REPUBLIC OF TURKEY

MARMARA UNIVERSITY

INSTITUTE OF HEALTH SCIENCES

CBCT EVALUATION OF THE RELATIONSHIP BETWEEN LOWER CENTRAL INCISOR INCLINATION AND MANDIBULAR SYMPHYSIS AMONG DIFFERENT SUBJECTS WITH NORMAL AND LONG FACE PATTERN.

TAYISIR GANEIBER

MASTER THESIS

DEPARTMENT of ORTHODONTICS

SUPERVISOR

Prof. Dr. Banu ÇAKIRER

ISTANBUL-2013

I. ACKNOWLEDGEMENTS

First of all, I would like to express my endless love and deep gratitude to my family for their love and support.

I would also like to express my gratitude to my thesis supervisor Professor Dr. Banu Çakırer, whose knowledge and experience led to the completion of this research project. Her consistent advice and encouragement is highly appreciated.

I would also like to thank all other faculty members, Professor Dr. Nejat Erverdi, Prof. Dr. Nazan Küçükkeles, Professor Dr. Sibel Biren, Professor Dr. Ahu Acar, Assist.Prof. Dr Mustafa Ateş, Assist Prof. Dr. Sirin Nevzatoglu, Dr. Nuray Yılmaz and Dr Melih Motro, who gave me the opportunity to be a member of this department and shared their knowledge with me.

Many thanks to Dr. Melih Motro for his major help and advice during the data collection and technical aspect of this thesis at the computer laboratory of Marmara University, without his assistant it will be almost impossible for me to finish my thesis, also I would like to thank Dt. Antonios Sygouros, Anas Dzulkhaini, Kadir Beycan and Paschalis Pamporakis for their priceless contribution.

Last but not least I would like to express my love to all my friends one by one and thank them for the great moments we shared during the last 3,5 years in the clinic: Evin, Elena, Maria, Ilias, Marifei, Müge, Ayşegül, Aved, Berza, Buket, Cihan, Işıl, Pınar, Yasemin, Duygu, Desen, Melis, Vasiliki, Thomas, Aris, Makis, Selcuk, Mahmoud, Abdullah, Cemre, Buket, Hamza, Rasha, Hossam, Momen, Hasan. I will always remember you with so much joy!

BEYAN

Bu tezin kendi çalışmam olduğunu, planlanmasından yazımına kadar hiçbir aşamasında etik dışı davranışımın olmadığını, tezdeki bütün bilgileri akademik ve etik kurallar içinde elde ettiğimi, tez çalışmasıyla elde edilmeyen bütün bilgi ve yorumlara kaynak gösterdiğimi ve bu kaynakları kaynaklar listesine aldığımı, tez çalışması ve yazımı sırasında patent ve telif haklarını ihlal edici bir davranışımın olmadığını beyan ederim.

12 May 2013

Tayisir Ganeiber

AFFIRMANCE

I affirm that this thesis study belongs to me. There is no immoral attitude in all stages from the planning stage of thesis to the writing stage. I gained all the information in the terms of academic and ethical rules. I stated sources for the information gained not with this thesis study. I showed the source in the list of sources, and again there is no copyright infringement in study and writing stage.

12May 2013

Tayisir Ganeiber

II CONTENTS

III. ABBREVIATIONS

1. °: Degrees
2. 14 mand plane: lower right central incisor – mandibular plane angle
3. 2D: two-dimensional
4. 3D: three-dimensional
5. AFH: Anterior Facial Height
6. AP: anterior-posterior
7. CBCT: Cone-Beam Computed Tomography
8. CT: Computed Tomography
9. DICOM: Digital Imaging Communications in Medicine
10. et al.: And others
11. fig: Figure
12. FMA: Frankfort horizontal plane
13. FOV: Field of View
14. FPDs: flat panel detectors
15. Go: Gonion
16. H: Height
17. HU: Hounsfield unit
18. ICC: Intraclass Correlation Coefficient
19. kVp: kilo voltage
20. LAT: Lateral
21. mA: milli amperes
22. MDCT: medical spiral system
23. Me: Menton
24. MIMICS: Materialize Interactive Medical Image Control Systems
25. mm: millimeter
26. MP angle: Mandibular Plane Angle
27. MPR: multi planar reformation
28. MRI: Magnetic Resonance Imaging
29. MSIs: Mini–screw implants

30. mSv: millisievert
31. N: Nasion
32. P: Probability
33. PFH: Posterior Facial Height
34. Pr: Prosthion
35. S: Sella
36. SD: Standard Deviation
37. SPSS: Statistical Package for Social Sciences
38. W: width

IV. FIGURE AND TABLE LIST

1. SUMMARY

The aim of this study is to elucidate any relationship between lower central incisor inclination and mandibular symphysis morphology among different subjects with normal and long facial growth pattern.

The material consisted of initial CBCT images of 74 Patients (mean age=16.9 years ± 5.3), who were divided based on their Mandibular plane angle into: Normal and High Angle mandibular growth pattern. Each group was divided into male and female subjects.

CBCT images were obtained by using Iluma Imtec imaging LLC, (3M Company Ardmore. Oklahoma. USA- 2007). The following parameters were measured: height and thickness of the entire symphysis, cancellous bone, vestibular and lingual cortical bone thickness at the apex of the lower right central incisor and possible inclination of the labial, lingual alveolar bone and the long axis of lower right central incisor.

The results showed that for both genders, all height and thickness measurements of symphyseal bone and lower right central incisor inclination of normal face group were higher compared to the long face group, except the symphysis height, which was found to be longer in long face group.

Significant correlation was found between the lower right central incisor inclination and its associated alveolar bone morphology in long face subjects.

Conclusions: There is a statistically significant relationship between facial type and the mandibular symphysis morphology. The morphology of the alveolar bone is affected by incisal inclination in the long face subjects.

Key words: Symphysis morphology, cone-beam computed tomography, lower incisor inclination, Facial type.

2. ÖZET

Normal ve Uzun Yüz yapısına Sahip Bireylerde alt keser inklinasyonalrı ve mandibular simfiz arasındaki ilşkinin CBCT ile değerlendirilmesi.

Bu çalışmanın amacı, konik-ışıklı bilgisayarlı tomografi görüntüleri üzerinde, alt santral kesici diş eğiminin mandibular simfiz morfolojisi ile olan ilşkisini Normal ve Uzun yüzlü bireylerde ayrı ayrı incelemek ve karşılaştırmaktır.

Çalışmanın materyalini Marmara Üniversitesi Diş Hekimliği Fakültesi Ortodonti ABD da tedavi edilen 74 hastanın (ortalama yaşı=16.9± 5.3 SD) ortodontik tedavi öncesi CBCT görüntüleri oluşturmaktadır. Bu hastalar madibular düzlem açılarına göre Dikey Büyüme ve Normal Büyüme yönüne sahip bireyler olarak iki gruba ayrıldı. Her bir grup içindeki bireyler de erkek ve kadın olarak 2 gruba ayrıldı. CBCT görüntüleri Iluma Imtec görüntüleme LLC (3M Company Ardmore. Oklahoma. USA- 2007) cihazı kullanılarak çekildi. Görüntüler üzerinde aşağıdaki parametreler ölçüldü: tüm simfizin, kortikal ve süngerimsi kemiğin yüksekliği ve kalınlığı, sağ alt santral kesici dişin inklinasyonu, labial ve lingual alveol kemiğinin inklinasyonu.

Ölçümler kadın ve erkek bireylerde ayrı ayrı değerlendirildi ancak cinsiyetler arasında fark olmadığı görülünce bireyler cinsiyet ayrımı yapılmaksızın sadece dikey yüz büyüme yönlerine gore grupkandırıldı. Normal yüz grubu değerleri uzun yüz grubu değerleri ile karşılaştırıldığında, simfiz yüksekliğinin uzun yüz grubunda artmış olduğu ancak diğer tüm ölçümlerin azaldığı bulundu..

Uzun yüze sahip bireylerde, alt sağ santral kesici eğiminin ilgili kemik morfolojisi i arasında anlamlı korelasyon bulundu.

Sonuç olarak, dikey yüz büyüme modelinin mandibular simfiz morfolojisi arasında istatiksel olarak anlamlı bir ilişki bulunmuştur. Uzun yüzlü bireylerde alveol kemiğinin morfolojisi keser eğiminden etkilenir.

