when the subject is not biting was measured. Then, I.P.F when the subject is biting was measured. These two values are recorded for each interproximal contact and the difference between them was calculated as the ACF. They found out that I.P.F when the subject is not biting is smaller than I.P.F when the subject is biting, and that since the occlusal load was subjected only to the second molar, the increase in I.P.F on biting could only have been due to a component of occlusal force transmitted anteriorly from the second molar. Additionally, they found out that ACF is not detected mesial to any open contacts and that biting with reduced load results in reduced ACF values for all of the subjects. They also observed that ACF is dissipated through the premolar and the canine contacts, however, in some subjects; it is being transmitted anteriorly along the arch beyond the midline.

Following Southard's measurement technique, a group of researchers evaluated the effects of ACF on mandibular dental arch. Acar, Alcan and Erverdi (1) searched the effects of ACF on postretention crowding. They evaluated 13 subjects treated without extractions and 19 cases treated with mandibular premolar extractions. They measured ACF through the contact points of the buccal teeth only on the mandibular arch, and found moderate positive correlations between ACF and the irregularity index (II) at all three contact points of the posterior dentition in nonexctraction group. In extraction group they reported a positive correlation between ACF and II only at the first molar - second premolar contact points. Regarding to these results they pointed out that ACF acting on the canines seems to be potentially capable of tipping the canines mesially and causing contact slippage at the mandibular anterior arch. From this standpoint they presented ACF as a potential cause of late lower anterior crowding, and suggested its affects on anterior crowding to be investigated in an untreated sample.

Similarly, Akay (3) studied 69 untreated subjects for evaluating the relationship between ACF and II in different facial types, and found out positive correlations between ACF and II at the first molar- second premolar and first premolar- canine contacts.

Turan-Güvercin (103), using the same measurement method and devices in her research, examined 45 treated patients for postretension relapse. However, she found out no relationship between ACF and postretension II, when extraction and nonextraction cases, cases with interproximal reproximation and without interproximal reproximation, cases with a retension device and without a retention device in her sample were compared.

4.2.6 Presence of third molars

Lower third molars have long been thought to be the possible cause of late lower anterior crowding. Thus, many researchers evaluated the presence or absence of third molars in a dental arch and the effect of their eruption or impaction on the alignment of the lower anterior teeth.

Engstöm, Engström and Sagne (27) evaluated the third molar development in relation to skeletal maturation and chronological age in a Swedish population. They found out that in 11% of 391 subjects, lower third molars were congenitally missing on one side or on both sides of the mandible. Additionally, development and maturation of the third molar germ were found to be strongly correlated with age and skeletal maturity. When hand-and-wrist radiographs were evaluated, they found out that crown mineralization of the third molar germ was completed by the time the epiphysis of proximal phalanx of second finger was as wide as its diaphysis. By the time middle phalanx of the third finger's epiphysis capped its diaphysis, crown formation of the third molar was completed in most of the subjects, and the root formation had begun. Completion of the root formation took place at different stages of the skeletal maturation in different individuals, but it came out that the formation of the root was completed, apex still being open, at age of 18,3 years in males and 18 years in females.

Richardson (88), in her research among 70 children, found out that most of the third molars developed at the age of 11 and 12 years, and added that late developers are also found whose third molars' crypts begin their formation at the age of 14, 15 or 16 years. The rate of four third molar agenesis in the early developers group and in the late developers group found out to be 5% and 11%, respectively. She also found no significant difference between the sizes of early developing and the late developing third molars.

Ng, Burns and Kerr (59) examined two groups of 66 patients, with erupted third molars and with impacted third molars. They found out that subjects with impacted third molars tend to have larger teeth and a greater degree of crowding than those with erupted lower third molars. They also reported that differences in arch dimensions between subjects with impacted and erupted lower third molars are small, although arch length and circumference in subjects with impacted third molars tend to be larger, particularly in females.

Forsberg (29) evaluated the tooth material and the amount of crowding in two groups of patients. In first group all four third molar teeth were erupted, while in the other group, third molar teeth were extracted for their failure to erupt. In the extraction group, tooth size and the sum of mesiodistal widths were found to be greater, being more pronounced in female subjects compared to males. They also found out that the dental arches in the extraction group tended to be more crowded than in the group with complete dentition. However, the differences between groups being small and statistically insignificant, he claimed that impaction of the third molars is not likely to cause more crowding, and that the difference in crowding between the groups is possibly associated with differences in tooth size.

Richardson (84) studied the changes in dental arches and in mandibular dimensions in a group of dental students, 33 men and 32 women, with and without lower third molars. The initial records were taken at the age of 18 and the final records were taken at the age of 21. According to her results, no significant difference in space condition took place in any of the groups, and no difference were found between men and women. Additionally, the position of the first molars on any side did not change significantly in both male and female groups. However, the dimension between articulare to pogonion and articulare to B point, both of which imply the mandibular dimension, increased significantly in all groups, being more prominent in males. Also a significant backward rotation of mandible was found in the whole sample. No significant change in the position of lower incisors were found in any of the groups. Regarding to these results, Richardson stated that, between the ages of 18 and 21, lower arch is stable in terms of tooth alignment and mesial drift, regardless of third molar status or continuing mandibular growth. However, she did not preclude the possibility that an increase in crowding may develop later in life.

Niedzielska (60) assessed the dental arch changes in 47 patients of whose third molars were extracted or decided to be left in situ. The patients were divided in two age groups, 14-18 and 19-32 years of age, and four treatment groups, unilateral third molar extraction, bilateral third molar extraction, bilateral third molar retention and bilateral third molar agenesis. Panoramic radiographs and plaster models were assessed. According to the results, length and width of dental arches increased in the third molar extraction sites, and decreased in the third molar retention sites. No change of dental arch length was observed in third molar agenesis group. The severity of crowding increased in dental arch segments where lower third molars retained, whereas it decreased more frequently on the sides where third molars were absent. Interpremolar and intermolar widths decreased in groups with retained third molars, whereas they increased in groups with extracted third molars and with third molar agenesis. However intercanine width did not change in any of the groups in three years interval. Ganss ratio, the ratio of retromolar space to third molar crown width, was low in cases whose length or width of dental arches increased or decreased. Medium to high Ganss ratios were correlated with a lack of change in the lower arch measurements. Regarding these changes, Niedzielska claimed that if sufficient space is available for the third molar to erupt, the tooth assumes a normal position in the dental arch, and does not exert any disadvantageous effect on the other teeth. However, if the space is inadequate, third molars may aggravate already existing crowding.

Harradine and Kirschen (37), in a prospective study, investigated the effects of randomly assigned extraction of third molars on late mandibular incisor crowding. Of 77 patients included in this study, 39 had previously gone for 2 lower premolar extractions without any orthodontic mechanotherapy. All of the 77 patients included, 45 female and 32 male, had crowded third molars and in randomly selected 44 patients, all third molars were removed. Sixty six months later all patients were recalled and final records were taken for assessment. OPT and lateral cephalometric radiographs and plaster study casts were analyzed to measure arch length, arch width and crowding/spacing status. For the data as a whole, II increased 0,9 mm, intercanine width decreased 0,4 mm, and arch length decreased 1,5 mm. When third molar extraction and nonextraction groups were compared, II increased more in nonextraction group compared to extraction group, the difference being statistically insignificant. Intercanine width did not change significantly between the groups. However, arch length for the nonextraction group decreased significantly compared to the extraction group. Regarding these changes, authors concluded that removal of mandibular third molars in an attempt to reduce the degree of late lower incisor crowding cannot be justified.

Most of these previously underlined studies have implied the possible effects of erupting or impacted lower third molar teeth by means of a mesially directed eruption force. In order to assess and quantify the amount of this mesially directed force, a group of researchers designed their studies.

In 1991, Southard et al. (95) hypothesized that a mesially directed force increases the tightness of all posterior tooth contacts mesial to madibular second molar, and that surgical removal of third molars relieves the tightness by eliminating this force. For this purpose, they bilaterally measured the contact tightness between mandibular posterior teeth in 20 patients with bilateral unerupted lower third molars, immediately before and after the unilateral removal of a third molar. Unexpectedly, they found out that mean proximal tightness decreased bilaterally in all contacts after *unilateral* removal of lower molars. The decrease was significant at 6-5 and 4-3 contact. They suspected that this bilateral relief of contact tightness resulted from placing the patient in a supine position for surgery. Thus, they designed another experiment to determine the effects of postural change on proximal contact tightness where no surgery had been performed. For 10 subjects they discovered a mean decrease in the tightness of all mandibular posterior contacts 2 hours after the patient had been moved from an upright to a supine position. The greatest reduction was found to be - %32 at 6-5 contact, and the smallest was found to be - % 10 at 4-3 contact. As a result, they concluded that removal of unerupted mandibular third molars does not significantly relieve proximal contact tightness, but that simple movement from an upright to a supine posture relieves such tightness dramatically.

After assessing their method *in vitro* on a formalin fixed human specimen (36), Fuhrmann et al. (35) measured the interdental frictional forces in a population of 44 patients with erupting maxillary and mandibular third molars. The measurements were taken preoperatively and postoperatively 1, 2, 3, 7 and 12 weeks and also 1 year after extraction or surgical removal of the third molars in all 4 quadrants. Over the first 4 to 12 weeks, interdental forces exhibited a significant postoperative average decrease of 16,1% in the maxilla and 18% in the mandible. After 1 year, the average reduction in the level of interdental forces was found to be 10,3% in the maxilla and 10,9 % in the mandible. 40,7 % of postoperative decrease in the interdental friction force was registered for third molars with a mesial angle of 66° to 90° to the tooth axis of the mandibular second molar. Additionally, they assessed a group of 40 undergraduate students as controls In control group I, 20 persons were measured for interdental friction forces over a 3 month period at 2 week intervals. In control group II, 10 persons were measured for the impact of body position on the interdental friction forces. In control group 3, 10 persons were examined for the impact of the chewing activity on the interdental friction forces. In control group I, the margin of fluctuation of interdental forces in a state of inertia was ±3,5% over a 3-month period. In control group II, interdental friction forces decreased significantly 15,1 % in the maxilla and 13,2 % in the mandible following a 1- hour period in supine position. In control group III, a nonsignificant average reduction of interdental forces were measured in the maxilla (7,8%) and mandible (8,6%), following a 5- minute period of chewing activity. Regarding these results, the authors concluded that the impact of the third molar on the interdental force relationship in a dental arch is frequently lower than often assumed, and that mesially angled third molar in addition to lack of space in the mandible is a certain cause of an increase in the level of interdental force within the dental arch.

These recent studies concentrating on the changes of interdental friction forces after the removal of mandibular third molars are lacking in assessing the correlation between the interproximal force and the lower incisor irregularity. As a result, we designed a study to examine whether a relationship exists between the interproximal forces and the lower incisor irregularity, and whether the eruption of lower third molars affect this relationship or not.

5. MATERIALS and METHOD:

5.1. Materials

5.1.1 Case selection

Participants of this study were selected among first, second and third year dental students of Marmara University Faculty of Dentistry. Three hundred thirty six students were examined. A group of 35 students, who met the selection criteria, volunteered to participate in the study. During the experimental period, 3 of them were eliminated from the study due to recently occurring proximal caries or mandatory extraction of lower third molars due to acute inflammation. Of the remaining 32, 20 had lower third molars bilaterally present, and 12 had bilaterally missing lower third molars. Seven participants were males and 25 were females. The mean age of our participants was 21,1 ± 1,3 years (minimum 19 maximum 24 years) in the beginning of the study.

Volunteers;

1- Having no congenitally missing tooth in the lower arch except lower third molars,
2- Having intact contact surfaces in lower posterior dentition, without any proximal caries and restorations,
3- Having no interdental diastemas in lower posterior dentition,
4- Having no or minimal crowding in lower posterior dentition,
5- Having no previous orthodontic treatment in the lower dental arch,

were included in our study.

The duration of the study was 12 months.

5.1.2. Patient records

Two study groups were organized. Twelve volunteers with bilateral missing lower third molars were included in Group I as controls, and 20 volunteers with bilaterally existing lower third molars were included in Group II. In both groups, lower intraoral study casts were taken initially. Acrylic caps holding 0,7 mm stainless steel metal bars with helices were prepared for both lower molars. For lower right molar, metal helix was bent distally, and for lower left molar, it was bent mesially, in order to distinguish right and left lower first molars from each other on radiographs. Cephalometric radiographs were taken with these acrylic caps mouthed on lower first molars, while panoramic radiographs were taken without acrylic caps. Study casts were prepared for model analyses. Interdental contact tightness was measured intraorally. Panoramic and cephalometric radiographs were obtained at baseline (T1) and 12. (T3) months only. Study casts were obtained and contact tightness measurements were performed at baseline (T1), 6. (T2), and 12. (T3) months.

The interproximal forces were recorded in the mouth of volunteers in between;

- left and right lower first molars and lower second premolars (36-35 and 46-45),
- left and right lower second premolars and lower first premolars (35-34 and 45-44),
- left and right lower first premolars and lower canines (34-33 and 44-43).

On cephalometric radiographs of the participants;

- the distance between left and right lower first molars and the vertical reference line (36-VP and 46-VP)
- the angle between left and right lower first molars and the mandibular plane (36-GoMe and 46-GoMe)
- the angle between lower incisors and mandibular plane (IMPA)
- ANB angle

- NAPg angle
- the distance between the points Ar and Pg (Ar-Pg)

were measured.

On panoramic radiographs of the patients in Group II;

- the angles between the long axes of left and right lower third molars and the transverse plane of mandible (38-GoGo and 48-GoGo)

were measured.

On lower dental study casts;

- Little's irregularity index (I.I.)
- arch length
- intercanine distance
- interpremolar distance
- intermolar distance

were measured.

5.1.3. Evaluation of the measurements

Speaking of interproximal force, any possible increase or decrease of this force in between the lower posterior teeth at three time intervals (T1-T2, T2-T3 and T1-T3), and differences between Group I and Group II were calculated.

On panoramic radiographs, any possible change in the position of lower third molars was recorded for Group II between T1-T3.

On lateral cephalometric radiographs, mesialization and/or mesial tipping of lower first molars, and the change in the lower incisor inclinations were calculated. Additionally, in order to distinguish the effects of late mandibular growth, the changes in mandibular dimensions were measured. All of the measurements were made between T1-T3. The recorded changes in Group I and Group II were compared for the significance of intergroup differences.

On dental study casts, the changes in lower incisor irregularity, lower arch length, and lower intercanine, interpremolar and intermolar distances between T1-T2, T2-T3 and T1-T3 were measured. The changes in Group I and Group II were compared for intragroup differences.

Taking the differences in all parameters into account, any possible correlations in between different variables were searched. Correlation analyses were carried out in between the changes in interproximal force and the changes in lower incisor irregularity, lower arch length, lower intercanine, interpremolar, intermolar width, and the changes in the position of lower first molars, lower incisors and lower third molars were assessed with correlation analysis.

5.2 Method

5.2.1 Measurement of interdental contact tightness

5.2.1.1 Strain gauge and strain indicator

To detect the interproximal force, interdental frictional force measurements for lower posterior dentition were made with a tension transducer that incorporated a 120Ω strain gauge (Model EA-06-062AP-120, Measurements Group, Inc, Raleigh, NC in figure 1) connected to a digital strain indicator (Model P-3500, Measurements Group, in figure 2). A 0.05-mm thick metal strip was replaced interproximally and withdrawn by using the hook of the tension transducer with a speed of 3 to 5 mm per second (Figure 3). The readings were taken from 3 contact points on both quadrants of the lower dental arch; first molar-second premolar (36-35 and 46-45), second premolar-first premolar (35-34 and 45-44), first premolar-canine (34-33 and 44-43). Each measurement was taken twice, and the readings were averaged. All measurements were taken when the participant was sitting in an upright position and was not biting. Frictional force measurements were converted to interproximal force values (I.P.F) with the formula *I.P.F = f/2u* (f = frictional force, u = coefficient of dynamic friction between human dental enamel and stainless steel strip) (62, 94, 36). By using an apparatus that applied a known I.P.F between extracted teeth, the coefficient of dynamic friction in our experimental setup was previously determined to be 0,145. The coefficient of dynamic friction previously determined by Southard et al. was used in the present study (98).

5.2.1.2 Calibration

The values read by the strain indicator used in this study were in micro-strains. In order to translate these values into Newton (N), the strain indicator was calibrated by known weights. The strain transducer in our experimental set-up was stabilized and cumulatively increasing weights were hang. The strain indicator was balanced to zero before the application of each increasing weight. A coefficient was calculated to convert micro strain values to Newton (0,19), and micro-strain measurements were multiplied by this standard deviation value in order to translate the I.P.F values into Newton.

Figure 1: Strain indicator.

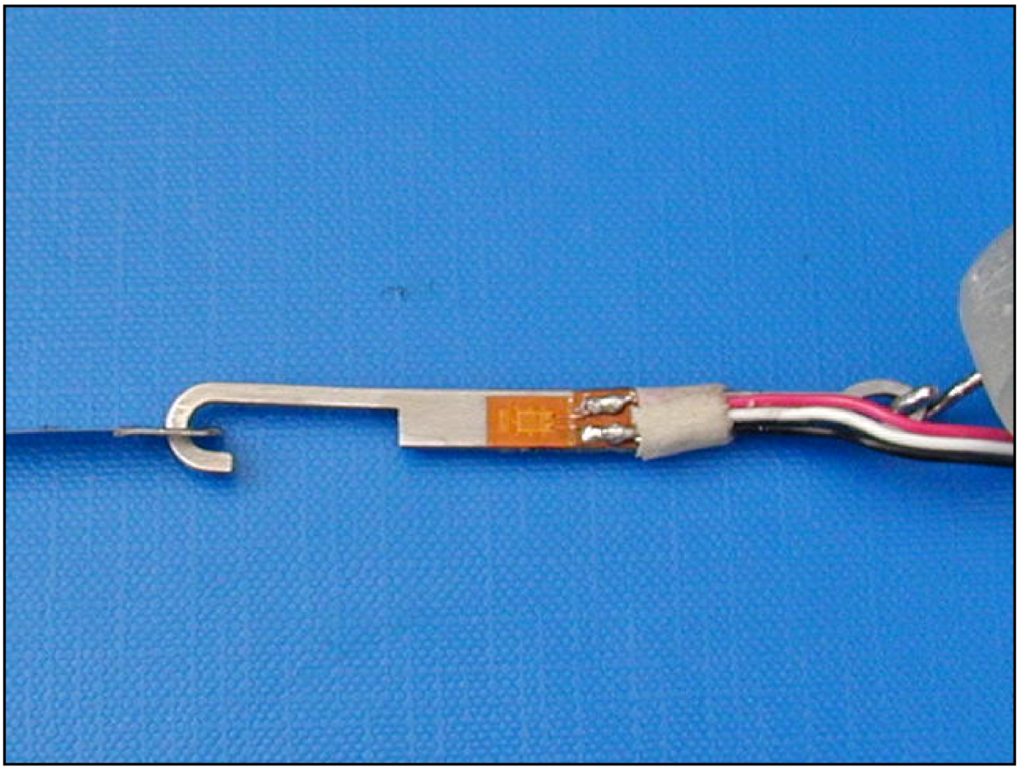

Figure 2: Strain gauge.

Figure 3: Intraoral measurement of interproximal force (I.P.F).

5.2.2 Evaluation of cephalometric and panoramic radiographs

5.2.2.1 Machines used in radiographic recording

Lateral cephalometric and panoramic radiographs of the participants were taken in Marmara University Faculty of Dentistry Department of Oral Diagnosis and Radiology. Veraviewapocs (J. Morita MFC. Corp., Kyoto-Japan) machine was used. The distance between the x-ray source and the subjects' ortho-axial plane was 180 cm, and the distance between the x-ray film and the subjects' ortho-axial plane was 12 cm. The subjects were posed for 1,1 second for cephalometric radiographs, and 8 seconds for panoramic radiographs.

Radiographic tracings were made manually on a drawing paper (Quantum, 94 gr/m²) with a 0,3 mm drawing pencil. In order to reduce the method error, the same observer traced the radiographs, and double images were centered while tracing.

5.2.2.2 Landmarks used in cephalometric tracing

1- Sella (S): The center of the hypophyseal fossa know as sella turcica.
2- Nasion (N): The most anterior point on the frontonasal suture in the midsagittal plane.
3- Point A (A): Deepest point of the curve of the bone between the anterior nasal spine and dental alveolus.
4- Point B (B): The deepest midline point on the mandible between infradentale and pogonion.
5- Pogonion (Pog or P): Most anterior point on the mental protuberance.
6- Menton (Me): Lowermost point of the contour of the mandibular symphysis.
7- Gonion (Go): The most posterior inferior point at the angle of mandible, located by intersection of the ramal plane and the mandibular plane.
8- Articulare (Ar): A point at the junction of the posterior border of the ramus and the inferior border of the posterior cranial base (occipital bone).
9- Lower Incisor Tip (LIT): The incisor tip of the most anterior mandibular incisor.
10- Lower Incisor Apex (LIA): The apex of the most anterior mandibular incisor.

All landmarks are displayed in figure 4.

5.2.2.3 Planes used in cephalometric tracing

11- SN: The plane passing through S and N points.
12- Constructed Frankfurt Horizontal Plane or X axis (CFH): Constructed Frankfurt horizontal plane; an artificial reference plane intersecting with point S by displaying 7° angle under SN plane.

13- Vertical Plane or Y axis (VP): An artificial reference plane perpendicular to X axis and passing through S.

14- MP: Mandibular plane passing through Go and Me points.

15- Lower incisor axis (LIA): The axis line drawn between LIT and LIA points.

16- NA: The plane between points N and A.

17- NB: The plane between points N and B.

18- APog: The plane between points A and Pog.

19-Lower Right Molar Axis: The axis of lower right molar determined by the metal stand in the acrylic cap.

20-Lower Left Molar Axis: The axis of lower left molar determined by the metal stand in the acrylic cap.

All planes are displayed in figure 5.

5.2.2.4 Angular measurements used in cephalometric evaluation

21- ANB: Angle displaying anteroposterior relationship between maxilla and mandible.

22- NAPog: Wide angle between the points N, A and Pog.

23- 36-MP (Lower left first molar axis to MP angle): Angle describing the position of lower left first molar.

24- 46-MP (Lower right first molar axis to MP angle): Angle describing the position of lower right first molar.

25- IMPA (Lower incisor axis to MP angle): Angle describing the position of lower incisor.

All angles are displayed in figure 6.

5.2.2.5 Linear measurements used in cephalometric evaluation

26- Ar-Pg: Distance between points Ar and Pog; describing the length of mandible.

27- 36-VP: Distance between lower left first molar and vertical reference plane.
28- 46-VP: Distance between lower right first molar and vertical reference plane.