Anahtar kelimeler: simfiz morfolojisi, cone-beam bilgisayarlı tomografi,alt keser eğimi,Yüz tipleri

3. INTRODUCTION AND AIMS

The human face has been the subject of study since man could first express himself, as civilizations have risen and subsequently faded away.

It is already known that facial growth is a complicated process, which reacts to multiple factors that combined to produce the unique feature of human face.

While genetic factors can impose a dominant control, changes in function, as with chronic oral respiration or thumb sucking, can induce an increase in the vertical facial dimension (155, 11). The interaction between the craniofacial skeleton and muscles of mastication also play an important role in the control of craniofacial growth, which involves significant changes in the vertical facial dimension (24,130).

There is evidence that the form of the mandible and maxilla, specifically the density and thickness of the cortical plate, adapts to the function of the masticatory apparatus (148). Frost’s mechanostat hypothesis provides an explanation of this adaptive process. It suggests that there is a range of strain values, which maintain the form and mass of the bone. Strains above this range induce bone production, strains below the maintenance range leads to bone loss (51).

Accompanying these dimensional changes are changes in the shape of the mandible, including alterations in the cortical bone shape, thickness, and mineralization, which reacts to changes in loading by forces developed through the dentition and joint as the muscles contract during function (24, 102).

Cortical bone thickness should respond to the complex functions of loading directly by the muscles attached to the mandible (73) as well as by the forces generated by the muscles to the articulating surfaces of the dentition and condyles so that muscles can provide forces to the cortical bone both directly and indirectly (72).

Ricketts et al. (120) described the long face pattern as being long and narrow with dental arches that are frequently crowded and have weak musculature and obtuse gonial angle.

In contrast, the short face pattern is short and wide with strong square mandible and broad dental arches, those features support the hypothesis that stronger muscle and high load function increase the bone thickness and density, which means cortical bone mineralization, does vary with vertical facial dimension (93, 94).

Identifying the relationship between the vertical growth pattern and thickness of the alveolar bone will help the practitioners to prescribe the best orthodontic treatment plan and anticipate the risk factor.

For example the clinician can choose the optimum type of mini implant diameter and length according to the facial height of his or her patient since hypodivergent (short face) patient usually have thicker cortical bone than hyperdivergent (long face) patient (103).

Also the mandibular symphysis shape and thickness is the anatomic factor that limits the forward movement of lower incisors, so awareness of this structure reduce the risk of potential damage to the root of teeth, gingival attachment and alveolar bone when moving teeth orthodontically (106,131).

A few studies have been conducted to find the relationship between the mandibular cortical bone thickness and facial divergence.

Masumoto concluded that buccal and lingual cortical plate thickness of the mandible was thinner in long face subject than the average and short subjects (97).

Also, Beckman and his colleagues have found that individuals with larger lower face heights had narrower maxillary and mandibular alveolar processes and symphyseal bone when compared to individuals with shorter lower facial heights (15).

Some of these studies were conducted on a small number of subjects or were using 2D image or X-rays to investigate the bone features, which were not reliable due to the poor image quality of the traditional X-rays such as superimposition, magnification or poor image details of small anatomical sites (150).

The purpose of this study was to evaluate Symphyseal bone morphology, thickness, and its relationship with vertical facial growth pattern and lower incisor inclination on 3D cone beam computed tomography images.

4. LITERATURE REVIEW

4.1 Vertical Facial Growth

The growth of the human face presents some of the most complex problems of biology, problems that continue to attract the attention of many anatomists and dental research workers.

The facial skeleton increase in size in all three planes: height, width and depth, but it grows in these three dimensions of space differentially, at different times and at different rates.

Growth of facial bone occurs in four ways:

(I) Replacement of cartilage by bone like in the spheno-occipital and sphenoethmoidal junctions at the base of skull, which contribute to the forward growth of face.

(II) Appositional growth, as well as modeling resorption on the surface of bones, contributes to growth in all directions.

(III) Sutural growth.

(IV) Growth of the nasal cartilage septum, which contributes to downward and forward growth of the face (18).

The growth of the facial skeleton is directed downward and forward as a result of bone apposition along certain growth sites (38) which have been documented by many methods. Good evidence has been presented that major sites of bony additions include the maxillomandibular complex sutures, maxillary alveolar process, the mandibular condyle and alveolar processes (41).

Since the mandible possesses an articulation with the skull, it is necessary that vertical growth increase in the anterior face exactly equal vertical growth increase in the posterior face in amount and timing or the mandible will rotate around its articulation, if vertical increase at the facial sutures and/or the alveolar process should exceed the vertical increase at the mandibular condyle, the mandibule would rotate back-ward and increase vertical facial dimension. Conversely, if the vertical growth at the condyle should exceed the sum of the vertical growth component at the facial sutures and alveolar process, the mandible would rotate forward and decrease the vertical facial dimension. Either one of these changes would alter the downward and forward constant vectorial direction of facial growth, extreme mandibular rotation can logically be expected to alter facial heights to extreme level (75). Therefore, the growth of lower jaw has a strong influence on the facial vertical growth.

The exact mechanism of how the vertical facial growth is guided is not clearly understood. While some authors believe that genetic concordance has strong influence on how the vertical facial pattern will grow (39), others have proved the important role of function and environment on the course of vertical facial growth (9, 54, 117).

4.2 Etiology of Vertical Malocclusion

Vertical malocclusion results from the interplay of many different etiological factors during the growth period. These factors may affect the mode of the skeletal and/ or dental growth, respiratory and oral functions or may cause some medical problems, which in turn effect the facial growth.

(I) Condylar Growth:

In studies of facial growth, by using metallic implant technique Bjork and Skieller (21, 23) demonstrated that the direction of growth of the lower jaw varies greatly in the normal population. Although the most common direction of the condylar growth was found to be vertical with some anterior component, a more extreme upward, forward growth pattern of the condyle also common. Posterior growth was less frequently observed.

Most likely, patients with upward and forward growth of the mandibular condyle (Fig 4.1) have reduced anterior face height, if they develop a malocclusion, it is nearly always associated with a deep bite. In more extreme cases of upward, forward growth of the condyle a Class II division 2 malocclusion in combination with a skeletal deep bite is common (22, 24).

In contrast patients with so called “long face syndrome” and a pronounced increase in lower face height, have a more posteriorly directed growth pattern of the condyle (Fig 4.2).

The direction of mandibular growth as expressed at the chin is mostly vertical, if they develop a malocclusion it is mostly an anterior open bite often in combination of Class I or II malocclusion.

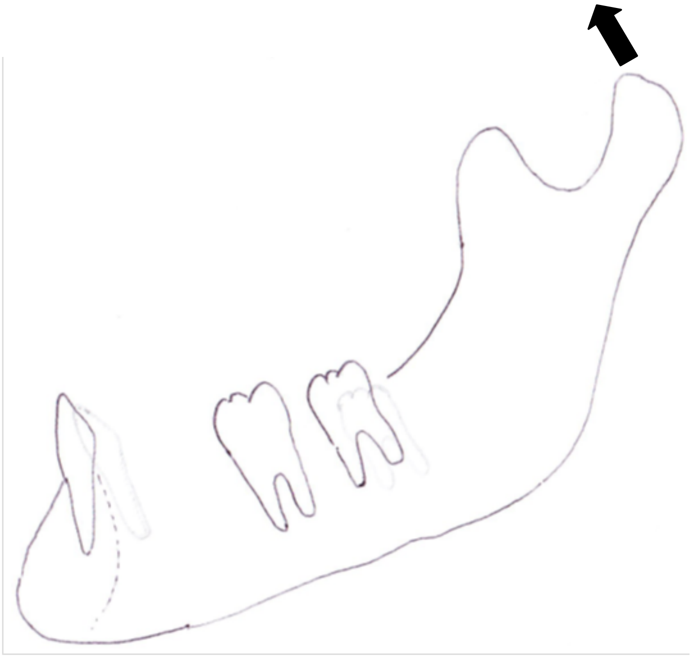


Fig 4.1 Upward, forward growth of the condyle

Fig 4.2 posteriorly directed growth of the condyle

(II) Ratio of Posterior Facial Height (PFH) to Anterior Facial Height (AFH)

Changes related to facial growth illustrated with the two extreme growth patterns (long face and short face) are due not only to differences in condylar growth direction , but are also the result of differences in the anterior facial height (AFH) and posterior facial height (PFH) (76). The anterior facial height measured from Nasion -the most anterior aspect of the frontonasal suture- to Menton -the most inferior part of chin- while posterior facial height is measured from Sella -Geometric center of the pitutary fossa located by inspection- to Gonion -the most inferior and posterior part of the mandibular angle.

The differences in height development lead to rotational growth or positional changes of the mandible that effect greatly the position of the chin.

The factors that determine the increase in the AFH are the eruption of the maxillary and mandibular posterior teeth and the amount of sutural lowering of the maxilla. PFH on the other hand is determined by the lowering of the temporomandibular fossae and condylar growth (76, 133).

When vertical condylar growth exceeds dentoalveolar growth i.e eruption of the teeth in the jaws, forward rotation of the mandible occurs (short face or horizontal growth pattern).

In contrast, if dentoalveolar growth is greater than vertical condylar growth, the resulting changes in mandibular position is backward rotation of the mandible (long face or vertical growth pattern).

(III) Muscle function

In a study of the facial morphology in three groups of subjects, low angle, average and high angle, Isaacson et al (75) found that high angle and low angle subjects had similar upper face height development. Vertical height from the palatal plane to the maxillary molar however was significantly greater in the high angle group than in normal and low angle groups.

The difference in posterior dentoalveolar development in the maxilla was found to be associated with weaker musculature in high angle cases as opposed to stronger musculature in the low angle cases as reported by Moller (100). Weijs and Hillen (146) who studied the facial muscle cross section using computed tomography, found that the masseter and medial pterygoid muscles were larger in persons with brachycephalic skulls, short faces, and a small jaw angle.

(VI) Air Way Problems

Airway obstruction or blocked airways can result from different causes like hypertrophy of tonsils or adenoid tissue, nasal septum deviation, large conchae or allergies, these conditions will force the patients to partially or completely breathe through their mouth.

Differences in mandibular rest position between normal and high angle cases and patency of the airways have been connected with the “long face syndrome”, a condition frequently observed in high angle cases and may affect mandibular posture allowing more freedom for posterior teeth eruption (108).

This hypothesis is supported by Linder-Aronson (9, 10) who demonstrated closing of the mandibular plane angle and reduction of the anterior face height following removal of adenoids and tonsillectomy.

(V) The Role of Abnormal Swallowing and Tongue Posture

During the 1950s and 1960s, some clinicians reincarnated and popularized the idea that open bite was caused by tongue thrusting and abnormal swallowing (54, 89). Some open bite treatment approaches were aimed at retraining or restricting the action of the tongue (64, 111) and correcting speech pattern (48, 26). However, Proffit and Mason (117) reported that a poor correlation existed between tongue thrust and open bite malocclusion. The research of Proffit has demonstrated that physical activities such as swallowing, chewing and speaking have no impact on the morphology of the dentition. Conversely, postural alteration leading to changes in lip and tongue resting pressure and posture play a significant role. Both orthodontic clinical experience and laboratory studies (115) indicate that the threshold for duration was between 4-8 hours per day, below this threshold force had no effect on tooth position, while, resting pressure apparently had an effect, even if the forces were light because of the long-term action.

On the other hand, Frankle concluded that an absence of competent oral seal was due to lack of adequate postural activity of the lip-valve musculature (50) and advocated the initiation of a regimen of lip seal exercise to address such a problem. To evaluate this hypothesis Frankle and Frankle (49) evaluated the form – function relationship in patients with severe skeletal open bite. Serial lateral head films were taken of 30 patients and 11 untreated subjects, all of whom characterized by severe skeletal open bite, the patients were treated with lip seal training and a function regulator appliance. During the 8 years interval, the values for mandibular plane relative to sella-nasion or the palatal plane changed in the treated group and fell to within the normal range, as did the ratios of the anterior facial height to lower anterior facial height and anterior facial height to posterior facial height. In contrast, the same measurements for the untreated controls remained unchanged or became worse.

4.3 Diagnosis of Vertical Malocclusion

The vertical dimension problem is complex and multifactorial, not only must the clinician recognize a vertical discrepant abnormality, he/she must be able to recognize its numerous components and understand their inter relationships.

The diagnosis must analyze all three components of a malocclusion facial, dental, and skeletal. Each component must be carefully studied and understood so that the proper questions are asked and the correct diagnostic decisions are made to lead to an effective treatment plan (85).

In general, vertical malocclusion can be divided to hyperdivergent (long face) and hypodivergent (short face).

(I) Hyperdivergent Malocclusion:

The anterior vertical excess has been given many other terms, such as vertical maxillary excess, hyperdivergent skeletal pattern, high angle case, long face, and skeletal open bite (98).

In summary, on clinical examination, long face patients are characterized by the following:

(i) Excessive anterior face height, particularly in the lower third.

(ii) Lip incompetence (resting lip separation >4mm). This judgment must be made with soft tissue at rest, not in a smile, Lip elevation during smiling is quite variable, and some exposure of gingival then may be neither abnormal nor unaesthetic.

(iii) A tendency toward anterior open bite, however, one third of long face patients have normal or excessive overbite, and only one in six has 4mm or more open bite.

(iv) A tendency toward mandibular deficiency and class II malocclusion, although the anterior posterior relationship can be anything from severe class II to mild class III. A severe class III problem puts the patient in a different category.

(v) A tendency toward more crowding of lower than upper incisors

(vi) A tendency toward a narrow maxilla and posterior cross bite, a finding in about half of the patients.

Cephalometrically, long face patients nearly always have the following:

(i) Rotation of the palatal plane down posteriorly (i.e. the maxilla has descended posteriorly more than anteriorly). This is shown clearly by the inclination of the palatal plane compare to the other horizontal reference planes. The linear distance from the cranial base to posterior landmarks e.g. Posterior nasal spine) usually is increased.

(ii) Excessive eruption of maxillary posterior teeth (i.e. the distance from the palatal plane to the cusps of the upper teeth is increased).

(iii) Rotation of the mandible down and back, giving an increased mandibular plane angle. To a large extent, this is secondary to the maxillary rotation and elongation of the maxillary molars, but the mandibular ramus often is short. If so, the mandible, as well as the maxilla, is part of the problem. The rotation usually is not related to excessive eruption of mandibular posterior teeth, linear distance from the lower border of the mandible to the cusps of the lower molars nearly always are normal.

(iv) Excessive eruption of maxillary and mandibular incisors is in partial for compensation of the jaw rotation. Even patients who have anterior open bite have this finding, but it is the greatest in those with a deep bite (116).

Although a number of investigators have tried to find a single cephalometric criterion that would reliably indicate the long face condition, this has proved impossible.

Fields et al (46) demonstrated that three cephalometric criteria in combination are necessary to quantify the condition observed by skilled clinicians, this is not a surprise finding, perhaps when the disturbed proportional jaw and tooth relationships of these patients are considered.

Several combinations of characteristics can be used for diagnosis, but the best result is based on a combination of increased mandibular plane angle, increased total anterior face height, and decreased percentage of upper versus lower face height. If a patient has all three, he/she can be considered to have a long face deformity with very high confidence.

(II) Hypodivergent Malocclusion:

The anterior vertical deficiency is characterized by the opposite features of the vertical excess and is called vertical maxillary deficiency, hypodivergent skeletal pattern, low angle case, short face, and skeletal deep bite (98).

Most hypodivergent or short face patients demonstrate these specific features, which can be summarized in the following list:

On clinical examination, you may notice the following features:

(i) Extra-oral characteristics may include –acute nasolabial angle, decreased lower facial height, no teeth showing at repose, flat mandibular plane angle, deep mentolabial fold, well-developed pogonion.

(ii) Dental Characteristics – Deep overbite.

Cephalometric evaluation of most hypodivergent patients exhibits the underlying feature:

Increased mandibular ramus height, increased poster facial height, flat mandibular plane angle, acute gonial angle, decreased anterior lower facial height, shorter than normal dentoalveolar height (20).

4.4 Anatomy and Ossification of the Mandible

The mandible, the largest and strongest bone of the face, serves for the reception of the lower teeth. It consists of a curved, horizontal portion, the body, and two perpendicular portions, the rami, which unite with the ends of the body nearly at right angles.