All linear measurements are displayed in figure 7.

5.2.2.6 Landmarks used in panoramic tracing

29- Go right: Gonion point of the right side of mandible.
30- Go left: Gonion point of the left side of mandible.

All panoramic landmarks are displayed in figure 8.

5.2.2.7 Planes used in panoramic tracing

31- Go-Go: The line between two Gonion points of mandible.
32- Lower right third molar axis (LRFMA): The axis line drawn by the help of acrylic cap of lower right first molar.
33- Lower left third molar axis (LLFMA): The axis line drawn by the help of acrylic cap of lower left first molar.

All planes are displayed in figure 9.

5.2.2.8 Angular measurements used in panoramic radiograph

34- 46-GoGo: The medial angle between the base of mandible and the axis of lower right first molar.
35- 36-GoGo: The medial angle between the base of mandible and the axis of lower left first molar.

All angles are displayed in figure 10.

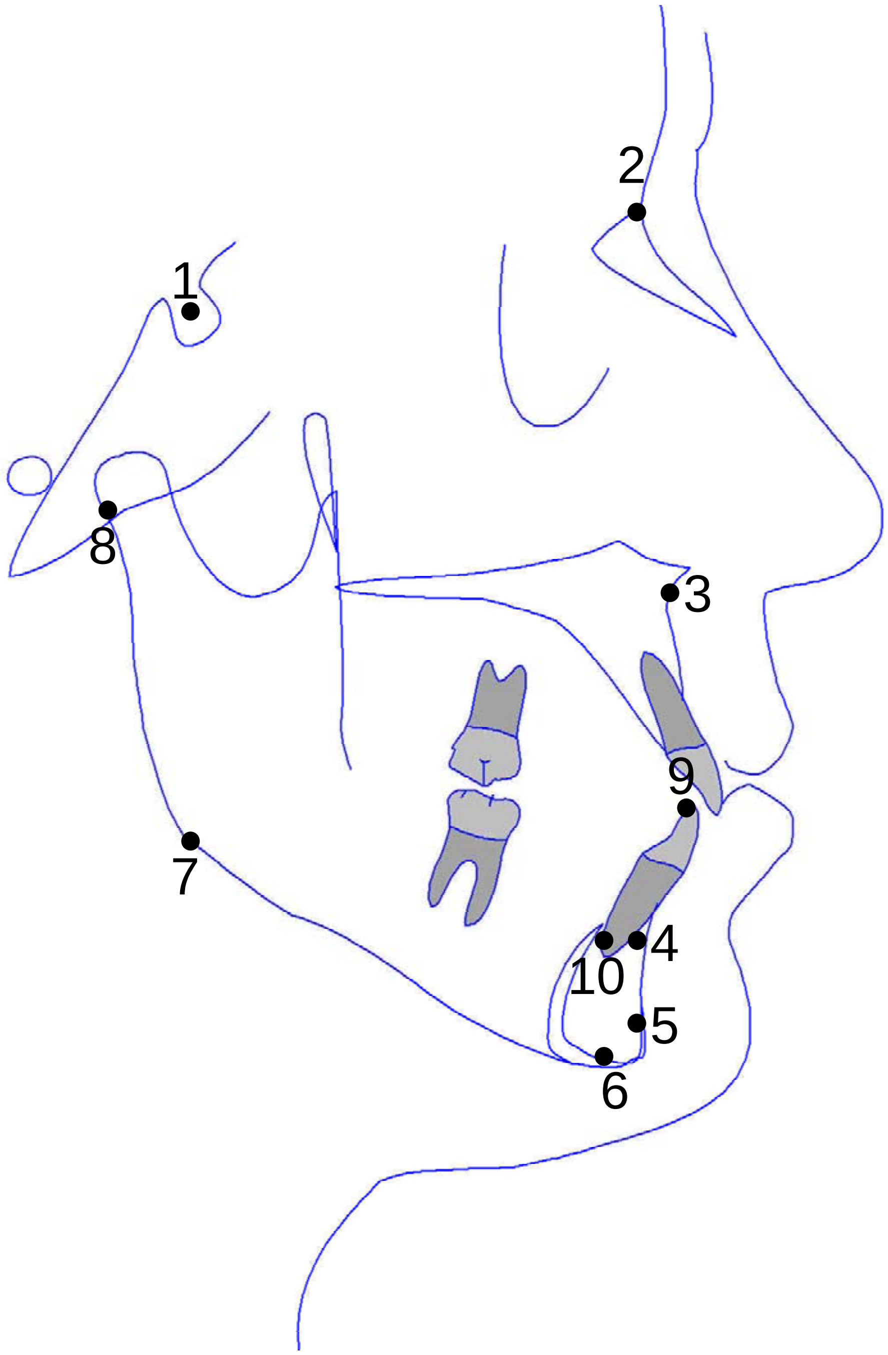

Figure 4: Landmarks used in cephalometric tracing.

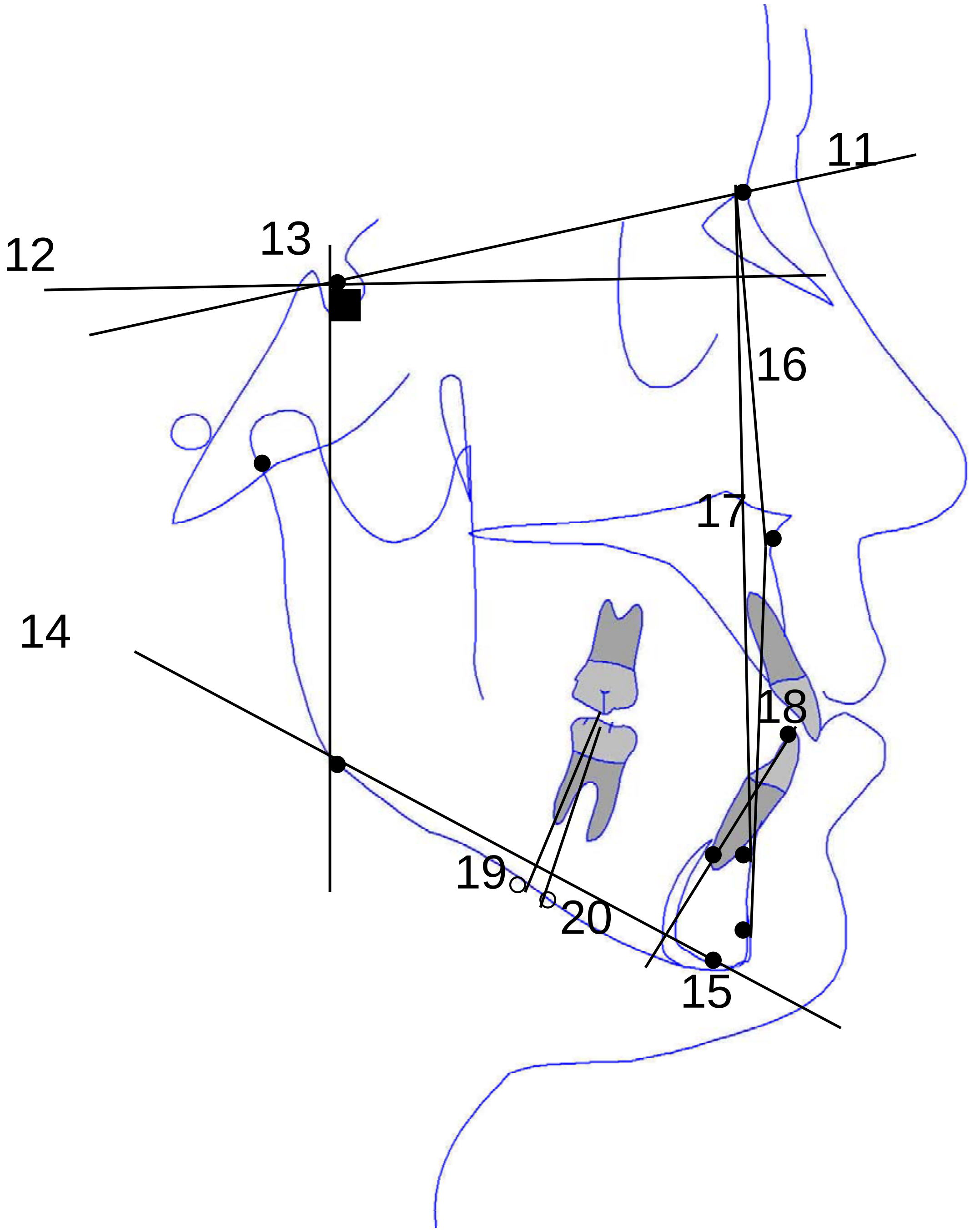

Figure 5: Planes used in cephalometric tracing.

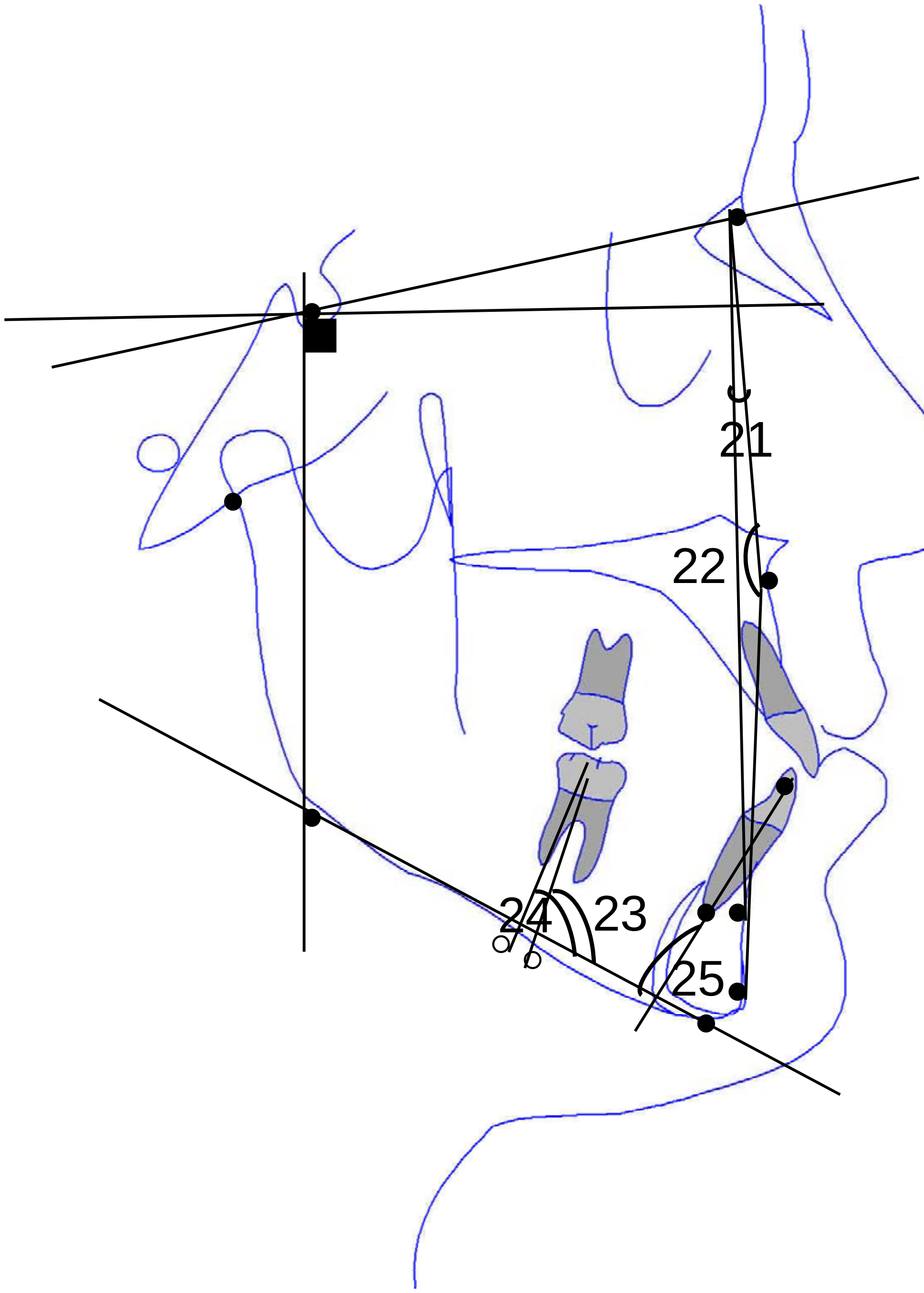

Figure 6: Angles measured for cephalometric evaluation.

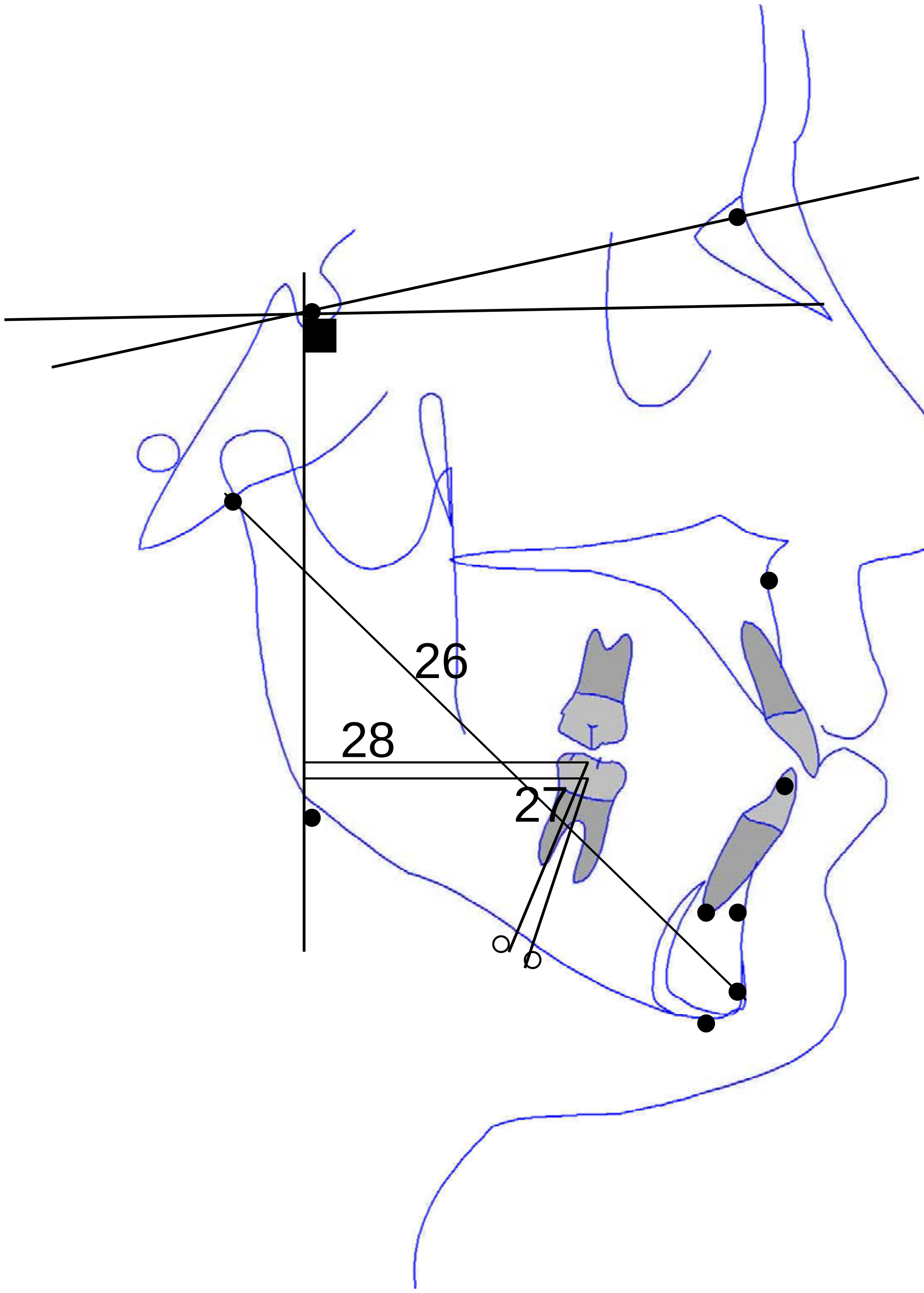

Figure 7: Linear measurements for cephalometric evaluation.

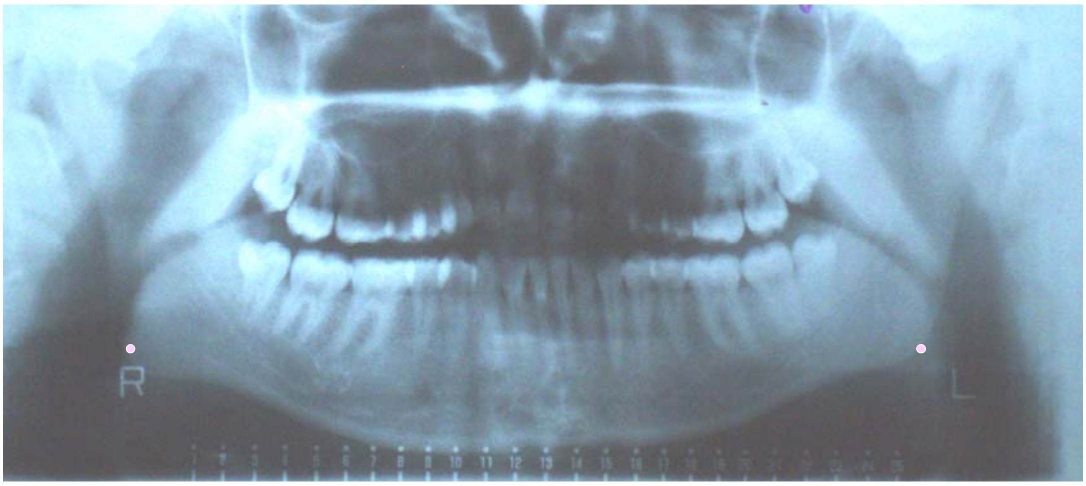

Figure 8: Landmarks used in panoramic tracing.

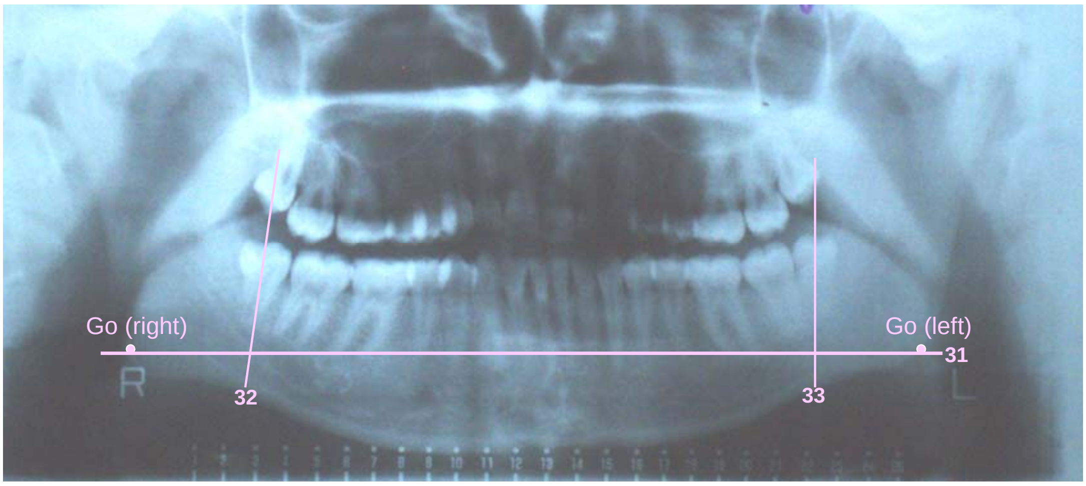

Figure 9: Planes used in panoramic tracing.

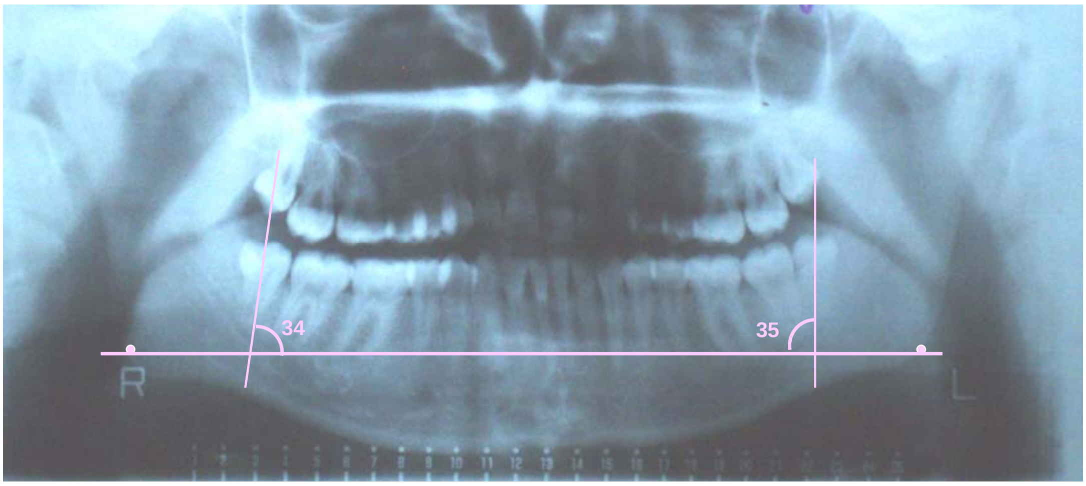

Figure 10: Angles measured in panoramic evaluation.