The Body (*corpus mandibulari)* is curved somewhat like a horseshoe and has two surfaces and two borders.

-Surfaces, the external surface is marked in the median line by a faint ridge, indicating the symphysis or line of junction of the two pieces of which the bone is composed at an early period of life. This ridge divides below and encloses a triangular eminence, the mental protuberance, the base of which is depressed in the center but raised on either side to form the mental tubercle. On either side of the symphysis, just below the incisor teeth, is a depression, the incisive fossa, which gives origin to the Mentalis and a small portion of the Orbicularis oris.

Below the second premolar tooth, on either side, mid way between the upper and lower borders of the body, is the mental foramen, for the passage of the mental vessels and nerve. Running backward and upward from each mental tubercle is a faint ridge, the oblique line, which is continuous with the anterior border of the ramus, it affords attachment to the Quadratus labii inferioris and Triangularis, the Platysma is attached below it. (Fig 4.3)

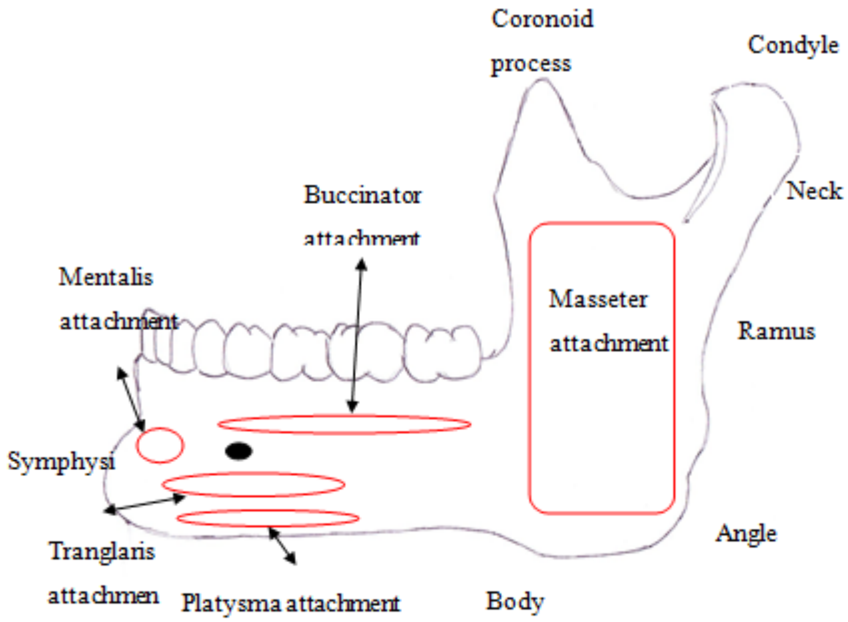


Fig 4.3 External Surface of the Mandible

The internal surface is concave from side to side. Near the lower part of the symphysis is a pair of laterally placed spines, termed the mental spines, which give origin to the Genioglossi. Immediately below these is a second pair of spines, or more frequently a median ridge or impression, for the origin of the Geniohyoidei. In some cases the mental spines are fused to form a single eminence, in others they are absent and their position is indicated merely by an irregularity of the surface.

Above the mental spines, a median foramen and furrow are sometimes seen, they mark the line of union of the halves of the bone. Below the mental spines, on either side of the middle line, is an oval depression for the attachment of the anterior belly of the Digastricus.

Extending upward and backward on either side from the lower part of the symphysis is the mylohyoid line, which gives origin to the Mylohyoideus, the posterior part of this line, near the alveolar margin, gives attachment to a small part of the Constrictor pharyngis superior, and to the pterygomandibular raphe. Above the anterior part of this line is a smooth triangular area against which the sublingual gland rests, and below the hinder part, an oval fossa for the submaxillary gland. (Fig 4.4)

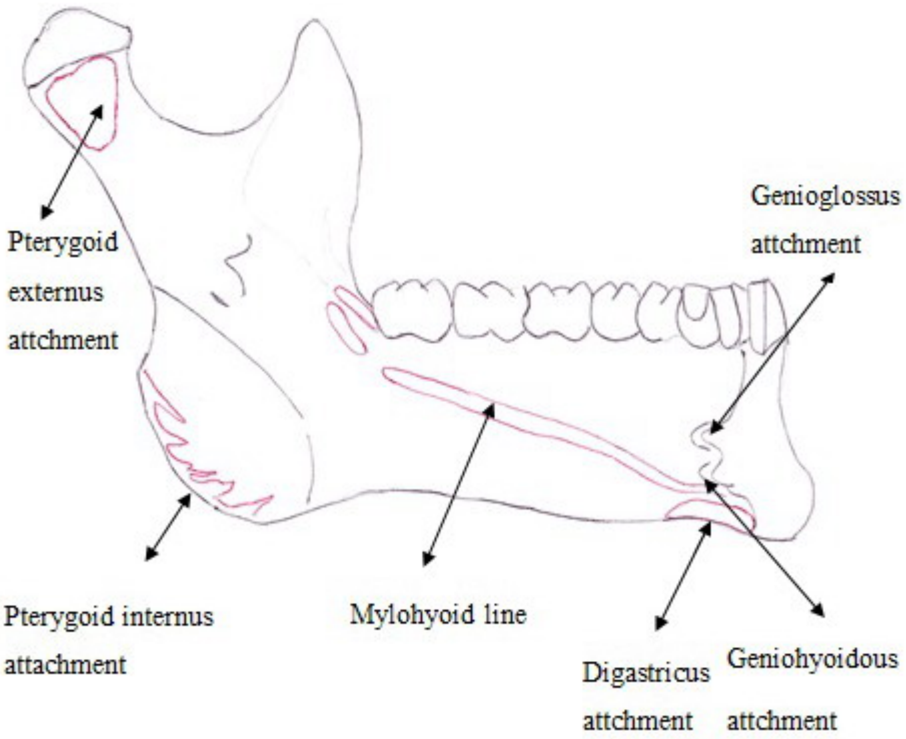


Fig 4.4 Internal Surface of the Mandible

Borders: the superior or alveolar border, wider behind than in front, is hollowed into cavities, for the reception of the teeth, these cavities are sixteen in number, and vary in depth and size according to the teeth which they contain.

On either side, the Buccinator is attached as far forward as the first molar tooth. The inferior border is rounded, longer than the superior, and thicker in front than behind, at the point where it joins the lower border of the ramus a shallow groove, for the external maxillary artery, may be present.

The Ramus (mandibul perpendicular portion). is quadrilateral in shape, and has two surfaces, four borders, and two processes.

Surfaces.—the lateral surface is flat and marked by oblique ridges at its lower part, it gives attachment throughout nearly the whole of its extent to the Masseter. The medial surface presents about its center the oblique mandibular foramen, for the entrance of the inferior alveolar vessels and nerve.

The margin of this opening is irregular, it presents in front a prominent ridge, surmounted by a sharp spine, the lingula mandibula, which gives attachment to the sphenomandibular ligament, at its lower and back part is a notch from which the mylohyoid groove runs obliquely downward and forward, and lodges the mylohyoid vessels and nerve.

Behind this groove is a rough surface, for the insertion of the Pterygoideus internus. The mandibular canal runs obliquely downward and forward in the ramus, and then horizontally forward in the body, where it is placed under the alveoli and communicates with them by small openings. On arriving at the incisor teeth, it turns back to communicate with the mental foramen, giving off two small canals which run to the cavities containing the incisor teeth. In the posterior two-thirds of the bone, the canal is situated near the internal surface of the mandible, and in the anterior third, near its external surface. It contains the inferior alveolar vessels and nerve, from which branches are distributed to the teeth.

The lower border of the ramus is thick, straight, and continuous with the inferior border of the body of the bone. At its junction with the posterior border is the angle of the mandible, which may be either inverted or averted and is marked by rough, oblique ridges on each side, for the attachment of the Masseter laterally, and the Pterygoideus internus medially, the stylomandibular ligament is attached to the angle between these muscles. The anterior border is thin above, thicker below, and continuous with the oblique line.

The posterior border is thick, smooth, rounded, and covered by the parotid gland. The upper border is thin, and is surmounted by two processes, the coronoid in front and the condyloid behind, separated by a deep concavity, the mandibular notch.

The Coronoid Process (processus coronoideus) is a thin, triangular eminence, which is flattened from side to side and varies in shape and size. Its anterior border is convex and is continuous below with the anterior border of the ramus, its posterior border is concave and forms the anterior boundary of the mandibular notch. Its lateral surface is smooth, and affords insertion to the Temporalis and Masseter. Its medial surface gives insertion to the Temporalis, and presents a ridge, which begins near the apex of the process and runs downward and forward to the inner side of the last molar tooth. Between this ridge and the anterior border is a grooved triangular area, the upper part of which gives attachment to the Temporalis, the lower part to some fibers of the Buccinator.

The Condyloid Process (processus condyloideus) is thicker than the coronoid, and consists of two portions: the condyle, and the constricted portion that supports it, the neck.

The condyle presents an articular surface for articulation with the articular disk of the temporomandibular joint, it is convex from front to back and from side to side, and extends farther on the posterior than on the anterior surface.

Its long axis is directed medial ward and slightly backward, and if prolonged to the middle line will meet that of the opposite condyle near the anterior margin of the foramen magnum.

At the lateral extremity of the condyle is a small tubercle for the attachment of the temporomandibular ligament. The neck is flattened from before backward and strengthened by ridges, which descend from the forepart and sides of the condyle. Its posterior surface is convex, its anterior presents a depression for the attachment of the Pterygoideus externus.

The mandibular notch, separating the two processes, is a deep semilunar depression, and is crossed by the masseteric vessels and nerve.

Ossification.—the mandible is ossified in the fibrous membrane covering the outer surfaces of Meckel's cartilages.

These cartilages form the cartilaginous bar of the mandibular arch, and are two in number, a right and a left. Their proximal or cranial ends are connected with the ear capsules, and their distal extremities are joined to one another at the symphysis by mesodermal tissue.

From the proximal end of each cartilage the malleus and incus, two of the bones of the middle ear, are developed, the next succeeding portion, as far as the lingula, is replaced by fibrous tissue, which persists to form the sphenomandibular ligament.

Ossification takes place in the membrane covering the outer surface of the ventral end of Meckel's cartilage and each half of the bone is formed from a single center that appears, near the mental foramen, about the sixth week of fetal life.

By the tenth week, the portion of Meckel's cartilage, which lies below and behind the incisor teeth, is surrounded and invaded by the membrane bone. Somewhat later, accessory nuclei of cartilage make their appearance, a wedge-shaped nucleus in the condyloid process and extending downward through the ramus, a small strip along the anterior border of the coronoid process, and smaller nuclei in the front part of both alveolar walls and along the front of the lower border of the bone.

These accessory nuclei possess no separate ossific centers, but are invaded by the surrounding membrane bone and undergo absorption. The inner alveolar border, usually described as arising from a separate ossific center (splenial center), is formed in the human mandible by an in growth from the main mass of the bone.

At birth, the bone consists of two parts, united by a fibrous symphysis, in which ossification takes place during the first year (58).

4.5 Bone Biology and Function

Bone, as an organ, has many distinct features and functions. The main role of the bony skeleton is to support the body. Secondary roles include acting as a mineral reserve, protecting internal organs, and, with the action of muscles, producing movements.

Genetics maps out bone's predisposed mass and morphology while also providing the potential for adaptation. The adaptation experienced by bone is actually a process of modeling and remodeling stimulated by the biomechanical environment in which it is surrounded. Local resorption and formation of the bony complex is the result of an intricate balance between the components of the cellular, muscular, and functional biomechanical environment (129,148).

Calcified bone is composed of 25% organic matrix (of which 2-5% are cells), 5% water, and 70% hydroxyapatite, an inorganic mineral. The main cells of bone are osteoblasts, osteocytes, and osteoclasts, all of which play specific roles in the formation and maintenance of bone.

Osteoblasts are matrix-producing cells that regulate the mineralization of the skeleton. The extracellular matrix is first produced and laid down by osteoblasts in the form of osteoid a newly synthesized, unmineralized collagen medium. In order to lay down the extracellular matrix they produce, osteoblasts must be closely arranged and rely heavily ontrans-membrane protein cell-cell contacts, along with specialized receptors.

It is necessary for the matrix to be an intricate lattice so as to maintain cellular function and responsiveness to metabolic and mechanical stimuli (45, 91) Likewise, it is important to have communication between the cells in order to sense the need for and to direct the locations of new bone formation (37).

Eventually, some osteoblasts may become “trapped” in their own calcified matrix. Once this occurs, they characteristically change into osteocytes, while at the same time remaining intricately connected to cells of similar characteristics, creating a 3-dimensional bony structure.

Osteocytes are structure-providing cells and compose about 90% of the cells of the adult skeleton. Since osteocytes are the primary cells in adult bone, and it is known that adult bone remodels, it may hold true that the osteocyte directs the resorption process by recruiting osteoclasts to specific locations (29).

A key player in the resorption process is the osteoclast. These cells are highly migratory, multinucleated, and polarized cells. With the help of their pleomorphic mitochondria, vacuoules, and lysosmoes, osteoclasts easily achieve their function of resorption (129).

Bones are capable of the withstanding the functional demands placed on them. In general, their hollow form creates a strong and rigid structure, allowing them to withstand weight-bearing forces such as compression. Being hollow also lightens the skeleton.

There are two basic, yet distinct appearances of bone: woven bone and lamellar bone. Woven bone is immature, poorly developed bone found in the embryonic and fetal stages of life and, in healthy adults, at ligament and tendon insertions, in areas of bony pathology where bone may not be strong and healthy, and at fracture healing sites. Mechanical stimulation, such as compression or tension, can cause rapid production of woven bone in a field of mature bone (122). Therefore, the production of woven bone is a strategic means of rapidly responding to changes in functional activity (129).

Lamellar bone appears within a few weeks after woven bone is deposited. It is the mature bone found in both cortical and trabecular bone. Cortical bone, otherwise known as compact bone, forms the cortex, or outer shell, of most bones and is much denser than its counterpart cancellous bone.

Cancellous bone, synonymous with trabecular bone or spongy bone is less dense, softer, weaker, and less stiff. It is highly vascular, contains red bone marrow and commonly occurs at the ends of long bones. Because of the bone marrow it contains, cancellous bone is the site of blood cell production.

As was mentioned previously, bone models and remodels in response to functional loads (148). Modeling occurs when bone is laid down with no regard for resorption, resorption is not a necessary function for modeling to occur.

Remodeling is an osteoclastic activity where pockets or areas of bone resorb and are filled-in with bone produced by osteoblasts. A classic example of this event is metaphyseal reshaping. Here, the widening of the diaphysis of long bones is achieved by deposition of bone on the periosteal and endosteal surfaces. As the diaphysis widens and lengthens so does the metaphysis.

To prevent an overly large metaphysis, remodeling must occur. The remodeling occurs by resorption of bone on the periosteal surface and apposition of bone on the endosteal surface, thus achieving a proportionate long bone (129).

Bone cells must be closely associated to sense signals in order begin the modeling and remodeling process. According to Pearson et al. (112), the way in which osteocytes sense loading is poorly understood, but some theories have been suggested.

The most widely known and referenced theory is that of Wolff's Law. This law states that bones model and remodel in response to mechanical and environmental influences (124). Osteocytes and their associated structures form intricate networks that may allow signal transduction of the sensation of stress and strain, thereby, signaling the involved bone to model or remodel (96).

Secondly, it is possible that the osteocytes and osteoblasts have plasma membranes that are susceptible to the sensation of stress and strain. They respond by altering the amounts of intra- and extracellular calcium, potentially signaling other intracellular responses. This could lead to large-scale bone responses (60).

Another hypothesis attempting to explain how bones sense loading has to do with small changes in electrical potentials due to strain-induced fluid flow within the bone matrix (28). It has also been said that strain-induced interstial fluid flow creates rapid diffusion of oxygen and nutrients to osteocytes, setting up an environment sufficient for modeling and remodeling (36).

A good way to describe how bone remodels in response to stress is to consider equilibrium models. These models hypothesize that cortical bone's response to external forces is to maintain a mechanically stable system (112).