5.2.3 Model Analyses

Measurements on dental study casts were made by a digital caliper that can measure within the limit of 0,01 mm. Following linear parameters were evaluated:

1- Little's irregularity index (II): The sum of distances between the anatomical contact points of six mandibular anterior teeth. (Figure 11)

2- Arch length: The sum of distances between the anatomical contact points of two mandibular central incisors and the anatomical contact points of left and right mandibular first molars. (Figure 11)

3- Intercanine width: The distance between the cusp tips of left and right mandibular first canines. (Figure 12)

4- Interpremolar width: The distance between the buccal cusp tips of left and right mandibular second premolars. (Figure 12)

5- Intermolar width. The distance between the mesiobuccal cusp tips of left and right mandibular first molars. (Figure 12)

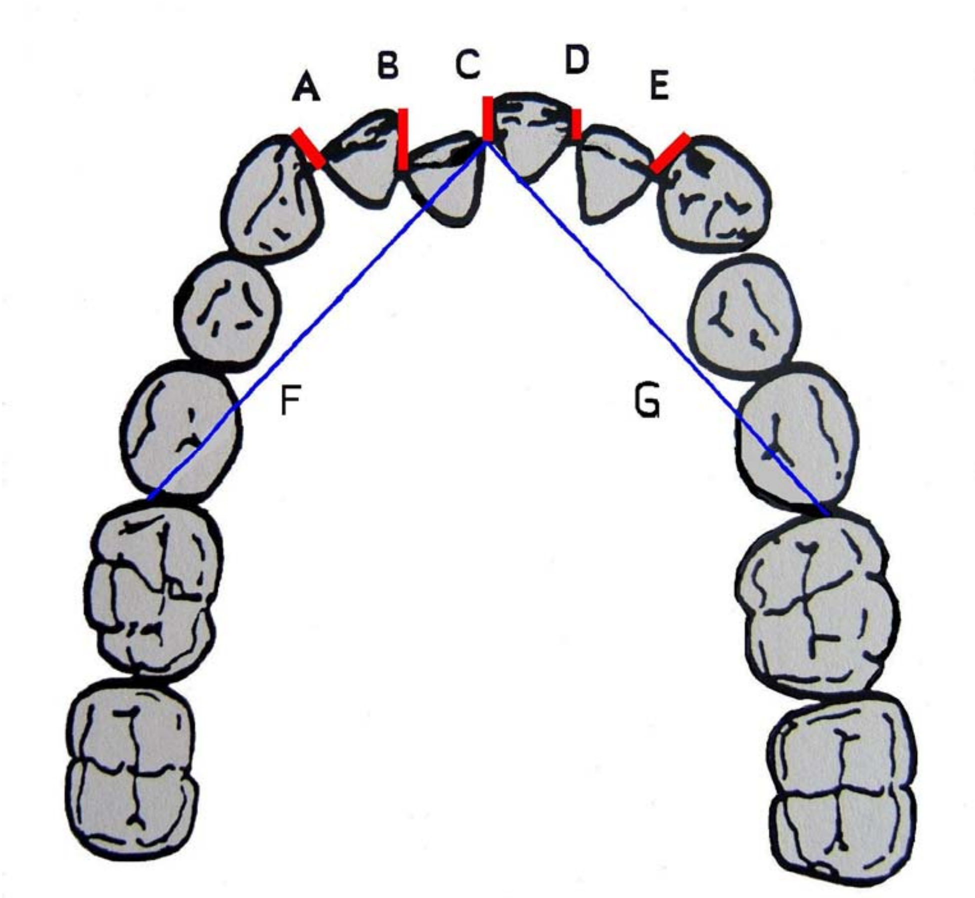

Figure 11: 1- Irregularity Index(II) = A+B+C+D+E

2- Arch length = F+G

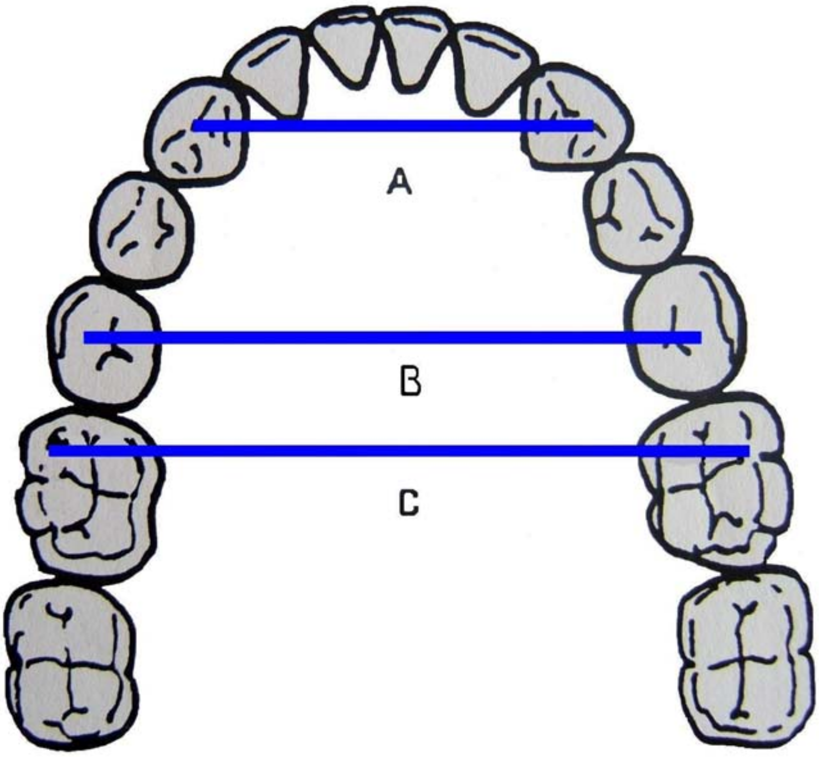

Figure 12: 3- Intercanine width (A)
4- Intercanine width (B)
5- Intermolar width (C)

5.3 Calculation of Method Error

One month after completion of model analyses, panoramic and cephalometric evaluations, and frictional measurements, 10 participants were randomly selected. For dental study casts, and panoramic and cephalometric radiographs, all of the parameters were measured for the second time. For I.P.F, all the measurements were carried out twice in the same section, 15 minutes following one another. Assessments were made to calculate the method error.

5.4 Statistical Method

SPSS (Statistical Package for Social Sciences) for Windows 15.0 software was used for statistical analyses. Parameters exhibiting normal distribution were evaluated by Student t test for intergroup differences, and parameters not exhibiting normal distribution were evaluated by Mann Whitney U test for intergroup differences. Parameters exhibiting normal distribution were evaluated by paired sample t test for intragroup differences. Spearman's rho correlation test was used to asses the relationships between different parameters. Intraclass correlation coefficient (ICC) was calculated for assessment of method error. Results were evaluated within a 95% confidence interval, and statistical significance level was assessed at $p<0.05$.

6. RESULTS:

6.1 Measurement Error

Table 1: Intraclass correlation coefficients and %95 confidence interval for model analysis, cephalometric analysis and panoramic analysis parameters.

		Intraclass correlation coefficient	%95 confidence interval	
Model Analysis	II (mm)	0,995	0,979	0,999
	Arch length (mm)	0,990	0,960	0,998
	Intercanine width(mm)	0,998	0,991	0,999
	Interpremolar width(mm)	0,999	0,996	1,000
	Intermolar width(mm)	0,999	0,996	1,000
Cephalometric Analysis	36-GoMe(°)	0,972	0,893	0,993
	46-GoM(°)	0,935	0,763	0,984
	36-VP(mm)	0,983	0,933	0,996
	46-VP(mm)	0,987	0,950	0,997
	IMPA(°)	0,928	0,737	0,982
	ANB(°)	0,963	0,858	0,991
	NAPg(°)	0,969	0,879	0,992
	Ar-Pg(mm)	0,984	0,938	0,996
Interproximal Force	36-35(N)	0,979	0,917	0,995
	35-34(N)	0,958	0,841	0,989
	34-33(N)	0,839	0,780	0,958
	46-45(N)	0,987	0,950	0,997
	45-44(N)	0,993	0,971	0,998
	44-43(N)	0,977	0,909	0,994
Panoramic Analysis	48-Go_LGo_R(°)	0,984	0,938	0,996
	38- Go_LGo_R (°)	0,995	0,981	0,999

Method error calculations for each parameter, and upper and lower limit for 95 % confidence interval are exhibited in table 1. Intraclass correlation coefficient (ICC) for every single parameter was found to be approximating 1.00. The lowest ICC was found to be 0.839 for I.P.F measurement at contact point 34-33. Findings suggest that I.P.F measurements, model analyses, cephalometric and panoramic measurements are reliable and within acceptable limits.

6.2 Model Analysis

6.2.1 Irregularity index (I.I)

Table 2: Evaluation of irregularity index (I.I)

II (mm)	Group I Mean±SD	Group II Mean±SD	p^{+}
T1	3,31±2,01	4,97±3,09	***0,108***
T2	3,97±2,16	5,60±3,28	***0,136***
T3	4,42±2,43	5,86±3,25	***0,197***
T1-T2 p^{++}	***0,002***	***0,001***	
T1-T3 p^{++}	***0,003***	***0,001***	
T2-T3 p^{++}	***0,027****	***0,001***	

$^{+}$ *Student t test* $^{++}$ *Paired Sample t test*

* *p<0.05* ** *p<0.01*

No significant difference exists between groups for II measurements at T1, T2 and T3 periods (p>0.05).

In Group I; the amount of increase in II between T1 and T2, and T1 and T3 are found to be highly significant (p<0.01). The amount of increase in I.I between T2 and T3 is found to be significant (p<0.05).

In Group II; the amount of increase in I.I between T1 and T2, T1 and T3, and T2 and T3 are found to be highly significant($p<0.01$)..

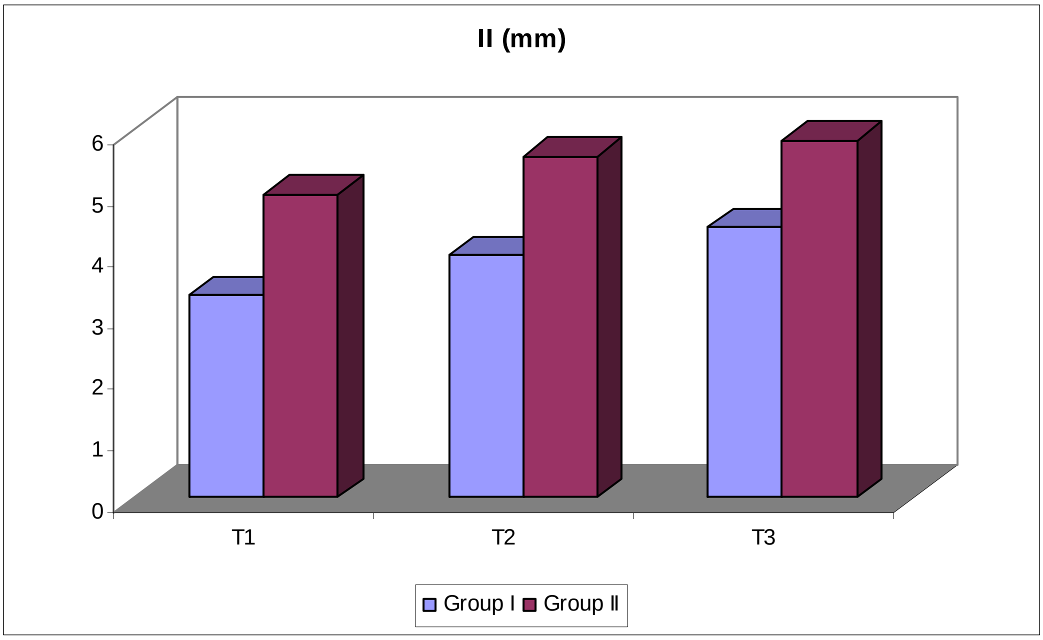

Figure 13: Incisor irregularity for group I and group II at 3 intervals.

6.2.2 Arch length

No significant difference between groups exists for arch length at T1, T2 and T3($p>0.05$).

Table 3: Arch length evaluation for groups at 3 measurement times.

Arch length (mm)	**Group I**	**Group II**	***p*** $^{+}$
T1	59,69±3,03	59,24±3,07	***0,689***
T2	59,18±2,99	58,65±2,88	***0,624***
T3	58,72±3,11	58,15±3,12	***0,616***
T1-T2 p $^{++}$	***0,003*****	***0,001*****	
T1-T3 p $^{++}$	***0,001*****	***0,001*****	
T2-T3 p $^{++}$	***0,001*****	***0,004*****	

$^{+}$ *Student t test* $^{++}$ *Paired Sample t test*

*** p<0.01*

In Group I; the amount of decrease in arch length between T1 and T2, T1 and T3, and T2 and T3 are found to be highly significant(p<0.01)..

In Group II; the amount of decrease in arch length between T1 and T2, T1 and T3, and T2 and T3 are found to be highly significant(p<0.01)..

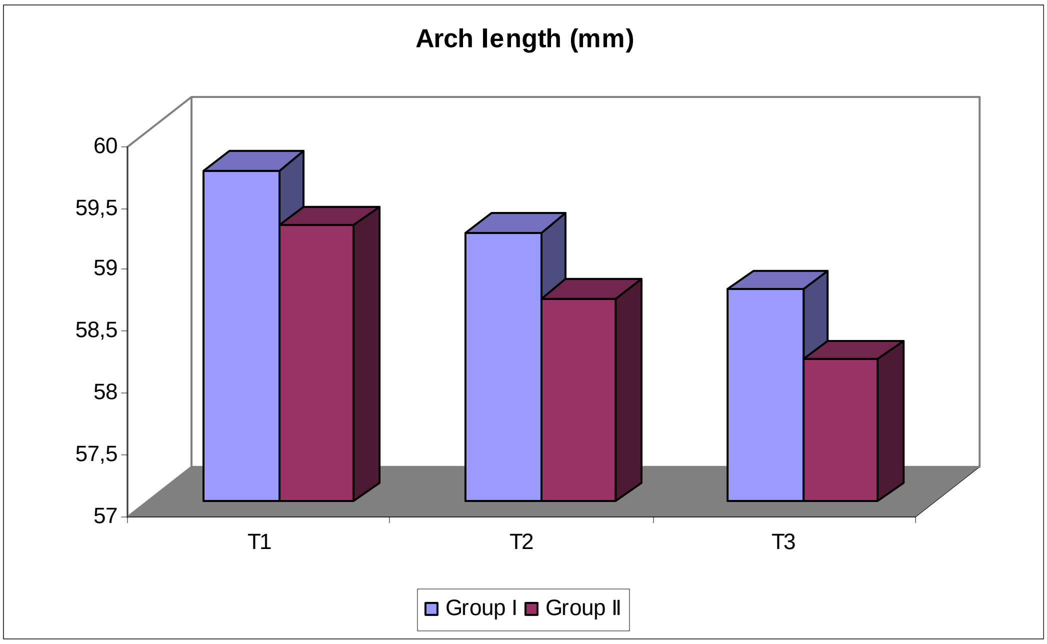

Figure 14: Arch length measurements of group I and group II at 3 intervals.

6.2.3 Intercanine Width

No significant difference exists between group I and group II for intercanine width measurements at T1, T2 and T3 periods ($p>0.05$).

In Group I; the amount of decrease in intercanine width between T1 and T2, T1 and T3 are found to be highly significant($p<0.01$). The amount of decrease in intercanine width between T2 and T3 are found to be significant($p<0.05$).

In Group II; ; the amount of decrease in intercanine width between T1 and T2, T1 and T3 are found to be highly significant($p<0.01$). The amount of decrease in intercanine width between T2 and T3 are found to be significant($p<0.05$)..

Table 4: Evaluation of intercanine width at three time intervals

Intercanine width (mm)	**Group I**	**Group II**	***p***$^{++}$
T1	25,12±1,83	26,04±1,55	***0,141***
T2	24,86±1,84	25,85±1,55	***0,116***
T3	24,70±1,89	25,59±1,72	***0,181***
T1-T2 p^{++}	***0,001****	***0,001****	
T1-T3 p^{++}	***0,001****	***0,001****	
T2-T3 p^{++}	***0,045****	***0,010****	

$^{+}$ *Student t test* $^{++}$ *Paired Sample t test*

** p<0.05* *** p<0.01*

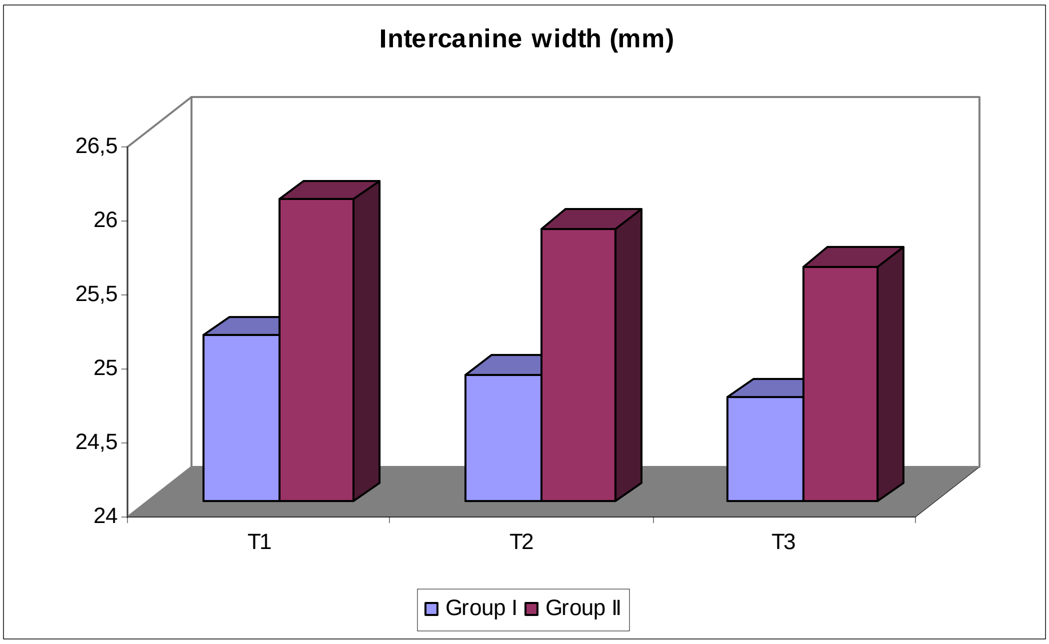

Figure 15: Intercanine width measurements of group I and group II at 3 intervals.

6.2.4 Interpremolar Width

Table 5: Interpremolar width evaluation

Interpremolar width (mm)	Group I	Group II	p^{+}
T1	38,40±2,53	38,01±3,35	***0,729***
T2	38,04±2,55	37,97±3,41	***0,951***
T3	37,75±2,52	37,73±3,40	***0,982***
T1-T2 p⁺⁺	***0,023****	***0,661***	
T1-T3 p⁺⁺	***0,002*****	***0,016****	
T2-T3 p⁺⁺	***0,004*****	***0,005*****	

$^{+}$ *Student t test* $^{++}$ *Paired Sample t test*

* *p<0.05* ** *p<0.01*

No significant difference exists between group I and group II for interpremolar width measurements at T1, T2 and T3 periods (p>0.05).

In Group I; the amount of decrease in interpremolar width between T1 and T2 is found to be significant (p<0.05). The amount of decrease in interpremolar width between T2 and T3, and T1 and T3 are found to be highly significant (p<0.01)..

In Group II; the amount of decrease in interpremolar width between T1 and T2, T1 and T3 are found to be significant(p<0.05). The amount of decrease in intercanine width between T2 and T3 are found to be highly significant(p<0.01)..

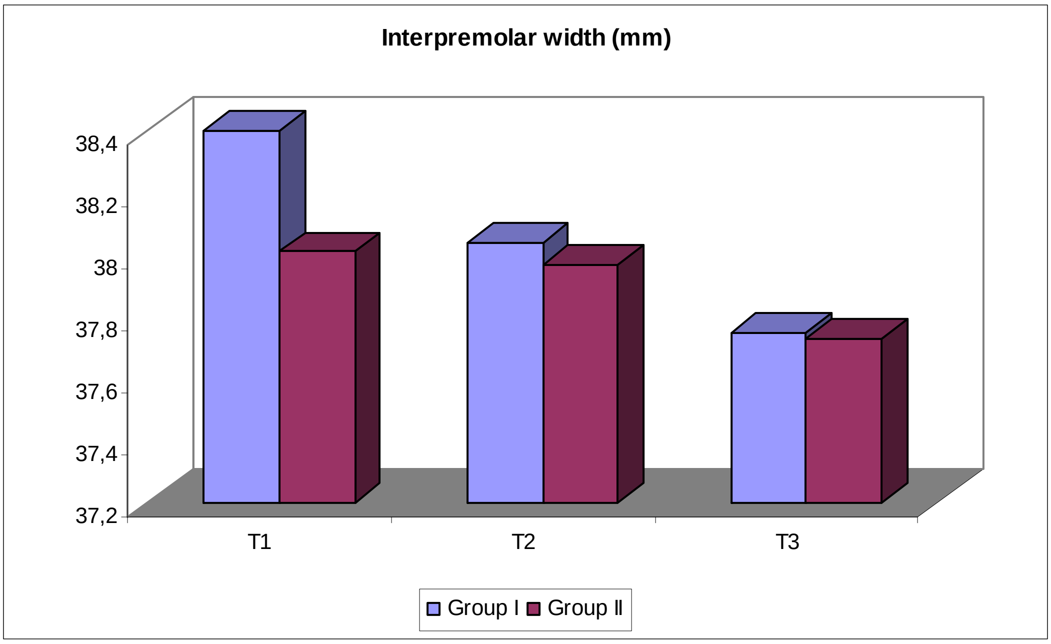

Figure 16: Interpremolar width measurements of group I and group II at 3 time intervals.

6.2.5 Intermolar Width

Table 6: Intermolar width evaluation

Intermolar width (mm)	Group I	Group II	p^{+}
T1	43,72±2,04	43,19±3,67	***0,650***
T2	43,18±2,37	42,94±3,55	***0,838***
T3	42,97±2,27	41,99±4,23	***0,466***
T1-T2 p $^{++}$	***0,002****	***0,050****	
T1-T3 p $^{++}$	***0,001****	***0,050****	
T2-T3 p $^{++}$	***0,076***	***0,108***	

$^{+}$ *Student t test* $^{++}$ *Paired Sample t test*

** p<0.05* *** p<0.01*

No significant difference exists between group I and group II for intermolar width measurements at T1, T2 and T3 periods ($p>0.05$).

In group I; the amount of decrease in intermolar width between T1 and T2, and T1 and T3 are found to be highly significant ($p<0.01$). The amount of decrease in intermolar width between T2 and T3 is found to be significant($p<0.05$)..

In group II; ; the amount of decrease in intermolar width between T1 and T2, T1 and T3, and T2 and T3 are found to be significant($p<0.05$).

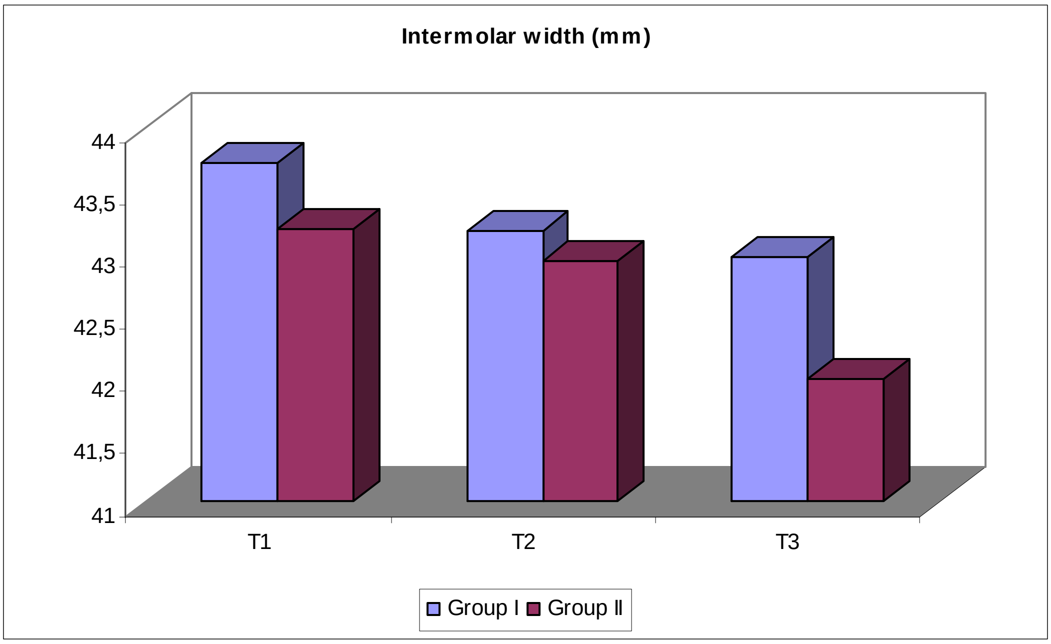

Figure 17: Intermolar width measurements of group I and group II at 3 intervals.

6.3 Cephalometric Analysis

Table 7: Evaluation of cephalometric analyses

		Group I	Group II	p^{+}
	T1	59,58±12,21	56,65±8,33	***0,425***
36– GoMe(°)	**T3**	59,41±11,91	56,80±8,09	***0,510***
	T1-T3 p^{++}	***0,894***	***0,927***	
	T1	62,66±7,35	60,90±7,73	***0,529***
46– GoMe(°)	**T3**	63,00±8,55	61,15±8,39	***0,554***
	T1-T3 p^{++}	***0,818***	***0,810***	
	T1	37,79±3,70	37,42±5,64	***0,826***
36 – VP(mm)	**T3**	36,87±4,02	37,25±5,52	***0,839***
	T1-T3 p^{++}	***0,276***	***0,755***	
	T1	35,20±3,22	34,75±6,59	***0,795***
46 – VP(mm)	**T3**	35,29±4,18	34,57±6,33	***0,730***
	T1-T3 p^{++}	***0,878***	***0,768***	
	T1	96,45±6,47	92,65±6,43	***0,116***
IMPA (°)	**T3**	96,75±5,22	92,85±5,72	***0,064***
	T1-T3 p^{++}	***0,708***	***0,694***	
	T1	3,91±2,27	3,70±1,75	***0,764***
ANB(°)	**T3**	3,83±2,44	3,50±2,01	***0,678***
	T1-T3 p^{++}	***0,723***	***0,163***	
	T1	174,25±6,16	175,02±4,34	***0,680***
NAPg(°)	**T3**	174,45±5,72	174,80±4,21	***0,847***
	T1-T3 p^{++}	***0,817***	***0,687***	
	T1	111,33±3,42	113,60±6,90	***0,226***
Ar-Pg (mm)	**T3**	111,50±3,28	114,40±6,98	***0,123***
	T1-T3 p^{++}	***0,551***	***0,004****	

$^{+}$ *Student t test* $^{++}$ *Paired Sample t test* ** *p<0.01*

6.3.1 36-GoMe Angle

No significant difference exists between group I and group II for 36-GoMe angle values at T1 and T3 periods (p>0.05).

In group I; no statistically significant difference is observed for 36-GoMe angle between T1 and T3 (p>0.05).Also in ***group II;*** no statistically significant difference is observed for 36-GoMe angle between T1 and T3(p>0.05).

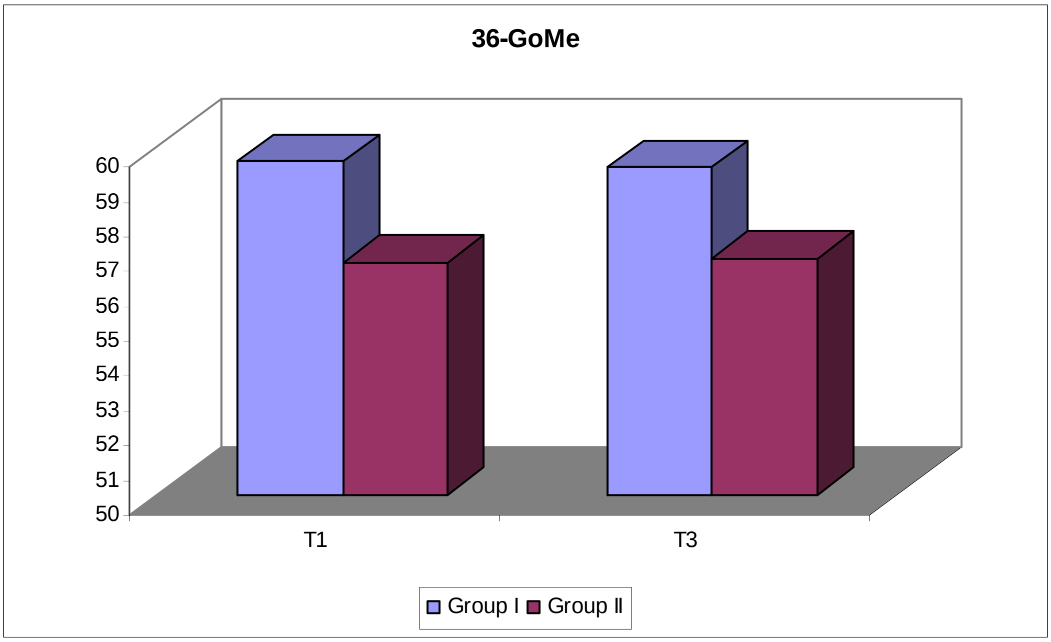

Figure 18: 36-GoMe angle of group I and group II at 2 time intervals.

6.3.2 46-GoMe Angle

No significant difference exists between group I and group II for 46-GoMe angle values at T1 and T3 periods (p>0.05).

In group I; no statistically significant difference is observed for 46-GoMe angle between T1 and T3(p>0.05).Also in ***group II;*** no statistically significant difference is observed for 46-GoMe angle between T1 and T3(p>0.05).

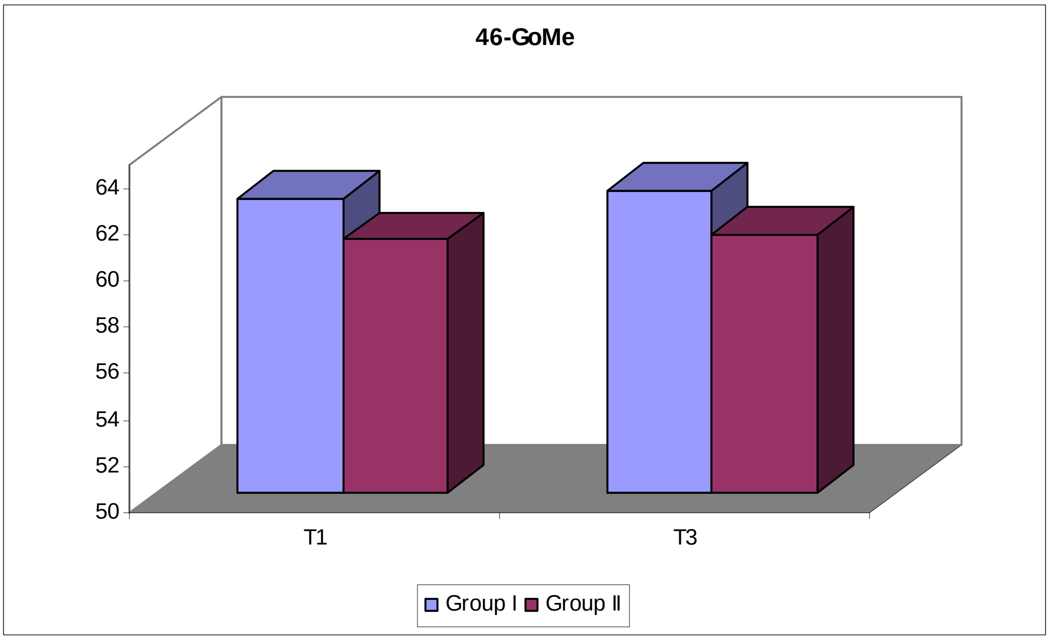

Figure 19: 46-GoMe angle of group I and group II at 2 time intervals

6.3.3 36-VP Distance

No significant difference exists between group I and group II for 36-VP distance values at T1 and T3 periods (p>0.05).

In group I; no statistically significant difference is observed for 36-VP distance between T1 and T3(p>0.05).Also in ***group II;*** no statistically significant difference is observed for 36-VP distance between T1 and T3(p>0.05).

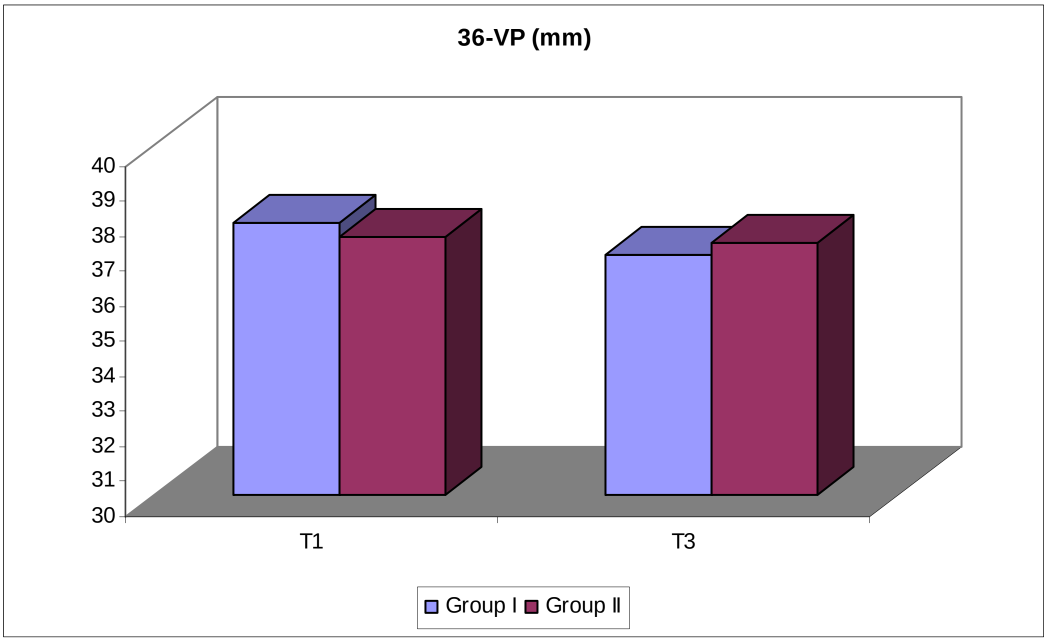

Figure 20: 36-VP values of group I and group II at 2 time intervals

6.3.4 46-VP Distance

No significant difference exists between group I and group II for 46-VP distance values at T1 and T3 periods ($p>0.05$).

In group I; no statistically significant difference is observed for 46-VP distance between T1 and T3($p>0.05$).Also in ***group II;*** no statistically significant difference is observed for 46-VP distance between T1 and T3($p>0.05$).

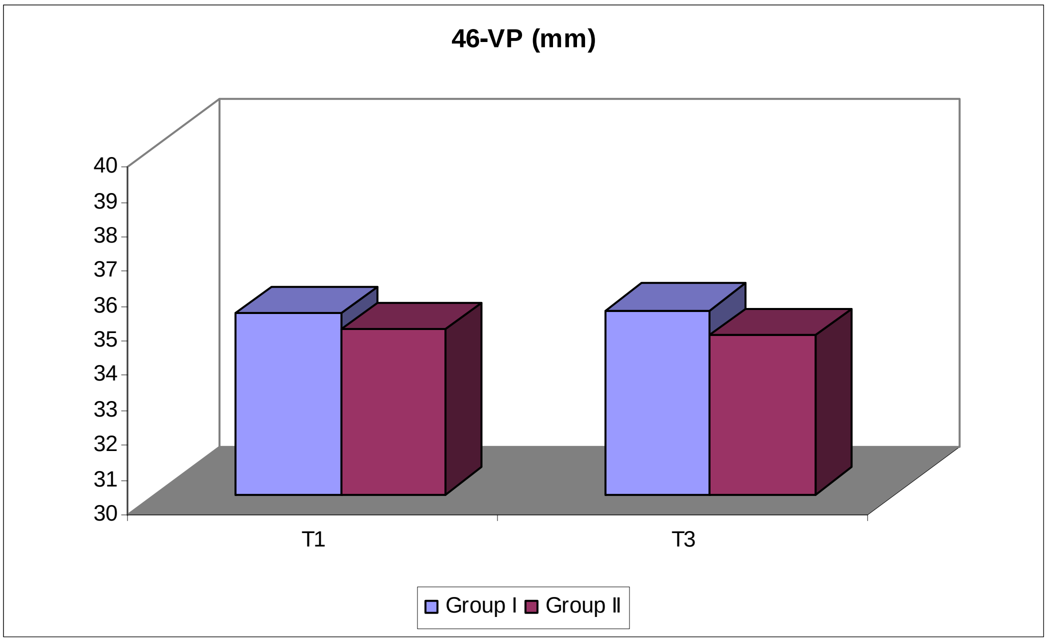

Figure 21: 46-VP values of group I and group II at 2 time intervals

6.3.5 IMPA Angle

No significant difference exists between group I and group II for IMPA angle values at T1 and T3 periods (p>0.05).

In group I; no statistically significant difference is observed for IMPA angle between T1 and T3(p>0.05).Also in ***group II;*** no statistically significant difference is observed for IMPA angle between T1 and T3(p>0.05).

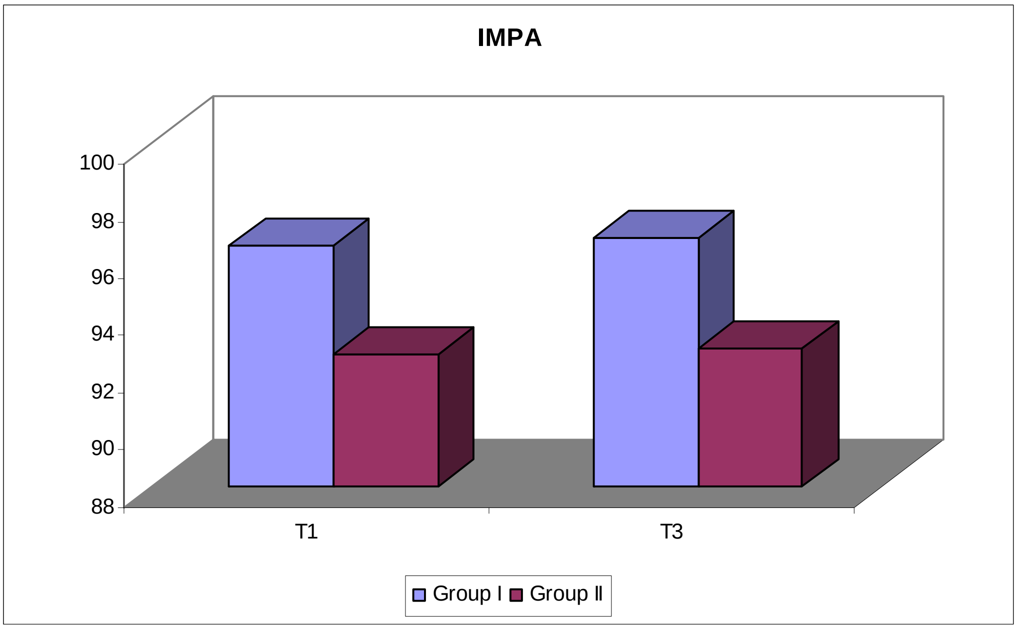

Figure 22: IMPA angle of group I and group II at 2 time intervals

6.3.6 ANB Angle

No significant difference exists between group I and group II for ANB angle values at T1 and T3 periods (p>0.05).

In group I; no statistically significant difference is observed for ANB angle between T1 and T3(p>0.05).Also in ***group II;*** no statistically significant difference is observed for ANB angle between T1 and T3(p>0.05).

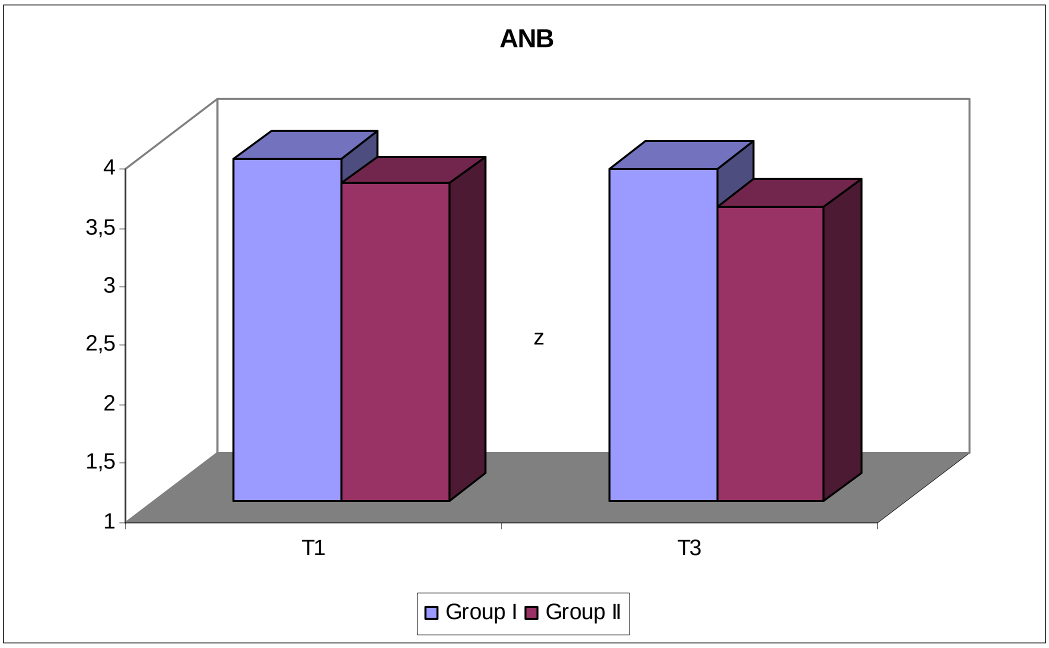

Figure 23: ANB angle of group I and group II at 2 time intervals

6.3.7 NAPg Angle

No significant difference exists between group I and group II for NAPg angle values at T1 and T3 periods (p>0.05).

In group I; no statistically significant difference is observed for NAPg angle between T1 and T3(p>0.05).Also in ***group II;*** no statistically significant difference is observed for NAPg angle between T1 and T3(p>0.05).

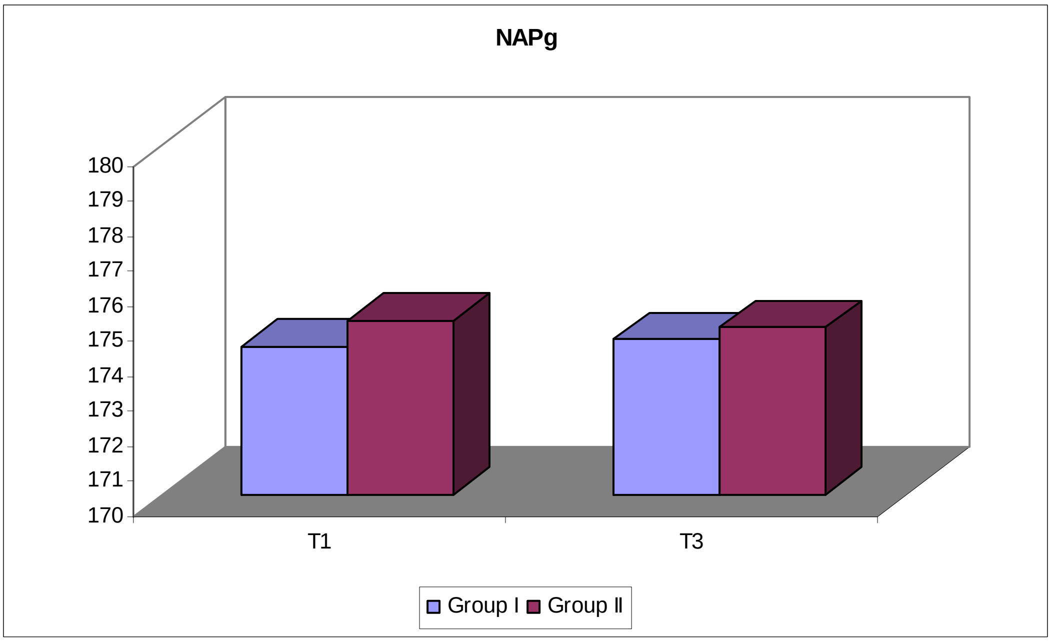

Figure 24: NAPg angle in group I and group II at 2 intervals.

6.3.8 Ar-Pg Distance

No significant difference exists between group I and group II for Ar-Pg distance values at T1 and T3 periods (p>0.05).

In group I; no statistically significant difference is observed for Ar-Pg distance between T1 and T3(p>0.05). But in ***group II;*** a highly significant increase is observed for Ar-Pg distance between T1 and T3(p<0.01).

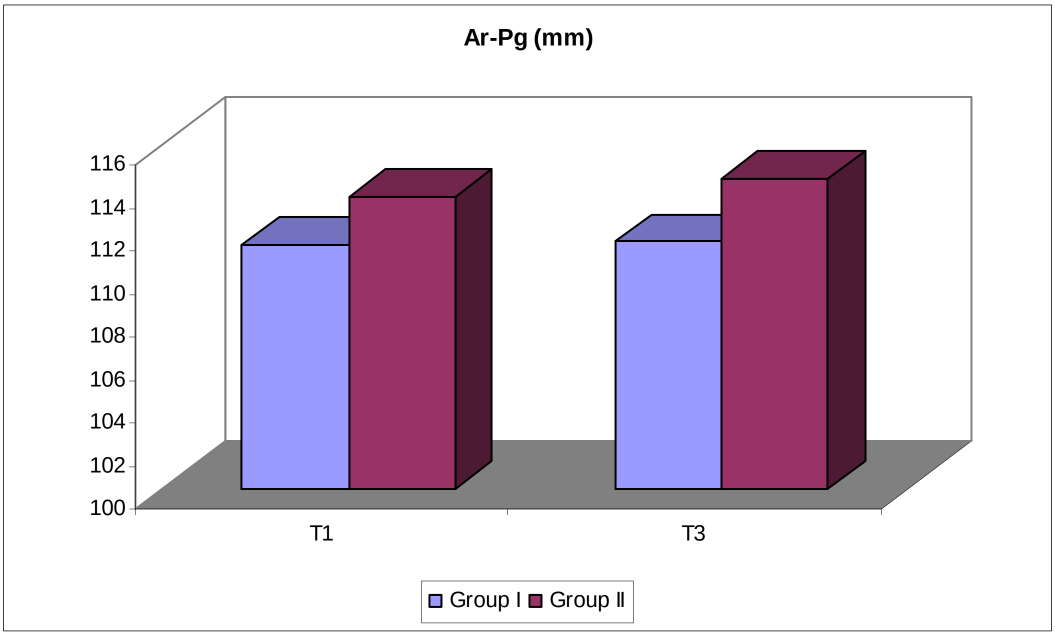

Figure 25: Ar-Pg distance in group I and group II at 2 time intervals

6. 4 Evaluation of Interproximal Force

I.P.F evaluation is made at six contact points between teeth 36-35, 35-34, 34-33, 46-45, 45-44, 44-43. Measurements were made for each contact point at 3 time intervals; T1, T2, and T3.