A couple of the most noteworthy equilibrium models are Frost's mechanostat hypothesis and the dynamic strain and dynamic equilibrium models (123, 19) which hypothesize that "bones alter their cross-sectional geometries during growth to keep peak strains at similar ranges and below some threshold." Thus, depending on the stresses and strains applied, cortical bone thickness of the human facial complex may vary within an individual and between individuals of different facial types and muscular morphologies.

4.6 Variation in cortical bone density and thickness at different maxillary and mandibular sites

Two characteristics, which are important when describing the osseous morphology of the mandible and maxilla, are cortical bone density and thickness.

Density is a description of the quality of cortical bone and its ability to withstand forces, such as the force applied when inserting a mini-screw implant.

Thickness is a measure of the quantity of cortical bone. It has been said that measuring cortical thickness is a good, if not the best, way to estimate bone mineralization (25).

Cortical bone density and thickness vary at different sites within and between the maxilla and mandible. This difference could be due to varying muscle strains throughout these bones. As was stated by Frost, (51) within a certain range, as strains associated with bone increase, the thickness of that associated cortical bone increases, as well. The following studies have been conducted describing the specific sites of cortical bone that vary in thickness and density within and between the maxilla and mandible.

Schwartz-Dabney and Dechow (127) measured cortical bone thickness and density in 10 adult cadaver mandibles. Cortical thickness was defined as the thickness from periosteum to the cortical-trabecular interface. Samples of bone were taken from 31 sites to determine whether there were any significant differences throughout the mandible. They concluded that cortical bone varied significantly throughout the mandible. Mandibular cortical bone was thickest at the inferior aspect of the symphysis and thinnest on the lingual side of the ramus. Though variability in the density throughout most sites was small, the density of the 31 sites varied more throughout the facial surface than the lingual surface. Over-all density was greater facially than lingually.

Ono et al, (110) evaluated buccal cortical bone thickness between the first premolar and first molar in the maxilla and mandible in 43 adult patients. CT scans were taken of all patients in the areas specified. Cortical bone thickness did not vary significantly from right to left sides. They evaluated cross sections of bone mesial and distal to the first molar, at vertical heights ranging from 1 to 15 mm below the alveolar crest. The average cortical bone thickness ranged between 1.09 and 1.62 mm in the maxilla and between 1.59 and 2.66 mm in the mandible. The further from the alveolar crest, the thicker the cortical bone tended to be, and the mandibular cortical bone was significantly thicker than that of the maxilla. Cortical bone distal to the first molar was significantly thicker than cortical bone mesial to the first molar in both the maxilla and the mandible.

Deguchi et al (34) used CT scans from 10 adults to measure the cortical bone thickness of various potential mini screw implant (MSI) placement sites in the maxilla and mandible. They took measurements at two vertical levels in the buccal region of the mandible and in buccal and lingual regions of the maxilla, those levels were specified as being at the occlusal level (3-4 mm apical to the gingival margin) and at the apical level (6-7 mm apical to the gingival margin). The common mini-screw implant sites measured were mesial and distal to the first molar and distal to the second molar.

No significant differences due to sex, age, or side of jaw were noted. Cortical bone thickness, however, varied significantly at certain sites within and between the maxilla and mandible. Significantly, less cortical bone was seen in the maxillary buccal region at the occlusal level distal to the second molar when compared with other areas in the maxilla.

Additionally, maxillary cortical bone was significantly thicker on the lingual side of the second molar site when compared to the buccal side. In the mandible, there was significantly more cortical bone mesial and distal to the second molar when compared with the maxilla.

No significant difference between vertical locations was noted within either the mandible or the maxilla. Yet, there was a significant difference between the mandible and maxilla at the different vertical heights. There was significantly more cortical bone in the mandibular molar region than the same region of the maxilla. This finding is consistent with that of Peterson et al (113).

Based on all the studies listed above (34, 110, 113, 127), it is evident that differences in cortical bone thickness and density exist between the mandible and maxilla and between some areas within the same jaw.

4.7 Cortical bone thickness and facial divergence

Cortical bone thickness is influenced by the stresses and strains produced by functional loads of associated muscles and mastication, and if facial divergence is related to muscular function, there might be a relationship between cortical bone thickness and facial divergence.

A few studies have been conducted attempting to answer this question. Masumoto et al, (97) measured the cortical bone thickness in the area around the first and second mandibular molars in a population of modern-day Japanese dry skulls using computerized tomography. The purpose of the study was to determine whether there was a difference in cortical bone thickness of the mandible between different face shapes. Thirty-one dry skulls were used and divided into long, average, and short-face groups based on Frankfort horizontal plane (FMA), gonial angle, facial axis, and mandibular arc. Cortical bone thickness was measured at nineteen points around the first and second mandibular molars. These points were on the external surface of the cortical bone every 15 degrees radiating from a center point within the alveolar process. Masumoto et al, (97) concluded that buccal and lingual cortical plate thickness was thicker in short face individuals than in the average and long face subjects. Additionally, significant correlation was found between FMA, and basal and lingual cortical bone thickness, as well as between mandibular arc - the measure of facial divergence described as the inclination of the mandibular corpus relative to the condylar axis (120) and buccal and lingual cortical bone thickness. This correlation showed that cortical bone was thicker in the dry skulls with shorter vertical dimensions than those with longer vertical dimensions.

A similar study was done by Tsunori et al (140) the purpose, again, was to determine whether there was a relationship between face type of Asiatic Indians and cortical bone thickness of the mandible. Thirty-nine dry skulls were divided into three groups based on face type. The parameters used to define the face types were FMA, palatal to mandibular plane angle, gonial angle, and the ratio of posterior facial height to anterior facial height (facial height index). CT scans were used to measure buccal, lingual, and basal cortical bone thickness in the region below the mandibular incisors, second premolars, first molars, and second molars. The results showed the same trend as reported in the previous study by Masumoto (97). Buccal cortical bone thickness in all the locations was thicker in the short face individuals when compared to average and long face individuals. On the lingual aspect of the mandible, the locations that had the thickest cortical bone were the first and second molar of the hypodivergent skulls. Lastly, basal cortical bone was the thickest beneath the lower incisors in the hypodivergent subjects when compared to the other two groups.

Beckmann et al, (15) looked at 460 pretreatment digitized cephalograms of adult Caucasian orthodontic patients to determine whether a relationship existed between lower facial height and the alveolar and basal bone of the anterior maxilla and mandible. They measured the anterior maxillary and mandibular alveolar depth - distance from a point on the anterior alveolar process just below the apex of the central incisor to a point on the lingual aspect of the alveolar process just below the apex of the central incisor.

This provided the thickness of the alveolar ridge from buccal to lingual in the anterior aspect of the mandible and maxilla. The researchers found that individuals with larger lower face heights had narrower maxillary and mandibular alveolar processes.

They also noted that a larger lower face height corresponded with a narrower and taller symphysis. Individuals with decreased lower face heights, however, had thicker anterior alveolar ridges from buccal to lingual, especially in the mandible. This study, however, did not distinguish the cortical bone from the total thickness of the alveolar ridge.

From the above mentioned studies (15, 97, 140), we can conclude that a correlation exists between the cortical bone thickness and the facial divergence where patients with vertical growth pattern- long face - have thinner cortical facial bone when compared to patients with normal growth and horizontal growth (short face).

Nevertheless, those previous researches has some shortcomings either due to small sample size or using 2D images for their investigation which is less reliable in small land marks identification or liner measurements of bony surface.

Therefore, our study is set to include a larger sample size in addition of utilizing CBCT technology for better understanding for the relationship between the facial divergence and symphysis bone morphology.

4.8 Cortical bone thickness and Masticatory muscle force

Bone is a dynamic tissue capable of adapting its structure to local mechanical stimuli by continuous bone renewal (142).

Many researchers have suggested that bone shape and structure are closely related to the attached muscle activity, during their experimental studies, significant correlations were found between changes in mechanical stress and subsequent morphological alteration of bone tissue (149).

A recent study in the field of orthopedics by Jones and his colleague's stated that the cortical thickness of the humeri of a group of professional tennis players, on the playing side was greater compared with the control side (81).

This finding supports the result of an animal experiment, which investigated the effects of training on the lower extremities by Saville and Whyte (125).

It is thought that a similar interaction occurs between bone shape and muscle activity in the maxillofacial complex.