6.4.1 I.P.F at contact surface 36-35

Table 8: Evaluation of I.P.F at contact surface 36-35 (N)

36-35 (N)	**Group I**	**Group II**	***p*+**
T1	22,60±7,32	23,36±9,48	***0,816***
T2	23,43±6,52	26,64±9,72	***0,320***
T3	28,35±9,80	33,86±10,15	***0,143***
***T1-T2 p*++**	***0,275***	***0,004*****	
***T1-T3 p*++**	***0,005*****	***0,001*****	
***T2-T3 p*++**	***0,007*****	***0,001*****	

+ Student t test *++ Paired Sample t test* *** p<0.01*

No significant difference exists between group I and group II for I.P.F values at contact point 36-35 at T1 and T3 periods (p>0.05).

In group I; no statistically significant difference is observed for I.P.F at 36-35 between T1 and T3 (p>0.05). A highly significant increase is observed for I.P.F at 36-35 between T1 and T3, and T2 and T3 (p<0.01).

In group II; a highly significant increase is observed for I.P.F at 36-35 between T1 and T3, T2 and T3, and T1 and T3 (p<0.01).

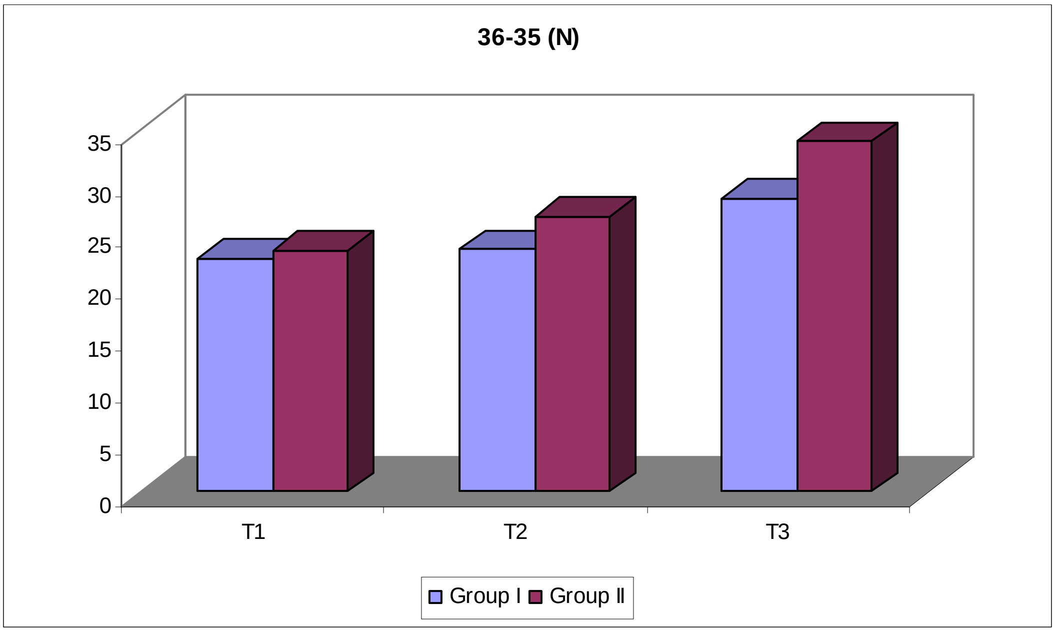

Figure 26: I.P.F values in group I and group II at contact surface 36-35 at 3 time intervals

6.4.2 I.P.F at contact surface 35-34

Table 9: Evaluation of I.P.F at contact surface 35-34 (N)

35-34 (N)	Group I	Group II	p^{+}
T1	17,69±5,32	16,96±7,26	***0,766***
T2	18,77±4,89	20,24±7,18	***0,537***
T3	19,87±5,67	24,19±7,17	***0,086***
T1-T2 p^{++}	***0,444***	***0,001*****	
T1-T3 p^{++}	***0,234***	***0,001*****	
T2-T3 p^{++}	***0,337***	***0,009*****	

$^{+}$ *Student t test* $^{++}$ *Paired Sample t test*

*** p<0.01*

No significant difference exists between group I and group II for I.P.F values at contact point 35-34 at T1, T2 and T3 periods (p>0.05).

In group I; no statistically significant difference is observed for I.P.F at 35-34 between T1 and T2, T2 andT3, and T1 and T3 (p>0.05). ***In group II;*** a highly significant increase is observed for I.P.F at 35-34 between T1 and T2, T2 and T3, and T1 and T3 (p<0.01).

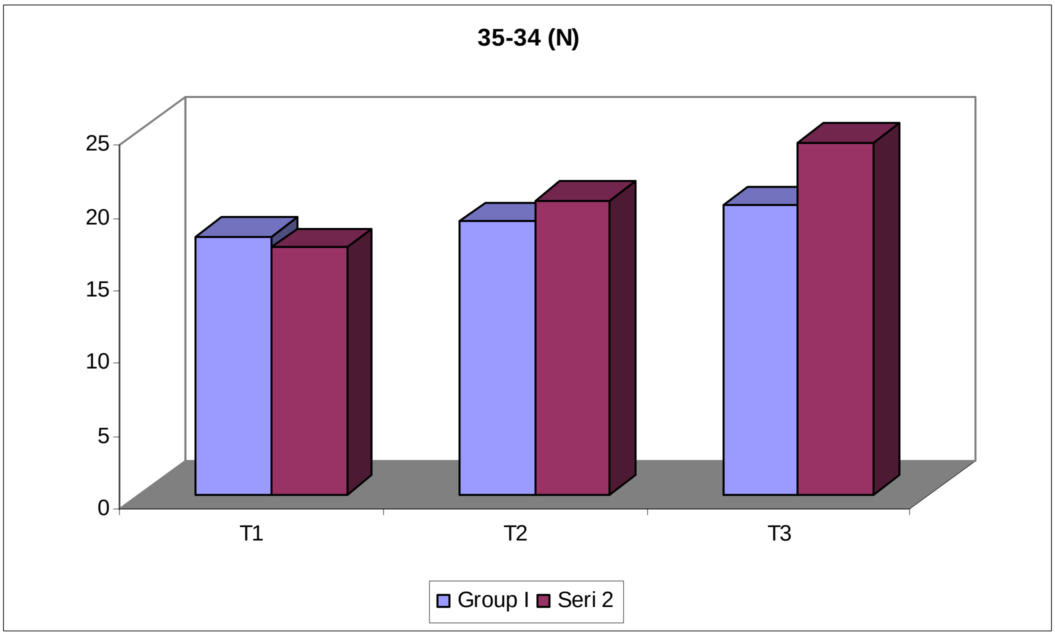

Figure 27: I.P.F values in group I and group II at contact surface 35-34

6.4.3 I.P.F at contact surface 34-33

Table 10: Evaluation of I.P.F at contact surface 34-33 (N)

34-33 (N)	Group I	Group II	p^{+}
T1	12,75±4,72	12,54±4,89	***0,905***
T2	13,84±4,44	14,52±5,87	***0,733***
T3	16,54±4,66	17,96±6,34	***0,507***
T1-T2 p^{++}	***0,424***	***0,004*****	
T1-T3 p^{++}	***0,001*****	***0,001*****	
T2-T3 p^{++}	***0,119***	***0,003*****	

$^{+}$ *Student t test* $^{++}$ *Paired Sample t test*

*** p<0.01*

No significant difference exists between group I and group II for I.P.F values at contact surface 34-33 at T1, T2 and T3 periods (p>0.05).

In group I; no statistically significant difference is observed for I.P.F at 34-33 between T1 and T2, T2 andT3. ($p>0.05$). A highly significant increase is observed for I.P.F at 34-33 between T1 and T3($p<0.01$).

In group II; a highly significant increase is observed for I.P.F at 34-33 between T1 and T2, T2 and T3, and T1 and T3 ($p<0.01$).

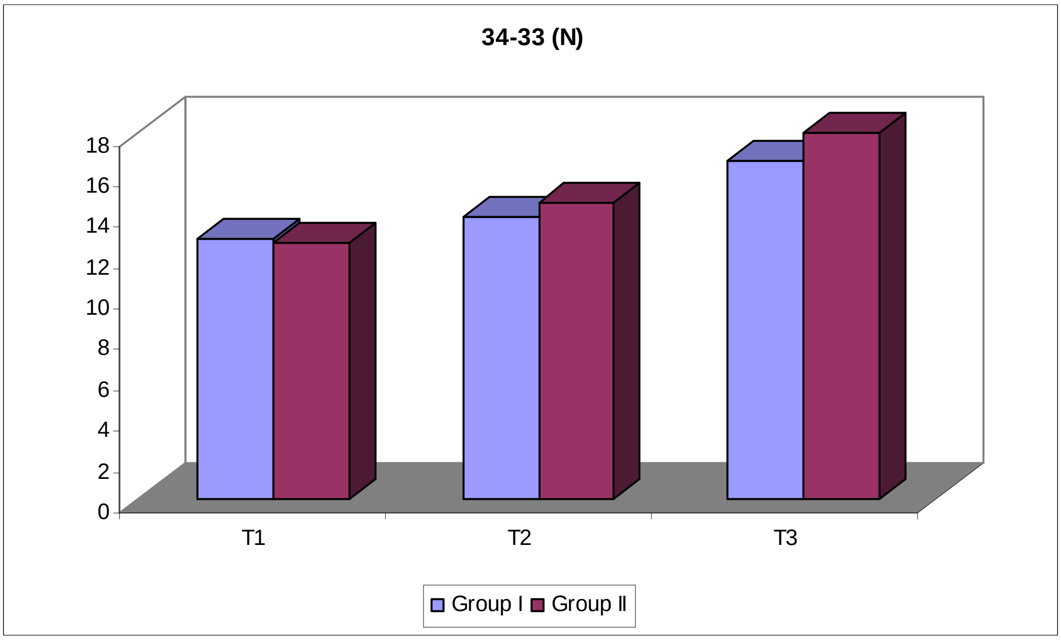

Figure 28: I.P.F values in group I and group II at contact surface 34-33 at 3 time intervals.

6.4.4 I.P.F at contact surface 46-45

Table 11: Evaluation of I.P.F at contact surface 46-45 (N)

46-45 (N)	Group I	Group II	^{+}p
T1	23,69±9,80	33,03±18,45	***0,072***
T2	26,97±9,99	39,75±18,87	***0,039****
T3	31,36±10,49	44,49±18,31	***0,031****
T1-T2 p^{++}	***0,039****	***0,001*****	
T1-T3 p^{++}	***0,003*****	***0,001*****	
T2-T3 p^{++}	***0,010****	***0,001*****	

$^{+}$ *Student t test* $^{++}$ *Paired Sample t test*

** p<0.05* *** p<0.01*

No significant difference exists between group I and group II for I.P.F values at contact surface 46-45 at T1. However, I.P.F values of group I were found to be significantly lower than those of group II at T2 and T3(p<0.05).

In group I; a significant increase is observed for I.P.F at 46-45 between T1 and T2(p<0.05). Increase in I.P.F between T2 and T3, and T1 and T3 are found to be highly significant (p<0.01).

In group II; a highly significant increase is observed for I.P.F at 46-45 between T1 and T2, T2 and T3, and T1 and T3 (p<0.01).

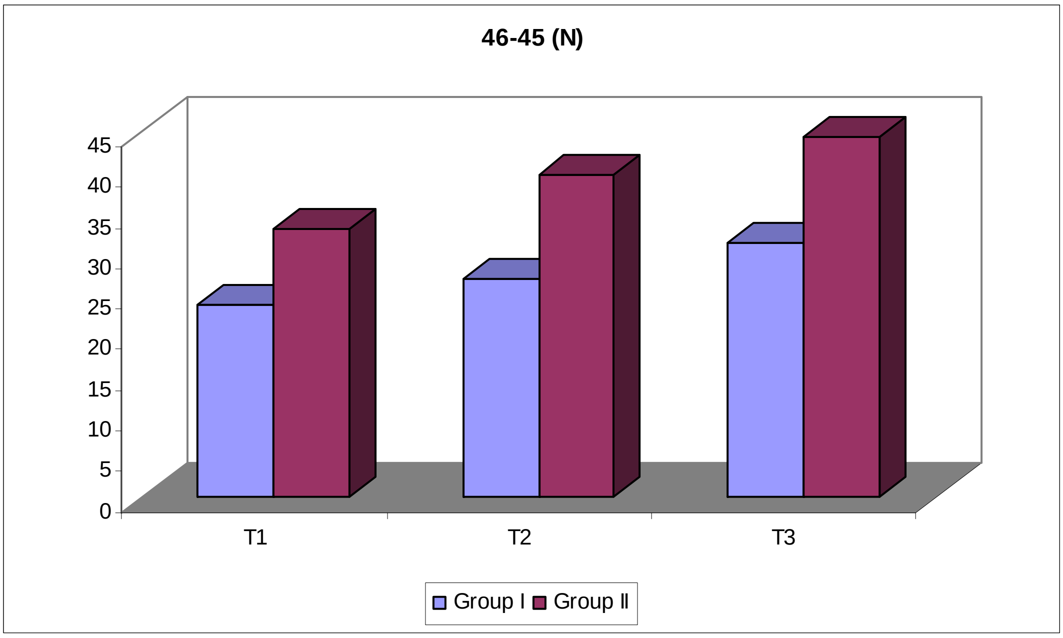

Figure 29: I.P.F values in group I and group II at contact surface 46-45 at 3 time intervals

6.4.5 I.P.F at contact surface 45-44

I.P.F values at contact point 45-44 of group I were found to be significantly lower than those of group II at T1,T2 and T3(p<0.05).

Table 12: Evaluation of I.P.F at contact surface 45-44 (N)

45-44 (N)	**Group I**	**Group II**	^{+}p
T1	14,54±8,75	25,33±14,69	***0,028****
T2	18,77±7,53	28,28±15,19	***0,025****
T3	21,78±7,82	31,89±13,53	***0,025****
T1-T2 p^{++}	***0,033****	***0,010****	
T1-T3 p^{++}	***0,006*****	***0,001*****	
T2-T3 p^{++}	***0,001*****	***0,010****	

$^{+}$ *Student t test* $^{++}$ *Paired Sample t test* ** p<0.05 ** p<0.01*

In group I; a significant increase is observed for I.P.F at 45-44 between T1 and T2(p<0.05). Increase in I.P.F between T2 and T3, and T1 and T3 are found to be highly significant (p<0.01). ***In group II;*** a significant increase is observed for I.P.F at 45-44 between T1 and T2, and T2 and T3 (p<0.05). A highly significant increase is observed for I.P.F at 46-45 between T1 and T3 (p<0.01).

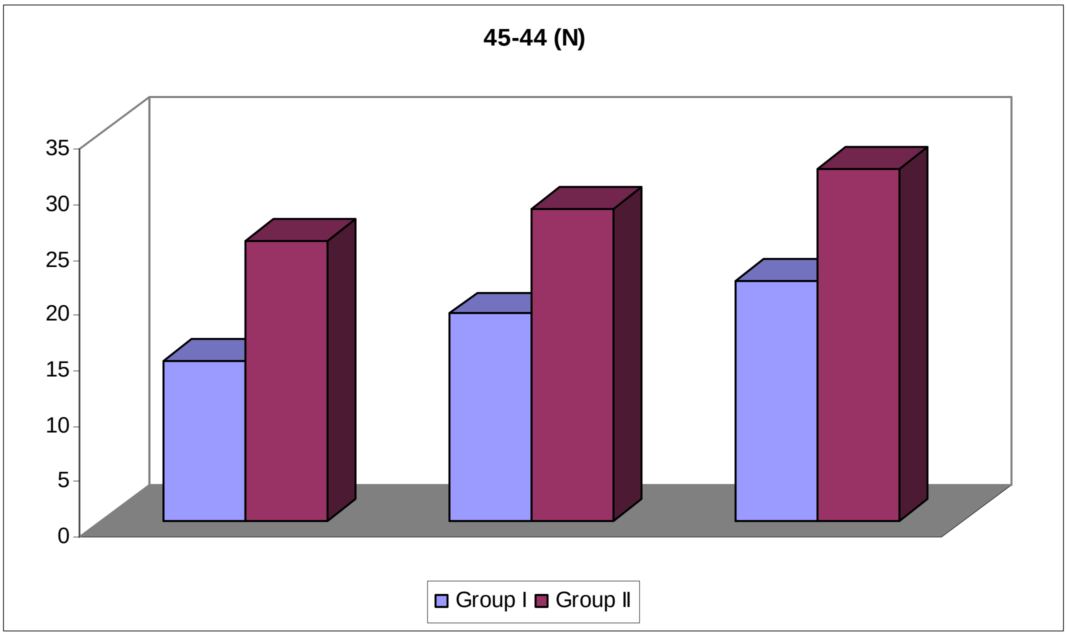

Figure 30: I.P.F values in group I and group II at contact surface 45-44 at 3 time intervals

6.4.6 I.P.F at contact surface 44-43

Table 13: Evaluation of I.P.F at contact surface 44-43 (N)

44-43 (N)	Group I	Group II	^{+}p
T1	13,30±5,30	16,94±10,86	***0,289***
T2	14,67±5,68	19,58±10,63	***0,152***
T3	16,58±5,33	22,70±10,76	***0,041****
T1-T2 p^{++}	***0,295***	***0,011****	
T1-T3 p^{++}	***0,015****	***0,001*****	
T2-T3 p^{++}	***0,112***	***0,004*****	

$^{+}$ *Student t test* $^{++}$ *Paired Sample t test*

* *p<0.05* ** *p<0.01*

No significant difference exists between group I and group II for I.P.F values at contact surface 44-43 at T1 and T2. However, I.P.F values of group I were found to be significantly lower than those of group II at T3 ($p<0.05$).

In group I; no significant difference is observed for I.P.F at 44-43 between T1 and T2, and T2 and T3($p<0.05$). However, increase in I.P.F between T1 and T3 is found to be statistically significant ($p<0.05$).

In group II; a significant increase is observed for I.P.F at 44-43 between T1 and T2. Additionally, increase observed for I.P.F at 44-43 between T2 and T3, and T1 and T3 are found to be highly significant ($p<0.01$).

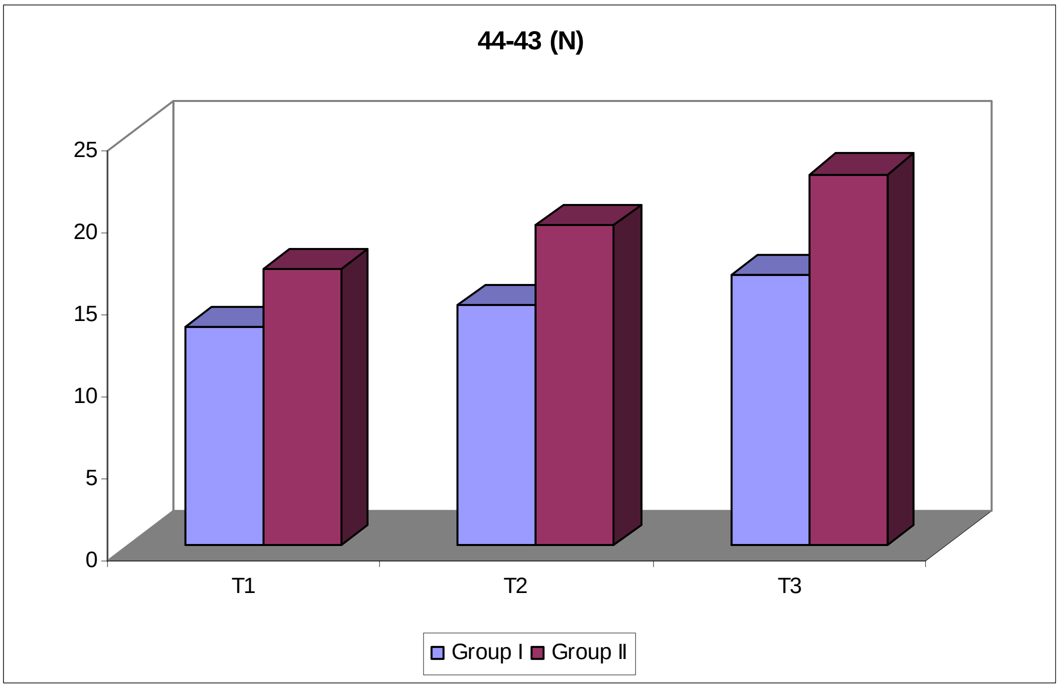

Figure 31: I.P.F values in group I and group II at contact surface 44-43 at 3 time intervals

6.5 Evaluation of Panoramic Radiographs

Table 14: Evaluation of panoramic parameters

		Group II
48-GoGo(°)	**T1**	56,80±18,41
	T3	56,30±16,76
	T1-T3 p $^{++}$	***0,626***
38-GoGo(°)	**T1**	55,80±25,64
	T3	56,10±24,26
	T1-T3 p $^{++}$	***0,703***

$^{++}$ *Paired Sample t test*

No significant difference exists in group II for 48-GoGo angle between T1 and T3 (p>0.05).

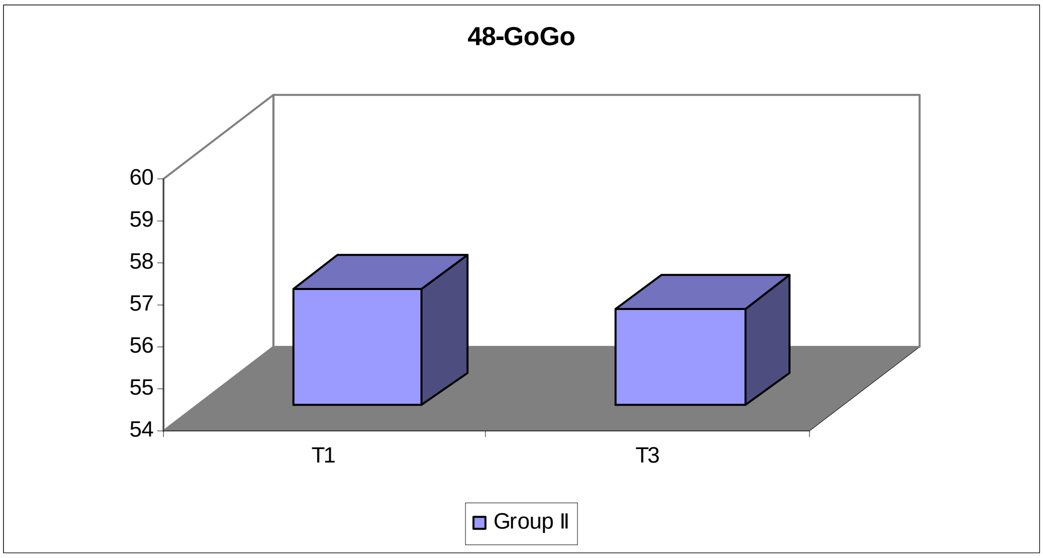

Figure 32: 48-GoGo angle in group I and group II at 2 time intervals

No significant difference exists in group II for 38-GoGo angle between T1 and T3 ($p>0.05$).

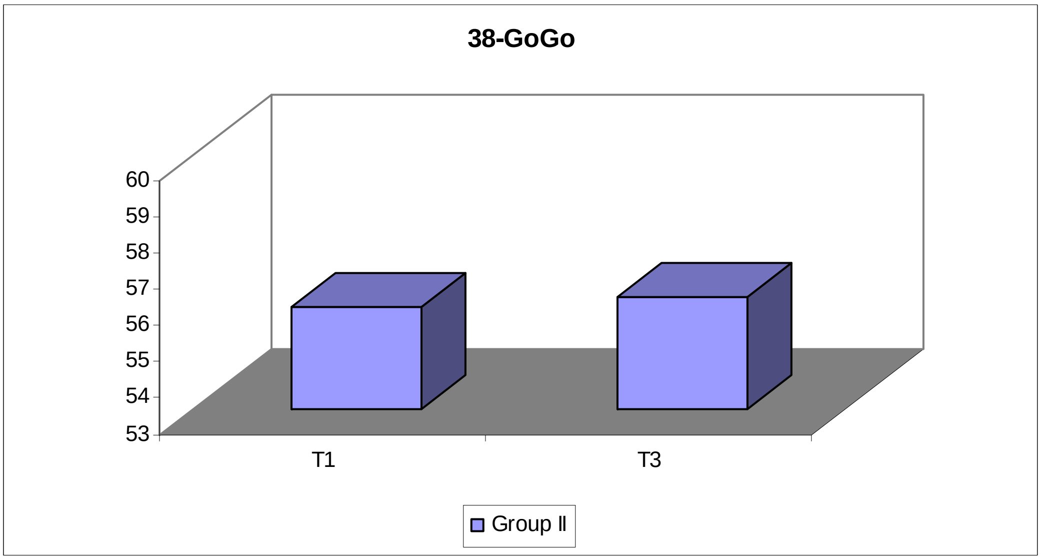

Figure 33: 38-GoGo angle in group I and group II at 2 time intervals

6.6 Evaluation of The Mean Differences for Experimental Parameters

6.6.1 Mean differences for model analysis parameters

Table 15: Mean differences of model analyses parameters for group I and II

		Group I (Median)	Group II (Median)	*p*
II (mm)	**T1-T2 difference**	0,65±0,55 (0,59)	0,62±0,49 (0,55)	***0,815***
	T1-T3 difference	1,10±0,99 (1,07)	0,88±0,58 (0,69)	***0,726***
	T2-T3 difference	0,45±0,62 (0,20)	0,26±0,20 (0,23)	***0,726***
Arch length (mm)	**T1-T2 difference**	-0,50±0,47 (-0,33)	-0,58±0,60 (-0,44)	***0,815***
	T1-T3 difference	-0,96±0,71 (-0,63)	-1,09±0,60 (-1,03)	***0,199***
	T2-T3 difference	-0,45±0,35 (-0,45)	-0,50±0,68 (-0,57)	***0,712***
Intercanine width (mm)	**T1-T2 difference**	-0,25±0,19 (-0,21)	-0,18±0,20 (-0,13)	***0,340***
	T1-T3 difference	-0,42±0,27 (-0,37)	-0,44±0,33 (-0,41)	***0,640***
	T2-T3 difference	-0,16±0,25 (-0,10)	-0,25±0,40 (-0,27)	***0,173***
Interpremolar width (mm)	**T1-T2 difference**	-0,35±0,47 (-0,39)	-0,03±0,36 (-0,03)	***0,045****
	T1-T3 difference	-0,64±0,57 (-0,58)	-0,28±0,47 (-0,16)	***0,073***
	T2-T3 difference	-0,28±0,27 (-0,31)	-0,24±0,34 (-0,18)	***0,683***
Intermolar width (mm)	**T1-T2 difference**	-0,54±0,45 (-0,62)	-0,24±0,53 (-0,14)	***0,124***
	T1-T3 difference	-0,74±0,39 (-0,71)	-1,19±2,57 (-0,54)	***0,448***
	T2-T3 difference	-0,20±0,36 (-0,30)	-0,95±2,51 (-0,38)	***0,235***

Mann Whitney U Test was used for evaluation. *$p<0.05$

In II (mm) measurements;

No significant difference exists between group I and group II for mean difference of II measurements between T1-T2, T1-T3, and T2-T3. ($p>0.05$).

In arch length(mm) measurements;

No significant difference exists between group I and group II for mean difference of arch length measurements between T1-T2, T1-T3, and T2-T3. ($p>0.05$).

In intercanine width measurements (mm);

No significant difference exists between group I and group II for mean difference of intercanine width measurements between T1-T2, T1-T3, and T2-T3. ($p>0.05$).

In interpremolar width (mm)measurements;

Mean difference of interpremolar width for group I is significantly higher than that of group II between T1-T2 ($p<0.05$). However, no significant difference exists between group I and group II for mean difference of interpremolar width measurements between T1-T3, and T2-T3. ($p>0.05$).

In intermolar width (mm) measurements;

No significant difference exists between group I and group II for mean difference of intermolar width measurements between T1-T2, T1-T3 and T2-T3. ($p>0.05$).

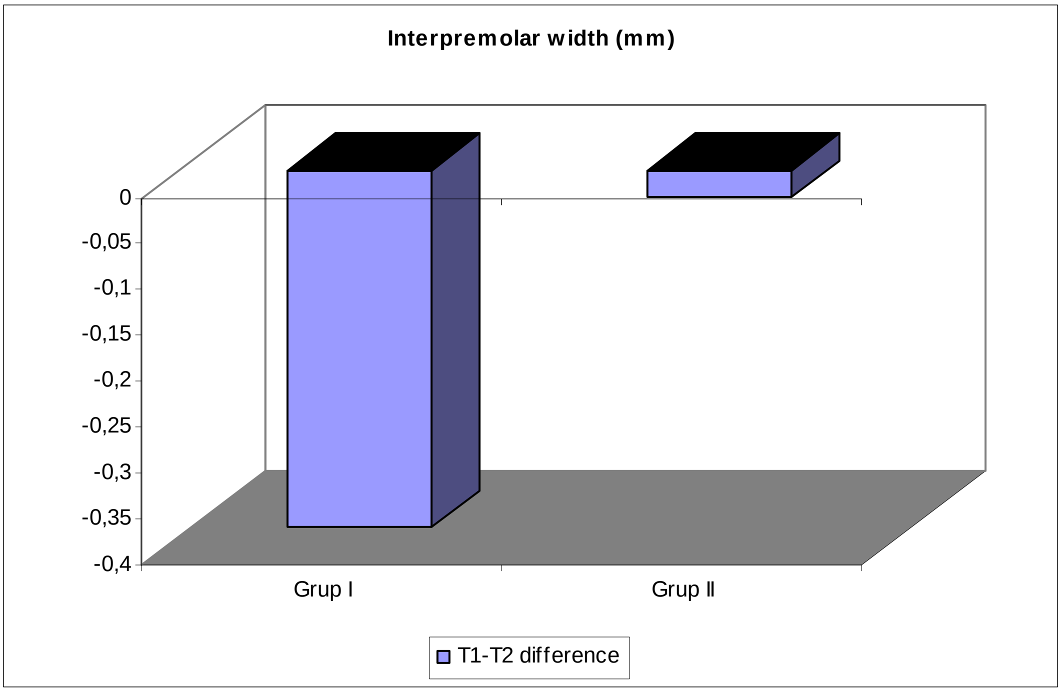

Figure 34: Mean difference of interpremolar width for group I and group II between T1 and T2

6.6.2 Mean Differences for cephalometric analysis parameters

No significant difference exists between group I and group II for mean difference of 36-GoMe measurements between T1-T3 (p>0.05).

No significant difference exists between group I and group II for mean difference of 46-GoMe measurements between T1-T3 (p>0.05).

No significant difference exists between group I and group II for mean difference of 36- VP measurements between T1-T3 (p>0.05).

No significant difference exists between group I and group II for mean difference of 46- VP measurements between T1-T3 (p>0.05).

No significant difference exists between group I and group II for mean difference of IMPA measurements between T1-T3 (p>0.05).

No significant difference exists between group I and group II for mean difference of ANB measurements between T1-T3 (p>0.05).

No significant difference exists between group I and group II for mean difference of NAPg measurements between T1-T3 (p>0.05).

No significant difference exists between group I and group II for mean difference of Ar-Pg measurements between T1-T3 (p>0.05).

Table 16: Evaluation of the changes in cephalometric parameters

T1-T3 difference	**Group I (Median)**	**Group II (Median)**	***p***
36– GoMe (°)	-0,16±4,23 (-1)	0,15±7,23 (0,50)	***0,423***
46 – GoMe (°)	0,33±4,88 (-1)	0,25±4,57 (1)	***0,860***
36 – VP (mm)	-0,91±2,77 (-1)	-0,17±2,46 (0,25)	***0,421***
46 – VP (mm)	0,08±1,83 (0)	-0,17±2,61 (0)	***0,969***
IMPA (°)	0,29±2,63 (0)	0,20±2,23 (0)	***0,906***
ANB (°)	-0,08±0,79 (0)	-0,20±0,61 (0)	***0,443***
NAPg (°)	0,20±3,04 (0)	-0,22±2,46 (0)	***0,637***
Ar-Pg (mm)	0,16±0,93 (0)	0,80±1,10 (0,50)	***0,122***

Mann Whitney U Test was used. * *p<0.05*

6.6.3 Mean differences for I.P.F measurements

Table 17: Mean differences for I.P.F values.

		Group I (Median)	Group II (Median)	p
36-35 (N)	T1-T2 difference	0,82±2,48 (0)	3,28±4,43 (3,30)	***0,014****
	T1-T3 difference	5,74±5,61 (4,95)	10,50±7,09 (8,20)	***0,065***
	T2-T3 difference	4,91±5,14 (4,90)	7,21±7,11 (4,90)	***0,569***
35-34 (N)	T1-T2 difference	0,82±2,48 (0)	3,28±4,43 (3,30)	***0,014****
	T1-T3 difference	5,74±5,61 (4,95)	10,50±7,09 (8,20)	***0,065***
	T2-T3 difference	4,91±5,14 (4,90)	7,21±7,11 (4,90)	***0,569***
34-33 (N)	T1-T2 difference	1,08±4,51 (0)	1,97±2,69 (1,65)	***0,370***
	T1-T3 difference	3,78±3,04 (3,30)	5,41±4,90 (3,30)	***0,311***
	T2-T3 difference	2,70±5,53 (3,25)	3,44±4,57 (3,30)	***0,737***
46-45 (N)	T1-T2 difference	3,28±4,84 (1,65)	6,71±5,37 (6,55)	***0,089***
	T1-T3 difference	7,67±7,16 (6,60)	11,46±6,68 (13,10)	***0,177***
	T2-T3 difference	4,39±4,89 (3,30)	4,74±4,68 (3,30)	***0,968***
45-44 (N)	T1-T2 difference	4,23±6,02 (3,30)	2,95±4,49 (1,60)	***0,499***
	T1-T3 difference	7,24±7,49 (3,30)	6,56±5,09 (6,55)	***0,875***
	T2-T3 difference	3,00±2,19 (3,30)	3,61±5,60 (3,30)	***0,984***
44-43 (N)	T1-T2 difference	1,36±4,30 (0)	2,64±4,21 (0)	***0,588***
	T2-T3 difference	3,27±3,94 (3,25)	5,76±5,61 (3,30)	***0,098***
	T2-T3 difference	1,90±3,82 (1,60)	3,12±4,19 (3,30)	***0,325***

Mann Whitney U Test was used. ** p<0.05*

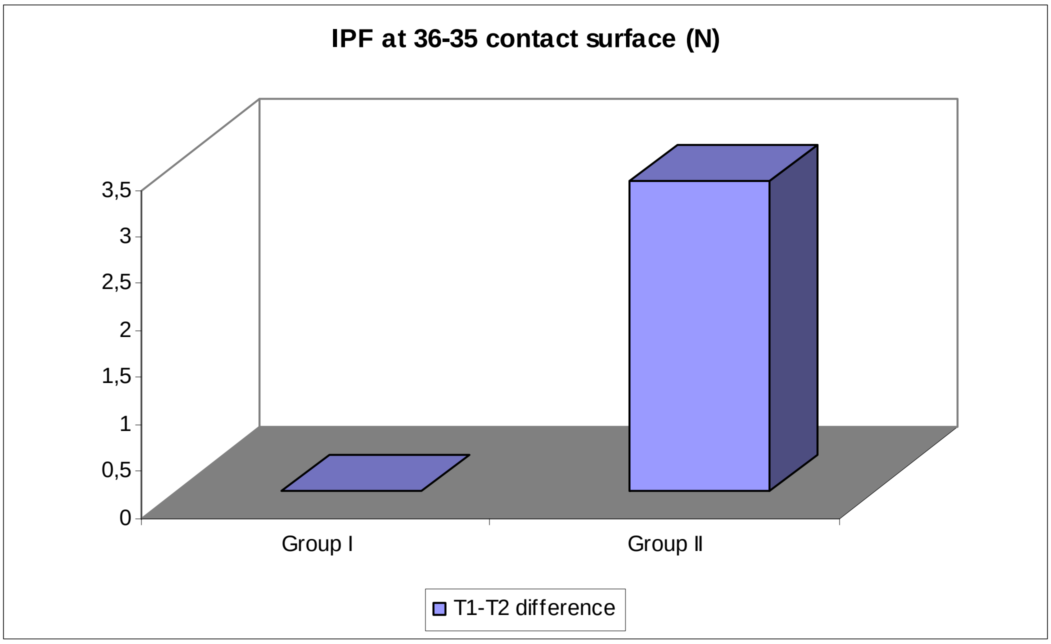

Figure 35: Mean difference of I.P.F at 36-35 between T1-T2

For I.P.F at 36-35 (N) measurements; mean difference of I.P.F in group II between T1-T2 is statistically significantly higher than that of group I ($p<0.05$). However, no statistically significant difference of I.P.F exists between T1-T3 and T2-T3 when group I and group II are compared ($p>0.05$).

For I.P.F at 35-34 (N) measurements; mean difference of I.P.F in group II between T1-T2 is statistically significantly higher than that of group I ($p<0.05$). However, no statistically significant difference of I.P.F exists between T1-T3 and T2-T3 when group I and group II are compared ($p>0.05$).

For I.P.F at 34-33 (N) measurements; no statistically significant difference of I.P.F exists between T1-T2, T1-T3 and T2-T3 when group I and group II are compared ($p>0.05$).

For I.P.F at 46-45 (N) measurements; no statistically significant difference of I.P.F exists between T1-T2, T1-T3 and T2-T3 when group I and group II are compared (p>0.05)

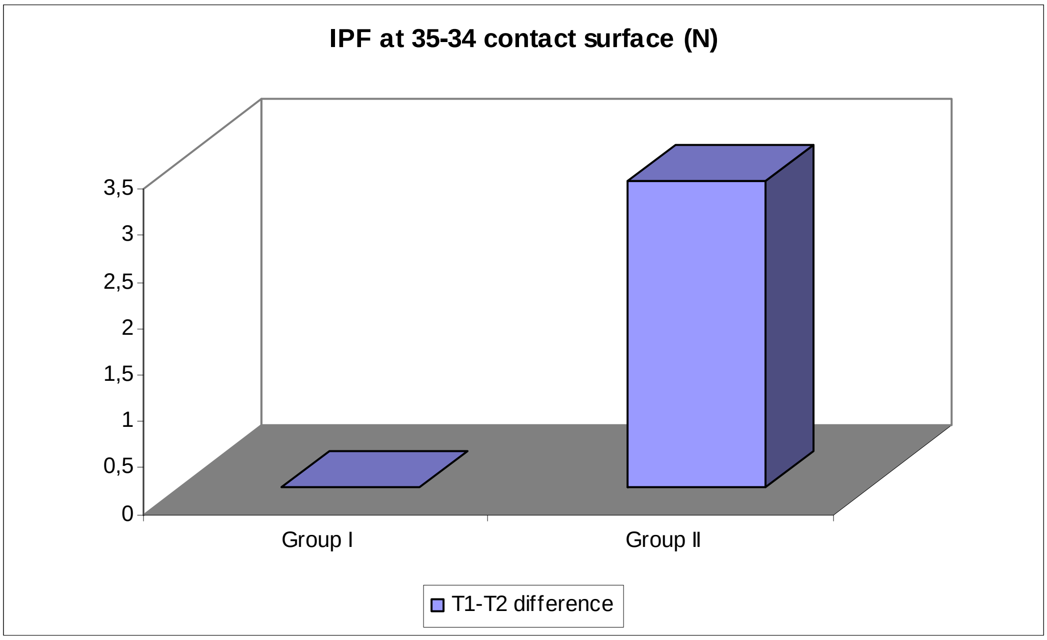

Figure 36: Mean difference of I.P.F at 35-34 between T1-T2i

For I.P.F at 45-44 (N)measurements; no statistically significant difference of I.P.F exists between T1-T2, T1-T3 and T2-T3 when group I and group II are compared (p>0.05)

For I.P.F at 44-43 (N)measurements; no statistically significant difference of I.P.F exists between T1-T2, T1-T3 and T2-T3 when group I and group II are compared (p>0.05)

6.7 Correlation Analyses

6.7.1 Correlation between I.P.F measurements and model analysis parameters

Table 18: Correlation table for I.P.F and model analysis parameters

			II	Arch length	Intercanine width	Interpremolar width	Intermolar width
Group I	36-35 (N)	r	0,349	0,057	0,271	0,014	-0,036
		p	***0,226***	***0,860***	***0,395***	***0,965***	***0,913***
	35-34 (N)	r	0,349	0,057	0,271	0,014	-0,036
		p	***0,266***	***0,860***	***0,395***	***0,965***	***0,913***
	34-33 (N)	r	-0,316	-0,256	0,181	-0,309	-0,583
		p	***0,317***	***0,422***	***0,573***	***0,328***	***0,047****
	46-45 (N)	r	0,255	-0,106	-0,014	0,255	0,390
		p	***0,423***	***0,742***	***0,965***	***0,423***	***0,210***
	45-44 (N)	r	0,088	0,393	0,001	0,375	0,207
		p	***0,786***	***0,206***	***1,000***	***0,229***	***0,519***
	44-43 (N)	r	-0,183	-0,015	-0,395	-0,628	-0,117
		p	***0,570***	***0,964***	***0,204***	***0,029****	***0,717***
Group II	36-35(N)	r	0,127	0,200	0,230	0,160	-0,043
		p	***0,592***	***0,398***	***0,330***	***0,501***	***0,857***
	35-34 (N)	r	0,127	0,200	0,230	0,160	-0,043
		p	***0,592***	***0,398***	***0,330***	***0,501***	***0,857***
	34-33 (N)	r	0,022	-0,065	0,132	-0,185	0,212
		p	***0,926***	***0,787***	***0,579***	***0,436***	***0,370***
	46-45 (N)	r	-0,231	-0,335	-0,181	-0,061	-0,394
		p	***0,326***	***0,149***	***0,446***	***0,798***	***0,085***
	45-44 (N)	r	-0,280	-0,276	-0,177	-0,220	-0,418
		p	***0,232***	***0,239***	***0,455***	***0,351***	***0,066***
	44-43 (N)	r	-0,161	-0,084	0,055	0,030	0,011
		p	***0,498***	***0,726***	***0,819***	***0,901***	***0,962***

Table 19 (Continued): *Spearman's Rho test was used.* *
p<0.05

For mean differences in Group I between T1-T3;

No statistically significant correlation exists between change in II and change in I.P.F at contact surfaces 36-35, 35-34, 34-33, 46-45, 45-44, 44-43 (p>0.05). No statistically significant correlation exists between change in arch length and change in I.P.F at contact surfaces 36-35, 35-34, 34-33, 46-45, 45-44, 44-43 (p>0.05). No statistically significant correlation exists between change in intercanine width and change in I.P.F at contact surfaces 36-35, 35-34, 34-33, 46-45, 45-44, 44-43 (p>0.05). No statistically significant correlation exists between change in interpremolar width and change in I.P.F at contact surfaces 36-35, 35-34, 34-33, 46-45, 45-44 (p>0.05); however, a negative correlation at level of 62,8 % exists between I.P.F change at contact surface 44-43 and interpremolar width. No statistically significant correlation exists between change in intermolar width and change in I.P.F at contact surfaces 36-35, 35-34, , 46-45, 45-44 (p>0.05); however, a negative correlation at level of 58,3 % exists between I.P.F change at contact surface 34-33 and interpremolar width.