Inoue and Ito pointed out that there has been a decrease in the human masticatory system caused by the changes of eating style associated with human dietary evolution. The poor functional stimulus through mastication was reported to have led to the under development of the mandible (74, 78).

Furthermore, Kiliaridis et al. (86) showed that the density of trabecular alignment and /or the thickness of cortical bone of the jaw were poorly developed due to the low level of stimulation from masticatory system.

Kiliaridis and Bresin (87) investigated on young growing rats by inserting a bite-opening appliance and by changing the food consistency, to soft diet. As a result, they proved that the consequent reduction of the intermittent forces applied to the alveolar bone during mastication caused a reduction of bone mineral density, accompanied by decreased trabecular bone volume and thickness.

Another study by Demes and his colleagues showed that the labial side of the mandibular posterior corpora had a thicker cortical bone than the lingual surface because of the combined effect of vertical occlusal force and torsion of the mandibular corpora (35).

A similar study by Hitoshi showed that the lingual surface of the symphysis has a thicker cortical bone than the labial surface due to the concentration of tensile stress during mastication (53).

From the results of the previous studies (35, 53, 74, 78, 81, 86, 125, 87) we can conclude that the cortical bone thickness and its mineral density is proportional to the amount of stress and strain applied on its surface through the attached muscles. Consequently, people with stronger and thicker facial muscle, as the short face people, have thickerfacial cortical bone than long face people who usually have weaker facial muscles.

4.9 Lower Incisor and Symphysis Cortical Bone Morphology

The orientation of lower incisors related to the rest of the facial skeleton has come to play a leading role in the treatment of orthodontic cases.

The position of the lower incisors in relation to their supporting bone is an important factor in orthodontic treatment planning, assessment of treatment progress, as well as determination of treatment outcome (1).

The dimension of the anterior alveolus appears to set limits to orthodontic treatment, and challenging these boundaries may accelerate iatrogenic sequelae.

Mulie and Ten Hoeve (104) demonstrated that anatomic limitations in the symphysis are associated with iatrogenic sequelae when these are challenged. The sequela noted in their sample was limited to resorption of mandibular incisor root, perforation of cortical plate of mandibular symphysis and loss of periodontal attachments.

For a better understanding of that relation, several investigators have examined the morphology of the alveolar bone in the mandibular incisor region using conventional cephalometric radiographs (121, 152).

Handelman studied the labial and lingual cortical plates at the level of incisor apex of 107 adult cephalometric films and noticed that the alveolar widths were found to be thin at the labial and lingual of the mandibular incisors in individuals with high vertical facial growth and their alveolar bone inclination do change according to the incisor inclination (61).

In addition, a recent study by Moiz Khan and Syed Hussain (85) in attempt to evaluate the relationship between the lower incisors inclination and the morphology of their supporting alveolar bone was published. In that research, they studied lateral cephalograms of 40 patients before their orthodontic treatment and they found a positive relationship between the incisal inclination and the contour of the alveolar bone structure. They also noticed that the thickness of lingual alveolar bone was reduced considerably when the incisal inclination increased buccally which can result in bony dehiscence during tooth movement.

From the above mention studies (61, 85, 104, 121, 152), can be concluded that there is a relationship between the incisors inclination and the morphology of the surrounding alveolar bone. However, the previous investigations have examined the morphology of the alveolar bone in the mandibular incisor region using conventional cephalometric radiographs. It is almost impossible, to examine accurately the labiolingual inclination and thickness of the alveolar bone in the mandibular incisor region using two-dimensional cephalometric radiographs. This is because the radiographic images of the labial and lingual surfaces of the alveolar bone in the mandibular incisor region are projected images of the most anterior and the most posterior parts of thealveolar bone, respectively, and do not correspond specifically to the incisor region. Also, the images of all structures in 3D space overlap each other with substantial geometric magnification error because of the divergent nature of the x-ray beam (154). Therefore, high-resolution CBCT technology was used to examine the shape and the size of alveolar bones without the disadvantages of conventional radiographs.

4.10 Cone Beam Technology

Imaging is an important diagnostic adjunct to the clinical assessment of the dental patient.

The introduction of panoramic radiography in the 1960s and its widespread adoption throughout the 1970s and 1980s heralded major progress in dental radiology, providing clinicians with a single comprehensive image of jaws and maxillofacial structures.

However, intra oral and extra oral procedures, used individually or in combination, suffer from the same inherent limitations of the two-dimensional (2D) projections: magnification, distortion, superimposition, and misrepresentation of structures (150).

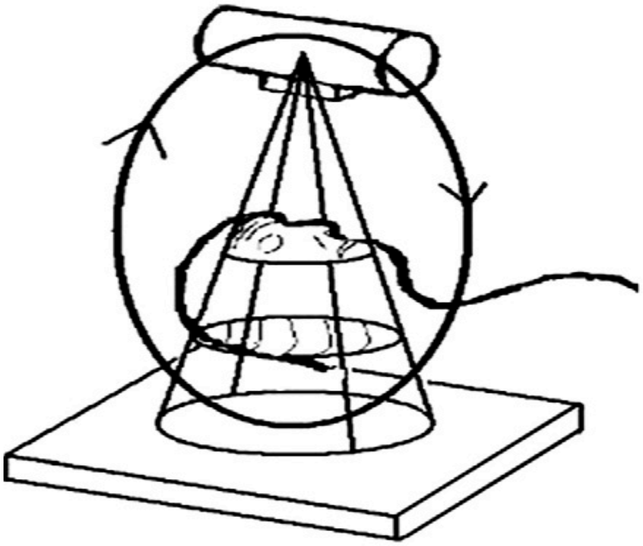
Introduction of three-dimensional imaging techniques have opened new possibilities for orthodontic diagnosis and treatment assessment (33).

Sir Godfrey Hounsfield developed computerized tomography in 1967 and since the first prototype, there has been a gradual evolution to five generations of such systems (30). Despite the usefulness of computed tomography (CT), the high cost and relatively high radiation exposure make this modality unsuitable for orthodontic purposes (40).

However, with the introduction of maxillofacial Cone Beam Computed Tomography (CBCT) 3D imaging has become more readily available for dental applications. CBCT was developed in the 1990s as an evolutionary process resulting from the demand for three-dimensional (3D) information obtained by conventional computerized tomography.

The advantages of CBCT over Conventional CT include low radiation dose, lower cost, potentially better access, and high spatial resolution (92, 43).

Cone Beam CT scanners are based on volumetric tomography, using 2D extended digit area detector. This is combined with a 3D x-ray beam. The cone-beam technique involves a single 360° scan in which the x-ray source and a reciprocating area detector synchronously move around the patient's head, which is stabilized with a head holder. At certain degree intervals, single projection images, known as "basis" images, are acquired. These are similar to lateral cephalometric radiographic images, each slightly offset from one another (Fig.4.5).



(b)

Figure 4.5 X-ray beam projection scheme of cone-beam CT

The x-ray source and the detector capture between 150 and 600 images resembling AP or LAT (anterior-posterior or lateral) images. The images are sent to the acquisition computer for reconstruction and area 1:1 compression. This series of basis projection images is referred to as the projection data. Software programs incorporating sophisticated algorithms including back-filtered projection are applied to these image data to generate a 3D volumetric data set, which can be used to provide primary reconstruction images in 3 orthogonal planes (axial, sagittal and coronal) .

Coronal section: A vertical plane extending from side to side that divides the body into front and back portions (fig 4.6a).

Sagittal section: An anterior posterior vertical plane passing through the body from front to back dividing it in half (fig 4.6b).

Axial section: Sections or slices on theaxial plane, these sections are taken as horizontal cuts through the anatomy (fig 4.6c).