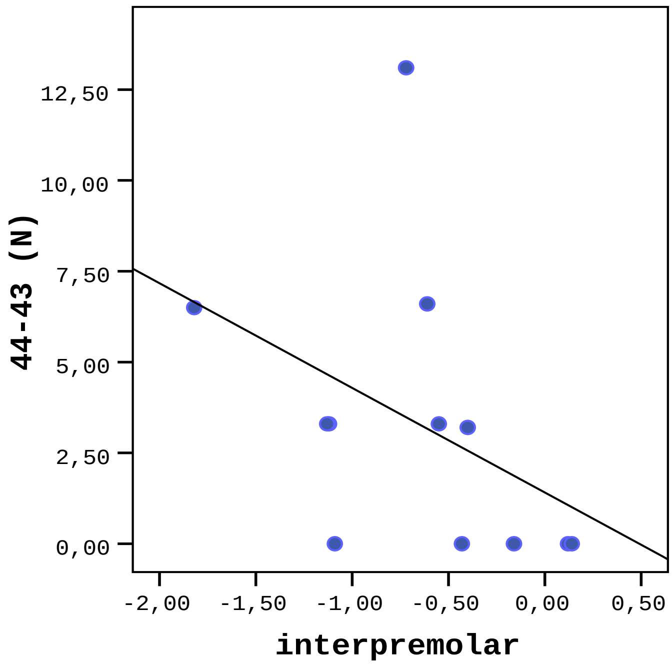

Figure 37: Correlation graphics between interpremolar width and I.P.F at contact surface 44-43 in group I

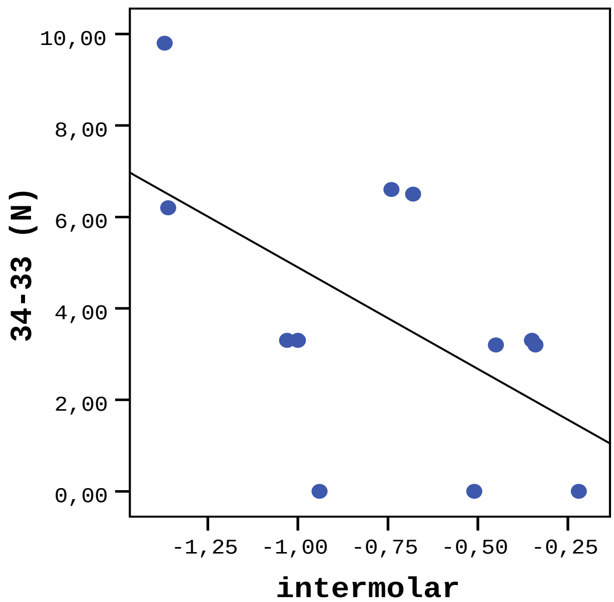

Figure 38: Correlation graphics between I.P.F at contact surface 34-33 and intermolar width in group I

For mean differences in Group II between T1-T3;

No statistically significant correlation exists between change in II and change in I.P.F at contact surfaces 36-35, 35-34, 34-33, 46-45, 45-44, 44-43 ($p>0.05$). No statistically significant correlation exists between change in arch length and change in I.P.F at contact surfaces 36-35, 35-34, 34-33, 46-45, 45-44, 44-43 ($p>0.05$). No statistically significant correlation exists between change in intercanine width and change in I.P.F at contact surfaces 36-35, 35-34, 34-33, 46-45, 45-44, 44-43 ($p>0.05$). No statistically significant correlation exists between change in interpremolar width and change in I.P.F at contact surfaces 36-35, 35-34, 34-33, 46-45, 45-44, 44-43 ($p>0.05$). No statistically significant correlation exists between change in intermolar width and change in I.P.F at contact surfaces 36-35, 35-34, 34-33 , 46-45, 45-44 ($p>0.05$).

6.7.2 Correlation between lower third molar axis and model analysis parameters and I.P.F measurements

Table 19: Correlation table between lower third molar axes and model analysis and I.P.F parameters.

			48-GoGo	38-GoGo
Group II	**II**	**r**	-0,005	-0,102
		p	***0,985***	***0,669***
	Arch length	**r**	0,127	-0,179
		p	***0,592***	***0,451***
	Intercanine width	**r**	0,317	-0,284
		p	***0,173***	***0,225***
	Interpremolar width	**r**	0,444	-0,174
		p	***0,050****	***0,463***
	Intermolar width	**r**	0,311	-0,086
		p	***0,182***	***0,719***
	36-35(N)	**r**	0,369	-0,185
		p	***0,110***	***0,435***
	35-34 (N)	**r**	0,369	-0,185
		p	***0,110***	***0,435***
	34-33 (N)	**r**	0,274	0,015
		p	***0,242***	***0,949***
	46-45 (N)	**r**	0,065	-0,138
		p	***0,785***	***0,561***
	45-44 (N)	**r**	-0,301	0,157
		p	***0,197***	***0,509***
	44-43 (N)	**r**	0,063	-0,299
		p	***0,793***	***0,200***

Spearman's Rho test was used for assessment .

** $p<0.05$*

In Group II between mean differences;

No statistically significant correlation was found between 48-GoGo and I.I, arch length, intercanine width, intermolar width, I.P.F at contact surfaces 36-35, 35-34, 34-33, 46-45, 45-44 and 44-43 ($p>0.05$). However, positive correlation at level of 44.4 % exists between 48-GoGo and interpremolar width ($p<0.05$).

No statistically significant correlation was found between 38-GoGo and I.I, arch length, intercanine width, interpremolar width, intermolar width, I.P.F at contact surfaces 36-35, 35-34, 34-33, 46-45, 45-44 and 44-43 ($p>0.05$).

7. DISCUSSION:

7.1 Discussion of Aim

Human dentition is a dynamic structure changing constantly throughout life. This change is particularly noticeable in the alignment of lower anterior teeth. Lower anterior malalignment increases in early mixed dentition, slightly decreases in mixed dentition by means of compensating factors acting during eruption of permanent incisors, and becomes more crowded after the eruption of lower second molars (11, 12, 13, 22, 45, 55, 81, 93, and 106). The cause for late lower anterior crowding is ambiguous by its multifactorial nature. Together with late mandibular growth, occlusal factors, soft tissue maturation, periodontal forces, anterior component of the occlusal force; mesially directed force from the erupting lower third molars were previously discussed as a cause for late lower anterior crowding. In the literature, late mandibular growth, soft tissue changes due to ageing such as retrusion of lips, changes in occlusal contacts between upper and lower anterior teeth, anterior component of the occlusal force, forces generated by periodontal membrane are addressed as a part of normal maturation process of man, and their impact on late lower anterior crowding is also referred as ‘’normal physiological maturation of the dentition’’ (11, 84, 92, 93). However, the effect of lower third molar on late lower anterior crowding still remains unclear, since contradictory data were revealed by different authors. Thus, the basic aim of this study is to define the effects of lower third molars on mandibular arch perimeters, dental alignment, and interdental force, to examine dental and skeletal radiographic changes in patients with and without lower third molars, and to distinguish whether molar third molars are directly related with lower anterior crowding or not.

To date, previous research implies that existence of lower third molars is positively contributing to an increase in lower anterior crowding in case of an already existing lack of space in the posterior dentition. For example, in a series of article on Belfast growth study material, it was stated that, between the ages 12 and 18, lower dentition migrated mesially significantly in subjects who had bilateral lower third molars, and that this change was accompanied by an increase in lower anterior crowding (72, 73, 79, 80). In another study on Bolton study group material, it was demonstrated that in between years 14 and 19, there is significantly more decrease in arch length in subjects with bilateral third molars, compared to the subjects who had congenitally missing lower third molars (106). In another article, the effect of unilateral lower third molar extraction on lower dental arch was examined. The author reported that the length and width of the lower arch increased in segments where third molars were extracted. Besides, the severity of crowding increased in segments where lower third molars were left in situ, whereas it decreased more frequently in segments where third molars were extracted. The author claimed that in case of inadequate space for the lower third molar to erupt, third molars may aggravate already existing crowding (60).

Although these studies mention a relationship between lower anterior crowding and existence of lower third molars, there are also other authors who reported that no such direct relationship exists. In their study Ades at al. reported that arch perimeter decreases and lower anterior crowding increases significantly as the individuals grow and mature, but they failed to show a direct relationship between agenesis of lower third molars and arch perimeters (2). Similarly, Richardson and Gormley demonstrated that, regardless of the situation of lower third molars, the changes in the alignment and the dimensions of lower arch in untreated subjects during the third decade of life are very small (90). In another study, Richardson found lower anterior alignment to be stable between the ages 18 and 21, regardless of the third molar situation (84).

Since studies on both side of the debate lacked in considering the force exerted by lower third molar to the lower dental arch, some authors attempted to measure this force. Southard et al. found that I.P.F has a tendency to decrease anteriorly. They also added that I.P.F decreased *bilaterally* just after the *unilateral* removal of a lower third molar. In an additional experiment they stated that this bilateral decrease after unilateral removal of the third molar is due to placing the patient in a supine position during surgery. Regardingly, they claimed that surgical enucleation of unerupted third molars does not relieve the I.P.F as they mentioned previously (95). Later on, Fuhrmann et al. tested the hypothesis in a similar experiment. They found out that I.P.F decreases only 10,9 % 1 year after the removal of the lower third molars, and added that the influence of lower third molars on I.P.F is frequently lower than often assumed, since difference between I.P.F values of extraction subjects and control subjects did not reveal any significance (35).

As revealed, the data on the impact of lower third molars on lower anterior crowding is contradictory. Although there is evidence that mesially directed force from erupting third molars may cause adverse effects on alignment of the teeth, no measurements were made to enlighten the interrelationship between the change in mandibular arch perimeter, the change in the position of lower dentition, and the change in I.P.F of lower posterior dentition. Besides, the comparison of I.P.F and lower anterior crowding in subjects with and without lower third molars is also lacking in available data. From this standpoint, our aim was to compare the I.P.F changes between the subjects with bilateral lower third molars and the subjects with bilateral agenesis of lower third molars. In order to distinguish the effects of the mesially directed force, the arc perimeter changes, changes in lower anterior alignment, changes in positions of lower first and third molars, and changes in mandibular length were measured. Additionally, we carried out correlation analysis between different parameters to address any possible relationship between I.P.F changes, changes in position of lower third molars, changes in I.I and arch perimeters.

7.2 Discussion of Material and Method

7.2.1 Discussion of model analysis

In this research, I.I, arch length and arch width at canine, premolar and molar region were measured on study casts in order to compare the changes in subjects having lower third molars and lacking lower third molars. Little's irregularity index was initially introduced in 1975 by Dr. Little. Since than, irregularity index has been frequently used by various authors to assess the malalignment of anterior teeth (2, 8, 37, 51, and 104). Nevertheless, ''incisor irregularity'' does not mean ''amount of incisor crowding'' or ''tooth size-arch length discrepancy of the incisor region''. Incisor irregularity index was defined as '' amount of linear displacement of anatomical contact points of the incisor teeth'', which gives an objective idea about the subjective crowding of an individual case (8). On the other hand, tooth size-arch length discrepancy is the clinical definition used to measure the space required for alignment of the teeth. In cases with noticeable displacement of lower anterior teeth, I.I would be more pronounced than space discrepancy. Yet, the cases with properly aligned anatomical contact points of teeth may have obvious distortion of arch shape, for example increased curve of Spee or Ω shaped arch form, which will require more space to align the teeth. The reason for us to measure I.I is, to evaluate the amount of displacement of lower anterior teeth which can also be visible by lay people.

In order to quantify the changes in arch perimeter, arch length, mandibular intercanine width, interpremolar width and intermolar width measurements were also used. We assessed arch length both for right side and left side of the arch in order to make a complete evaluation. Richardson also used tooth size-arch length discrepancy in variety of her researches (72, 75, 76, 78, and 83). Differently, Niedzielska (60) and Vego (106) measured the arch perimeter by dividing the arch in six segments, 36-35, 34-33, 32-31, 41-42, 43-44, 45-46, and adding these six separate measurements to sum the total arch perimeter. This technique can easily reveal the changes arch length, besides it can give an idea about the contact irregularity. Lindqvist and Thilander (49) also used the same method to measure the arch perimeter, but they transferred the contact points of the teeth on a horizontal plane by using stereograph. They also calculated the arch length as the sum of lengths between anatomical contact points of two incisors and mesial contact points of left and right first molars (2, 37, 49, 90), while Mores et al. measured the mandibular arch length as the distance between anatomical contact points of lower incisors and the line passing through mesial contact points of left and right lower first molars (55). In our study, arch length on left and right sides were simply measured between contact point of lower right and left central incisor and mesial marginal contact point of lower left and right first molars, which can easily quantify any drift in the dental arch.

In our research, the arch width measurements were carried out between right and left side lower canine tips in canine region, between buccal cusp tips of left and right lower second premolars in premolar region, and between mesiobuccal cusp tips of left and right side lower first molars in molar region. Similar techniques were previously used by various authors to study the change in mandibular dental arch form (2, 37, 55, 60, 90, and 104).

7.2.2 Discussion of radiographic analyzing methods

In orthodontics, facial and dental condition of the patients are usually evaluated by taking 90° lateral cephalograms, and panoramic radiographs. In cases with skeletal deformities or pathologies, additional records like posteroanterior cephalograms, CT scans, MRI scans and other necessary scanning techniques are used. In this research, 90° lateral cephalograms, and panoramic radiographs, which are the part of standard orthodontic evaluation, were examined for dental and skeletal changes that take place in the mandible.

In previous researches on lower third molars, 60° cephalograms, 90° cephalograms and 45° cephalograms were used for the evaluation of dental and skeletal changes in the maxillomandibular complex. For example, Richardson, in all her studies on third molar effects, used left and right 60° cephalograms to assess the positional changes of lower first molars and lower third molars. Her reason to use an angulated cephalogram was that 60° angulation enables the researcher to distinguish right side teeth from the left side teeth. She measured the total molar space, retromolar space, angulations of first, second and third molars, and changes in these angulations on 60° cephalograms (70-74, 76, 78, 80, 81, 84, 85, 88, and 89). 90° cephalograms were also used in her studies for estimating growth changes of mandible and inclination changes of lower incisors (70, 78, 80, 81, 84, and 89).

In addition to 45°, 60°, and 90°lateral cephalograms, different kinds of radiographies for evaluating lower third molars were used by various authors. For example, Ventå et al. used panoramic radiographs to evaluate the angular changes of lower third molars, using occlusal planes of lower first, second and third molars (107), whereas Zelli used 45° cephalograms (112). Lindqvist ant Thilander (49), and Olive and Basford (61) used posteroanterior cephalograms to evaluate the positional changes of lower third molars, and lateral cephalograms to evaluate the positional changes of lower first and third molars.

A group of researchers working on maxillomandibular growth in adult life used lateral cephalometric radiographs, and assessed the angular and metric changes in positions of lower incisors, lower first molars, and lower third molars. They also evaluated the changes in mandibular length and mandibular position. (4, 18, 20, 24, 30, 34, 42).

In our study, we used lateral cephalograms to measure the changes in position of lower first molars and lower incisors. The advantageous point in using panoramic radiograph or posteroanterior radiograph is, they enable the researcher to assess left and right side teeth accurately, while it will not always be possible to distinguish left and right side molars on a 90° lateral cephalogram due to superimposition of images. For this reason, we applied acrylic caps holding metal bars to right and left side lower first molars in order to distinguish them. We also evaluated the late growth changes of mandible on lateral cephalograms. We did not take 45° or 60° cephalograms to assess third molar situations, since this would increase the amount of X-ray that the volunteer is subjected. We used panoramic radiographs instead, which we took initially to control the lower third molar situations for each volunteer. But unlike Ventå et al(107), we did not measure the angle occurring between the occlusal plane formed by lower first and second molars and the occlusal surface of the third molars, since orientation of occlusal surfaces would change due to mesial tipping of the teeth. Instead, we drew the mandibular plane between left and right Gonion points, and measured the medial angle between the axis of the left and right lower third molars and mandibular plane.

7.3.3 Discussion of I.P.F measurements

In our research, we measured I.P.F values at 6-5, 5-4, 4-3 contact surfaces, and compared the measurements of lower molar genesis and lower molar agenesis groups, which was not compared by Southard and Fuhrmann previously (35, 95).

Osborn, in 1961, is the first researcher to define interproximal force between the teeth. He stated that interproximal forces of the dentition is related to interdental dynamic frictional forces, within the formula *I.P.F (Interproximal force)= F (frictional force) / 2u (coefficient of dynamic friction)* (62). We include the same formulation to assess I.P.F, which was also used by Southard et al. and Fuhrmann et al. (35, 95).

Southard et al. carried out the I.P.F measurements with a tension transducer hooked through a perforated 0,04 mm thick metal strip. The metal strip was withdrawn between contact points 36-35, 35-34, 34-33, 46-45, 45-44, and 44-43. They did not make measurements at 7-6 contacts, due to difficulties in placing and withdrawing the metal strip because of masticatory muscles and the cheeks. The I.P.F values were read in a supine position before and right after the removal of unerupted lower third molars. Later, they evaluated another group of patients to assess the effect of body posture on I.P.F values, and they found out that I.P.F values are smaller in supine position compared to upright position (95).

In 2000, Fuhrmann et al. measured I.P.F values at contact surfaces of 6-5, 5-4, 4-3, both in maxilla and mandible, in right and left quadrants. They read the I.P.F values of extraction patients with erupting third molars in an upright position, while they made the readings in a control group of patients in a supine position. By means of this, they evaluated the effects of body posture on the I.P.F values, and found out that I.P.F values are smaller in a supine position (35).

In our experimental procedure, a similar tension transducer hooked through a perforated metal strip of 0,05 mm thickness was used. We measured I.P.F in group I with bilaterally congenitally missing lower third molars, and in group II with bilaterally existing lower third molars. Taking the previously released data into consideration, all I.P.F readings were carried out in an upright position, between contact points 36-35, 35-34, 34-33, 46-45, 45-44, and 44-43, at baseline, 6th months and 12th months.

7.3 Discussion of The Results

7.3.1 Discussion of the model analysis results

When the overall change in model analysis parameters are evaluated, I.I increased in both groups between T1-T2, T1-T3 and T2-T3 ($p<0.01$), the mean difference being insignificant when groups are compared ($p>0.05$) (Tables 1 and 15).When I.I change is examined between baseline (T1) and final(T3) measurements, a significant increase of 1,1±0,99 mm in group I and 0,88±0,58 mm in group I.I is seen, the mean difference being insignificant among the groups (Tables 2 and 15). Our results concord with the results of other researches from the aspect of incisor irregularity. When literature is overviewed, the increase in lower anterior malalignment in adulthood is a common finding of various authors. For instance, Sinclair and Little (93) found 0,30±1,42 mm increase in I.I in a population of 65 untreated individuals. Similarly, Richardson and Gormley (90) reported 0,1±0,4 mm increase in incisor crowding between 18-21 years, and 0,2±0,4 mm increase between 18-28 years. As a difference, they used tooth size/arch length discrepancy for the evaluation. Bishara et al. (11) studied tooth size/arch length discrepancy in 30 untreated individuals, and found out that crowding in the lower arch increased 0,9±0,9 mm between 25-45 years. Richardson (81) found out that incisor crowding increased in 80 % of the subjects between 1-50 years of age. In an untreated sample, Carter and McNamara (22) found significant increase in II, 1,41 mm in females and 1,76 mm in females, between ages 16 and 48. All these researchers demonstrated that lower anterior crowding continues to increase in adult life. It can be stated that the amount of increase in lower anterior crowding in our given sample is similar to the results of mentioned studies in which I.I was used for comparison, although a similar amount of increase occurred in a shorter duration in our sample. However, none of these studies implied the effect of third molars in increasing lower anterior crowding, since they did not compare the subjects with and without lower third molars. In order to evaluate the effect of lower third molars on lower dental arch, correlation analysis was made in group II between changes in 38-GoGo angle, 48-GoGo angle and model analysis parameters. The results revealed that no correlation exists except for 48-GoGo and interpremolar width. Regarding the lack of correlation between lower third molars and lower I.I, and since the comparison of mean differences between the groups did not reach the level of significance in our study, we assume that the presence of lower third molars did not play the leading role in the increasing irregularity in our sample (Table 19).

Contradictory data is available on this aspect of the subject. For instance, Ades et al. (2), in a group of 97 orthodontically treated patients, and similar to our findings, he found out that extraction, eruption, impaction or agenesis of lower third molars did not influence the amount of posttreatment incisor irregularity. Harradine and Kirschen (37) also examined the effects of third molar extraction on lower anterior crowding in 77 patients and found out that II increased 1,1±2,72 mm in nonextraction patients, and 0,8±1,23 mm in extraction patients, respectively. However the mean difference of II between the groups did not reach the level of significance. On the contrary, a group of researchers suggested in their study that genesis, agenesis, impaction and extraction of lower third molars may have an influence on lower anterior alignment. Ng et al. (59) studied the effect of lower third molar impaction in a group of 66 untreated patients. They found out that crowding was 1,45 mm higher in patients with impacted lower third molars, difference being statistically significant. However, Ng et al. did not include subjects with lower third molar agenesis in their sample. Instead, they only quantified the effect of extraction of lower third molars in the lower dental arch. Niedzielska (60) studied the effects of agenesis, extraction and retention of lower third molars in a population of 47 patients between 14-18 and 19-31 years of age. According to the results, lower arch crowding tended to decrease 0.1 to 0.6 mm in sites where lower third molars were extracted, whereas it tended to increase in sites of retention of lower third molars, decrease being more pronounced in incisor, canine and premolar region. She also added that arch perimeter did not change in sites with third molar agenesis during the observation period. She suggested that, dental arches being parabolic in shape rather than straight, any mesial force from posterior of the arch may cause canines to go outside the parabola, thus may create a contact slippage and cause lower incisor crowding to increase. When the results of our study and other studies are taken into consideration, we assume that the unfavorable effect of lower third molar on the lower anterior crowding is limited, since we could not detect any correlation between I.P.F values and I.I in neither group I nor group II (Table 18). In order to test our assumption, correlation analysis in group II was made between lower third molar inclination and I.P.F values. No significant correlation was found at any of the contact points between I.P.F and lower third molar inclination. Regarding this result, we assume that existence of lower third molars does not affect the I.P.F values significantly (Table 19).

In our study, overall decrease in arch length during the experimental period is 0,96±0,71 mm in group I and 1,09±0,6 mm in group II respectively, mean differences of 2 groups being insignificant when compared (Tables 3 and 15).**.** When the correlation values are evaluated, the lower third molar situation did not correlate with arch length. Besides, the changes in axes of lower third molars on both sides lack significant correlation with I.P.F values at any of the contact surfaces (Table 19). Additionally, no significant correlation was found between I.P.F and arch length neither in group I nor in group II. Regarding these results, our assumption is that arch length decrease in our sample took place independent of the third molar situation. The decrease in arch length in this sample is similar with the results of a group of workers. For instance, Carter and McNamara (22*)*, Richardson and Gormley (90), Mills(54*)*, Bishara et al (11, 12), Sinclair and Little(93) reported decrease in arch length in their untreated adult population samples. But these researchers did not include a subgroup of subjects with agenesis of lower third molars. Thus, unlike our research, their results do not give an accurate idea of the effect of lower third molars on the mandibular arch perimeter. Some researchers investigated the effect of extraction of lower third molars on mandibular arch perimeter. For example, Niedzielska (60) in her study demonstrated that retention of the lower third molar resulted in a decrease of 1.15 mm to 0.25 mm in the arch length, whereas 0.4 to 0.7 mm increase was observed in sites where third molars were extracted. Additionally, she stated that no change was observed in mandibular arch length in sites with agenesis of third molars. Lidqvist and Thilander (49) demonstrated that the extraction of the lower third molar caused favorable effects on mandibular arch length only in 70 % of their given sample. Harradine et al.(37) found that mandibular arch length decreased significantly by 0.7 mm in subjects whose lower third molars were kept in mouth, compared to subjects who had gone through third molar extraction. On the contrary, Ades et al. (2) demonstrated that extraction, retention, impaction or congenital agenesis of lower third molars do not reveal any significant difference on lower arch length at young adulthood. Contradicting Ades et al, Vego (106) studied the changes in arch perimeter in adults with genesis or agenesis of mandibular third molars. She found out that arch perimeter loss was significantly greater by 0,8 mm in subjects with bilateral genesis of lower third molars, compared to subjects with bilateral agenesis of lower third molars. To date, our results are in agreement with the results of Ades et al. However, Niedzielska, Vego, Lindqvist and Thilander and Harradine et al. imply that extraction of lower third molar and termination of the mesially directed force from the third molar may have a favorable effect on lower arch length. Nevertheless, although the results of their study reveal significant differences, we assume that the effect of lower third molar extraction on lower arch length is questionable from the point of clinical significance, when the arch length changes reported in these studies are quantified. The correlation between I.P.F and arch length being insignificant in our sample also supports our assumption (Table 18).

In our given sample, intercanine width decreased significantly ($p<0.01$) in both group I and group II in overall experimental period (T1-T3) Interpremolar width also decreased significantly (for group I $p<0.01$, for group II $p<0.05$) in both group I and group II in overall experimental period (T1-T3). Intermolar width decreased significantly (for group I $p<0.01$, for group II $p<0.05$) in both group I and group II in overall experimental period (T1-T3). For all arch width measurements, mean differences between group I and group II were statistically insignificant (Tables 4, 5, 6 and 15). It is evident that, lower arch widths follow the tendency of reduction in our sample, as it was reported by various authors previously (11, 13, 22, 45, 54, 90, and 110). However, Moorrees and Chadha (55) found intecanine width very stable after the eruption of permanent dentition. Likely, Sinclair and Little(93) found intercanine width very stable in men, while they observed only minor decreases in women in an untreated adult sample. Bondevik (17) reported decrease of the mandibular intercanine width, whilst he announced an increase in intermolar width between 22-32 years of age. When the effects of lower third molars on lower arch widths were evaluated, Niedzielska (60) found that extraction of lower third molars caused an increase in intercanine, interpremolar and intermolar width, supporting the idea that when the unfavorable effects of lower third molars were eliminated, the lower dentition became more stable anteroposteriorly. However, Harradine et al. (37) and Ades et al (2) demonstrated in their sample that, the decrease in intercanine width did not exhibit a significant difference when lower third molar extraction and lower third molar retention cases were compared, implying that existence of the third molars had only a limited effect in their sample.

In our sample, the arch length decrease at lower canine, second premolar and first molar region was greater in group II compared to group I, although the difference between the groups was insignificant. Regarding the contradictory data available about the effect of lower third molars on lower arch widths, the correlation between lower third molar axis and arch widths in our sample was evaluated. It was found out that lower third molars lack in correlation with intercanine width and intermolar width, but positive correlation at level of 44,4 % exists only between lower right third molar axis and interpremolar width (Table 19). Regarding this result, it can be stated that existence of lower third molars did not affect the lower arch width significantly in our sample.

Taking these findings into consideration, it can be stated that lower incisor irregularity followed the trend to increase, while arch length and arch widths followed the trend to decrease in our given sample. Since the mean differences of the changes between group I and group II did not reach the level of significance, we assume that the presence of lower third molar was not the primary cause to the shortening and narrowing of the mandibular dental arch, and to the increase in lower incisor irregularity. The lack of significant correlation between the changes in the axes of lower third molars and lower I.I, arch length, intercanine width and intermolar width also supports our assumption. However, we could not preclude the possibility that mean difference of the changes being insignificant when third molar genesis and agenesis groups are compared may be due to the short observation period and limited sample size.

7.3.2 Discussion of the changes in cephalometric and panoramic parameters

Mesialization of the dentition and late mandibular growth have long been discussed as a cause of unfavorable changes in dental alignment. In our study groups, lateral cephalometric and panoramic radiographs were also examined to evaluate the dental and skeletal changes, and to differentiate their effects from the effects of lower third molars. The results of our evaluation demonstrates that no statistically significant change occurred in 12 months period for group I and group II in the position of lower first molars, lower third molars and lower incisors ($p>0.05$). Interpreting the skeletal changes, no significant change occurred in ANB and NAPg values in group I and group II. However, in group II, Ar-Pg distance, which indicates the mandibular length, increased significantly by 0,8±1,1 mm. Yet, mean difference of Ar-Pg between T1-T3 was insignificant when group I and group II were compared (Tables 7 and 16). The results of the statistical analysis show that the lower dentition was stable both in group I and group II in the given sample, which means that neither lower incisors nor lower first ant third molars moved significantly in the anteroposterior direction. Although the increase in the length of the mandible found to be insignificant in group I, there is evidence that mandible tends to increase in length in our sample as the increase was significant in group II.

Studying literature, one can see that contradictory data is available on skeletal and dental changes that take place in adult life. For example, Siatkowsky (94) stated in his study group that late mandibular growth forces lower incisors tip lingually in a more uprighted position, accounts for decrease in arch length and anterior arch circumference, therefore increases lower anterior malalignment. Similarly, Bishara et al. (10), in a group of untreated subjects followed between 25-46 years of age, demonstrated that parameters dictating mandibular length and mandibular position increased, and lower incisors were uprighted. Since lower anterior crowding also increased in the same group, the authors speculated that adolescents with a well aligned dentition should expect various amounts of crowding to occur in anterior region of dental arches as part of the normal maturation process. These results are contradicting with the results of our study, since the length of the mandible increased insignificantly in group I, significantly in group II, but the lower incisors were proclined insignificantly both in group I and group II. Similar to our results, Gormely and Richardson (42, 90), in a group of adult population, demonstrated that although the length of the mandible increased, the lower incisor-mandibular plane relationship stayed stable between 18 and 28 years of age. They suggested that since the lower incisor inclination in their study sample did not respond to late mandibular growth, the increase in lower anterior crowding in their group is a part of normal maturation process of the dental arches. They assumed that these late lower crowding occurs due to the changes in periodontal membrane as a part of normal ageing process or an inflammatory response. Sinclair and Little (92), studying the dentofacial changes in a group which were evaluated previously (93), reported mandible to rotate forward, anterior facial height, lower facial height and posterior facial height to increase, lower incisors to erupt and procline, lower molars to erupt into a relatively mesial position, all implying a mesial movement of the mandibular dentition. However, they found no correlation between the parameters reflecting lower incisor position and parameters reflecting amount and direction of the facial growth, which supports our results. They also reported that they were not able to demonstrate any relationship between the increase in lower incisor irregularity, decrease in lower arch length and width, and dentofacial changes of their study group. As a result, they suggested the changes that take place in adult life in dental arches and facial structures are a part of normal ‘’maturation process’’ of the dentofacial complex (92, 93). Richardson (75) in a study on young adults between ages 13 and 18, found out that the length of the mandible increased, lower incisors proclined, lower first molars were mesialized, intercanine width stayed stable, and intermolar width increased in her sample. She stated that the increase in lower anterior crowding is a result of mesialization of the dentition, and added that while the incisor crowding increases, some incisors may procline, some may retrocline due to the contact slippage, and explained the proclination of lower incisors by this way.

Another group of researchers suggested dentoalveolar and facial changes occurring as a result of other factors, rather than late mandibular growth or normal maturation process. For example, Richardson (84) studied dental students at age of 18 for 3 years, and found that space condition, lower incisor position and lower molar position stayed stable. However she noted significant increase in mandibular length and found mandible to rotate backwards significantly. Regarding these results, she suggested that lower arch crowding developing later in life, after a period of relative stability, is more likely to be due to changes in periodontal support, as in periodontal disease or ageing, which allow teeth to move under pressures they previously resisted. She reached to the same conclusion in another study of which she researched a group of adult patients between 18 and 50 years of age(81). Arman-Akgül and Toygar (4) suggested in their study that the skeletal and dentoalveolar changes, increase in facial height, increase in mandibular length, extrusion of lower molars and lower incisors, increase in incisor irregularity, decrease in arch length and width, did not correlate with each other. As a result, they suggested late lower anterior crowding to be related with the changes in perioral musculature, particularly age related retrusion of upper lips and decrease in lip thickness.

Our research and other researches available in the literature show that mandible continues to increase in length during adulthood, dentition tends to move forward to create a decrease in arch circumference, but the response of lower incisors may rather be in favor of proclination or retroclination, which may change interindividually.

When correlation between lower third molar axis and lower arch perimeters were assessed, no correlation between I.I, arch length, intercanine width and intermolar width existed. Positive correlation was shown only between lower right molar axis and interpremolar width. This lack of correlation supports the idea that the effect of lower third molar on the lower dental arch is less than it was assumed previously. When we look for the available literature, various authors support our findings. For example, Ades et al. (2) carried out a research on treated adults of mean age 18. They extracted lower third molars in one group of patients, and they left them in situ in the other group. In the long term follow up for 10 years, they found out that mandibular length increased, lower incisor inclination returned to its original values before orthodontic treatment, lower first molars tipped mesially, lower incisor irregularity increased, mandibular arch length and intercanine width decreased. When mean differences of the parameters were compared, no significant difference between lower third molar extraction and lower third molar retention was found. As a result, they assumed that the effect of lower third molar on the lower first molars and lower incisors is not as evident as it was supposed previously. Lindqvist and Thilander (49), in a research carried out among a group of patients between 15,5 -18,5 years of age, examined the effects of lower third molar extraction. It came out that, uprighting of lower first and second molars occurred if lower third molars were extracted. However, mean difference in other cephalometric variables did not exhibit any significant difference among two groups. Additionally, no correlation was found between changes in lower arch length and changes in cephalometric parameters in any of the groups.

In our group of adult samples during 12 months of observation period, cephalometric variables, angulations of lower incisors and lower first and third molars with mandibular plane, distance between vertical reference plane and lower first molars, which indicate the changes in dental structures, were found to be stable, compared to lower incisor irregularity and lower arch perimeters. Though, it can be suggested that third molar presence or absence in our group did not influence the position of lower first molars and lower incisors unfavorably, due to the lack of correlation between lower I.I, arch length, intercanine width, interpremolar width and intermolar width. As for the skeletal changes, only Ar-Pg distance indicating mandibular growth increased in group II, mean difference in Ar-Pg between group I and group II being insignificant. However, we should include the possibility that, in case of a longer observation period, comparison of skeletal and dental parameters may display intergroup differences due to accumulative characteristic of the changes. On behalf of these results, we suggest that late mandibular growth should be included as a possible cause for late lower anterior crowding, since small but continuous increments of mandibular growth may carry lower incisors in anterior direction and reduce the overjet, which may change the occlusal contacts in between upper and lower incisors. When the interincisor occlusal relationship changes, it is apparent that counteracting forces during occlusion may cause slippage of contacts, thus increase the lower anterior crowding (19, 64).

7.3.3 Discussion of the changes in I.P.F

According to our findings, I.P.F values revealed significant increase at all contact surfaces during the overall experimental period. When groups were compared, mean difference of I.P.F between T1 and T2 was found to be significantly higher in group II than in group I at contact surfaces 36-35 and 35-34. We assume that mean difference of I.P.F in group II being significant only on the left side may be due to the habit of chewing predominantly on one side. No significant intergroup differences were found when mean differences between T1 and T3 were compared (tables 8, 9, 10, 11, 12, 13 and 17), giving the idea that genesis of third lower third molars and increase in I.P.F levels are not directly correlated.

For further investigation, correlation analyses were performed between changes in I.P.F, dental arch changes and lower third molar positions, According to the results, some degree of correlation is found only for group I: A negative correlation between the change in intermolar width and the change in I.P.F at contact surface 34-33 at level of % 58,3, and a negative correlation between the change in interpremolar width and the change in I.P.F at contact surface 44-43 at level of % 62,8 (Table 19). That means, if the arch width is narrow posteriorly, the interdental force transmitted towards the anterior of the arch increases in group I. We assume that, the reasons to these correlations may be as follows:

1- If the posterior teeth tip lingually in a narrower arch form, the orientation of periodontal fibers, the fibers which are assumed to be creating the force to maintain the interdental contacts, may change in a more oblique position, and in this oblique position of fibers, periodontal ligament may have to generate greater I.P.F values in order to keep the teeth from further displacement.

2- The teeth surviving in a narrower arch form will probably be in a more tight contact relationship, since the space for the teeth to align is relatively limited, and these tighter contacts may likely produce higher values of I.P.F, in order to avoid further contact slippage. Akay's (3) results supports our assumption, since she found out significantly higher I.P.F values in subjects with severe crowding, compared to subjects with mild or minor crowding.

According to our results, change in I.P.F values at any of the contact point does not correlate with the increase in II neither in group I nor in group II. As a result, we suggest that genesis of lower third molars may rather not be closely related with the unfavorable changes in lower incisor alignment, as it was assumed previously. To test this assumption, correlation analysis was made for group II between panoramic parameters and I.P.F. Results revealed that lower third molar axis is not significantly correlated with I.P.F at any of the contact surfaces. All data available by the results of our study demonstrates that existence of lower third molars did not cause any significant unfavorable effects on the lower dental arch in the given period.

If we summarize the evidence revealed in literature, we can see that only a few researchers worked on the interrelationship between I.P.F and third molar status. For example, Fuhrmann et al, carried out a research on the effects of bilateral third molar extraction on I.P.F in a group of patients with mean age 20,5. They found significant reduction by 0,19 N in I.P.F readings in the mandible, and a continuous reduction of the transmitted force anteriorly. One year after extraction, I.P.F values were found to be decreased by 0,14 N, compared to baseline values, which indicates an increase by 0.05 N in the postoperative period. In this study, increase in I.P.F despite the lower third molar extraction goes parallel to our findings which demonstrated that I.P.F increases in time regardless of the third molar situation. They also took incisor irregularity into consideration, and found out that severity of the lower anterior crowding did not affect the release in I.P.F significantly. The most striking result of this study is that postoperative I.P.F decrease in patients with mesially angulated third molars were significantly greater than that of patients with uprighted third molars, while there was no change in I.P.F values of control group patients who had retained lower first molars. However, the comparison between third molar retention group and extraction group did not reveal any significant difference. Regarding these results, the authors suggested that the impact of lower third molar on I.P.F is lower than often assumed (35). The findings of our research, revealing that the third molar impact on I.P.F is insignificant, corresponds with the findings of Fuhrmann et al, when cases with third molar in mouth and cases without third molars are compared.

Southard et al., searched the effect of unilateral extraction of third molar on interdental contact tightness in a group of patients mean aged 20,6 years. They pointed that I.P.F values decreased from posterior to anterior. They found out that mean contact tightness decreased bilaterally after unilateral extraction, the relief being significant in 6-5 and 4-3 contacts in extraction site, and in 6-5 contact in nonextraction site. They also found that the difference between the decreased I.P.F in extraction and nonextraction sites was insignificant (-% 13,4 in extraction site, - %10,8 in nonextraction site). Additionally, they demonstrated that no correlation existed between I.P.F values and stage of third molar root development, third molar root length, third molar angulations and the depth of the third molar-second molar contact below the functional occlusal plane. These results support our results, since no correlation in group II was found between lower third molar axis and I.P.F at any of the contact points. Remarkably, Southard et al. assumed that the bilateral decrease in I.P.F after unilateral extraction of lower third molar is due to the supine position in which the measurements were made. However, they did not preclude the possibility of the third molar effect on dental malalignment. Instead, they claimed that long-acting effects of posture and possibly other factors overwhelm any effect from unerupted third molars on interproximal forces (95). Our results correspond with the assumptions of Southard et al, due to the fact that increase in I.P.F is lacking a correlation with increase in lower incisor irregularity in both of our study groups, and in group II, lower third molar axis is lacking correlation with I.P.F at any of the contact surfaces.

When we examine the literature available, we see that some authors support the idea that I.P.F is a compressive force holding the teeth together against the forces directed from tongue and the perioral musculature, while others assume that its character is resistive as it withstands the displacement of the teeth. We assume that the values recorded by different measurement techniques reveal a compressing force, since anything to separate the proximal contact has a thickness which create an increase in the width of neighboring periodontal space. When the object separating the contact is removed, the contracted periodontal fibers return their original positions and create a compressive force. For measuring the initial I.P.F without any separating device in between the contacts, Southard et al. tried a mathematical method. Their extrapolation was based on a linear decrease in force with metal strips decreasing in thickness. As a result, they found out that an initial mean I.P.F of 36,7 g exists between approximating teeth. Regardingly, they suggested that contact surfaces of adjacent teeth are maintained in a continuous state of compression, and that this compressive force is generated by the supporting periodontium, which supports our assumption (96). Unlike Southard et al., Vardimon et al.(105) used a different measurement principle to prove that I.P.F is the resistance force acting against the displacement of adjacent teeth. They evaluated I.P.F values in spaced and nonspaced dental arches, by measuring the resistance force of the adjacent teeth to the insertion of a metal strip binded to a bow-jig onto which a strain gauge is attached, rather than the friction force created between them. The idea was that during the placement of the separator between the teeth, a resistive force occurs and this resistive force causes a distortion in the bow-jig, and strain indicator reads the amount of this resistive force which cause distortion. They demonstrated that I.P.F values in spaced dentitions were significantly lower than that of nonspaced dentitions, and that the difference was more pronounced if the space was located in the anterior region. Regarding these results, the authors suggested that greater I.P.F values at posterior region compared to anterior region is the resistance mechanism of the dentition against mesial drift phenomenon and against the anterior component of the occlusal force. Besides, they assumed that the significant I.P.F reduction that took place in dentitions with anterior diastemas supports the resistant theory. Their assumption was due to the idea that the more the space is located anteriorly, the more the effects of mesial drift is diminished by having more posterior dental units resisting against the mesial drift. Our objection to the resistive force is that, whenever some equipment thicker than the contact is placed in a contact surface, the teeth are separated to cause the contraction of the periodontal ligament, and the periodontal ligament fibers would try to turn to their original form. This rebound action of the periodontal membrane is also likely to cause the distortion of the separating system, which makes it almost difficult to differentiate whether the I.P.F has a resistive or contractile character. Supporting our assumption, the resistance theory is conflicting with the findings of Moss and Picton (57), who stated in *macaca fascicularis* monkeys that, provided an interdental space, migration of the posterior teeth towards the space was greater than that of anterior teeth, which supports involvement of a compressive characteristics of I.P.F.

In each one of the studies, periodontal membrane was underlined as the source of I.P.F due to the transseptal fiber system. Evidence based data reveals that periodontal membrane is holding the teeth in a stable position against the counteracting labial and lingual forces from the musculature, and that any change in this counteraction may disable the periodontal ligament to keep the teeth in their proper alignment (68). In the literature, there is some evidence that periodontal membrane responds to local and environmental changes that affect the tissues. Previously, Moss and Picton (57, 66) proved the role of periodontal ligament in displacement of adjacent teeth towards a space, by measuring the force generated during the displacement. In another article, they also demonstrated that transseptal fiber system in the interdental papillae has also an important role in the mesial drift phenomenon, since they found out that when trauma is directed to the interdental soft tissues, the mesial drift of teeth in *Macaca irus* monkeys ceases (66). In addition, James and Taylor (44) stated that accumulated fibroblasts in between bone explants of chick embryos created a contractile stress which cause the adjacent bone explants to move towards each other. Ryan et al (91) demonstrated that fibroblast cells migrating human granulation tissue exhibit myofibroblastic characteristics that cause contraction between the wound segments. Additionally, Garant (40) described junctions between fibroblasts and connections from cells to collagen fibers, indicating the motile tendencies of these cells. Bellows et al (5) showed that human gingival fibroblasts cause collagen gel to contract more rapidly than the other cell types. All of these cellular based studies imply that the migration of fibroblast cells as a response to any change in physiological and pathological impact to the tissues cause a contractile force.

Regarding our results, the effect of mesially directed force from lower third molars on I.P.F still remains questionable, since the mean difference in

I.P.F changes during the experimental period was statistically insignificant when the two groups were compared. Literature available reveals that periodontal membrane cells are capable of producing contractile forces as a response to the alterations in the environmental condition. Therefore, it can be speculated that I.P.F increase in time may not be the cause of late lower anterior crowding. Instead, it may be the response of periodontal membrane against other factors like late mandibular growth, anterior component of the occlusal force, or soft tissue maturation, in order to keep the teeth in proper contact. Though, further crossectional studies on younger and elder subjects would be informative to detect the I.P.F levels at different ages, thus would enable us to understand the characteristics and fluctuation of I.P.F values during the maturation process.

8. CONCLUSION:

In our study sample:

1- Lower incisor irregularity increased, lower arch length, lower intercanine width, lower interpremolar width and lower intermolar width decreased significantly both in lower third molar genesis and lower third molar agenesis group during the experimental period of 12 months. However, the mean difference in corresponding values did not reveal any significant difference when groups were compared.

2- According to the cephalometric and panoramic variables, lower third molar position in group II found to be stable in the given period. Lower first molar and lower incisor axis to the mandibular plane, and the distance between lower first molars and vertical reference plane did not reveal any significant difference both in group I and group II. ANB angle and NAPg angle did not reveal any significant difference in both groups, indicating that the maxillomandibular relationship to the cranium was stable during the experimental period. For all the parameters mentioned, no statistically significant difference between group I and group II was found when mean changes in overall experimental period were compared. However, in group II, the increase in Ar-Pg distance was found to be significant in group I, indicating an increase in the mandibular length. Nevertheless, the comparison of mean difference in Ar-Pg in group I and group II was found to be insignificant.

3- I.P.F values increased significantly both in group I and group II, uncorrelated with the increase in incisor irregularity. Mean differences of I.P.F revealed significant difference only at contact points 36-35 and 35-34 between baseline and T2(6th month) measurements, in favor of group II. No significant difference was found for group I and group II, when mean difference of I.P.F values between T1-T3 were compared.

4- No significant correlation was found between I.P.F measurements, II measurements, arch length and intercanine width measurements of both group I and group II. However, in group I, significant negative correlations were demonstrated between increase in I.P.F at contact surface 34-33 and intermolar width, and increase in I.P.F at contact surface 44-43 and interpremolar width.

5- No significant correlation was found between the change in lower third molar axis and the increase in I.P.F. Additionally, no significant correlation was found between the change in lower third molar axis and increase in I.I, and decrease arch length, intercanine width and intermolar width. Positive correlation between lower third molar axis and interpremolar width existed only for the lower right third molar.

6- Regarding our result, we assume that the impact of lower third molars on late lower anterior crowding was insignificant in our sample during the experimental period.

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