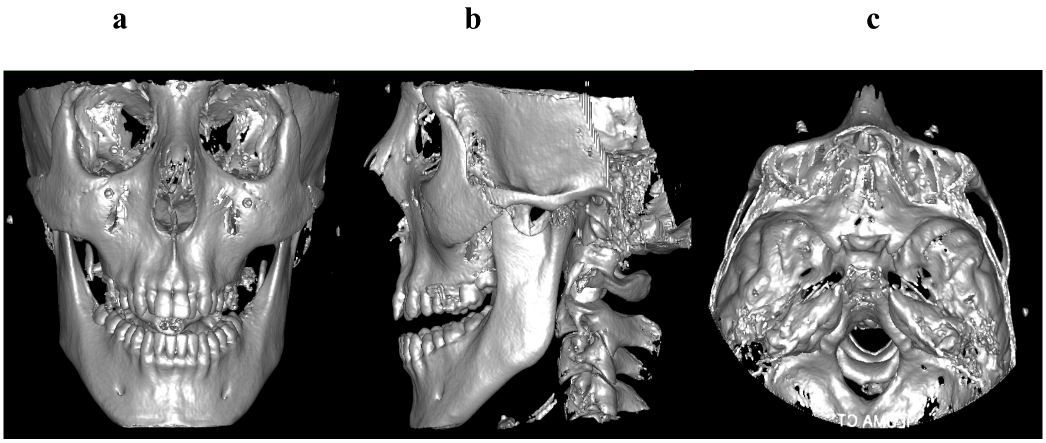


Figure 4.6 CBCT images of skull a: Coronal. b: Sagittal. c: Axial.

CBCT allows the creation of “real time” images, not only in the axial, coronal and in sagittal planes but also 2-dimensional (2D) images in the oblique and even in the curved image planes a process referred to as multi planar reformation (MPR). In addition, CBCT data are amenable to reformation in a volume, rather than a slice, providing 3-dimensional (3D) information (151).

4.11 Advantages of Cone Beam over Conventional computed tomography

CBCT is well suited for imaging the craniofacial area as it provides clear images of highly contrasted structures and is extremely useful for evaluating bone (134). Although limitations currently exist in the use of this technology for soft tissue imaging, efforts are being directed toward the development of techniques and software algorithms to improve signal-to-noise ratio and to increase contrast (157).

The use of CBCT technology in clinical practice provides a number of potential advantages for maxillofacial imaging compared with conventional CT:

X-ray beam limitation: Reducing the size of the irradiated area by collimation of the primary x-ray beam to the area of interest minimizes the radiation dose.

Image accuracy: The volumetric data set comprises 3D block of smaller cuboid structures, known as voxels (combination of volume and pixel), each representing a specific degree of x-ray absorption. The size of these voxels determines the image resolution. In conventional CT, the voxels are anisotropic — rectangular cubes where the longest dimension of the voxel is the axial slice thickness and is determined by slice pitch, a function of gantry motion. All CBCT units provide voxel resolutions that are isotropic equal in all 3 dimensions. This produces sub-millimeter resolution (often exceeding the highest grade multi-slice CT) ranging from 0.4 mm to as low as 0.125 mm.

Rapid scan time: Because CBCT acquires all basis images in a single rotation, scan time is rapid (10–70 seconds) and comparable with that of medical spiral MDCT systems.

Dose reduction: Published reports indicate that the effective dose of radiation (average range 36.9 – 50.3 microsievert [µSv]) (31, 92) is significantly reduced by up to 98% compared with "conventional" fan-beam CT systems (average range for mandible 1,320–3,324 µSv; average range for maxilla 1,031–1,420 µSv). This reduces the effective patient dose to approximately that of a film-based periapical survey of the dentition (13–100 µSv) (19, 21) or 4–15 times that of a single panoramic radiograph (2.9–11 µSv) (55, 107, 126).

Display modes unique to maxillofacial imaging: Since workstations are required access and interaction with medical CT data are not possible. Although such data can be "converted" and imported into proprietary programs for use on personal computers (e.g., Sim/Plant, Materialise, Leuven, Belgium), this process is expensive and requires an intermediary stage that can extend the diagnostic phase. On the other hand, reconstruction of CBCT data is performed natively by a personal computer. In addition, software can be made available to the user, not just by the radiologist, either via direct purchase or innovative "per use" license from various vendors (e.g., Imaging Sciences International). This provides the clinician with the opportunity to use chair-side image display, real-time analysis and MPR (multi planner region) modes that are task specific. Because the CBCT volumetric data set is isotropic, the entire volume can be reoriented so that the patient's anatomic features are realigned. In addition, cursor-driven measurement algorithms allow the clinician to do real-time dimensional assessment (151).

Reduced image artifact: With manufacturers' artifact suppression algorithms and increasing number of projections, the clinical experience has shown that CBCT images can result in a low level of metal artifact, particularly in secondary reconstructions designed for viewing the teeth and jaws (31).

Considering only the radiation dose, the use of a CBCT image is not recommended routinely in orthodontic practice because conventional images deliver lower doses to patients. Therefore, the decision-making in oral radiology is a balance between the risk assessment and the diagnostic information needed. However, when 3D imaging is required in orthodontic practice, CBCT should be the method of choice and should be preferred over multi-slice CT (6).

4.12 Reliability of Cone Beam Computed Tomography 3D images in measurements

Many researches and investigations were carried out to assess the credibility and the reliability of Cone Beam Computed Tomography image measurements and its comparison to the actual size and measurement of the patient's samples.

It was reported that CBCT scans allow the orthodontist to assess the patient's hard and soft tissue in three dimensions (57) and the accuracy and reliability of such images have been tested and were found to be adequate for implant planning, periodontal disease quantification, and assessment of tumor/lesion volume. In addition, radiographic reconstructions were found to provide accurate and reliable linear measurements (66, 114).

Hilgers and coworkers in 2005 compared direct measurements of the temporomandibular joint region with those made on the MPR (Multi planner Region) images of a CBCT scan (iCAT) with 0.4 mm slice thickness of 25 dry skulls, and found that CBCT measurements were accurate and reproducible (68).

More recently, Berco and coworkers used a single skull, where fiducial radiopaque markers (stainless steel balls 0.5 mm diameter) were used to identify the landmarks to be measured. Landmarks were identified on the iCAT MPR images with a 0.4 mm slice thickness. In this single skull study, investigators were able to demonstrate much greater accuracy (0.2 mm mean difference) than was reported previously. However, because of the study's extremely small sample size, these results were suggested to be validated further (17).

Lagrave and colleagues conducted an experiment that demonstrated the extremely high reproducibility of CBCT measurements on a prototype mandible using titanium markers with a hollow funnel-like shape (90).

Bruno Fraza˜o Gribela and his co-workers found that there was no statistically significant difference between CBCT measurements and direct craniometric measurements (mean difference, 0.1 mm) and they believed that CBCT craniometric measurements were accurate to a subvoxel size and could be used as a quantitative orthodontic diagnostic tool (59).

Sebastian Baumgaertel and his colleagues have proved that dental measurements from CBCT volumes could be used for quantitative analysis (14).

Today, existing software allows us to take full advantage of CBCT scans in performing 3D measurements and developing 3D craniofacial analyses. These 3D measurements, made on CBCT images, can be more accurate and reproducible and have the potential to aid in the craniofacial diagnosis of facial asymmetries, functional shifts, and canted occlusal planes (89, 141).

4.13 Cone Beam and Radiation

Radiographic examinations play an essential part in dental practice. Because a certain amount of radiation is inevitably delivered to patients, it should be as low as possible.

Precautions should be taken since diagnostic examinations are the largest source of man-made radiation exposure to the general population, contributing about 40% of the total annual worldwide exposure from all sources (28).

What is Radiation and how it affects human

What the radiation is and the possible risk of radiation on human body needs to be clarified.

The use of ionizing radiation in medicine began with the discovery of x-rays by Roentgen in 1895. Ionizing radiation is the portion of the electromagnetic spectrum with sufficient energy to pass through matter and physically dislodge orbital electrons to form ions. These ions, in turn, can produce biological changes when introduced into tissue.

The adverse effects of radiation are grouped into two categories: deterministic effects and stochastic effects (109).

Deterministic effects are based on cell killing and are characterized by a threshold dose. Below that threshold dose there is no clinical effect. With exposures above the threshold dose the severity of the injury increases with dose.

Stochastic effects, including cancer and heritable diseases are based on genetic mutation. In this incidence the frequency of the response, but not the severity, is proportional to dose. Further, there is no-threshold or ‘‘safe’’ dose with stochastic effects.

It is essential to understand that it is possible to make some adjustment on the CBCT machine in order to reduce the radiation risk on patients, these adjustments include:

(I) X-ray tube voltage and mAs:

The kilo voltage (kVp) of an X-ray tube is the potential difference between anode and cathode during operation.

The product of the tube current is measured in milli amperes (mA) and the exposure time is measured in seconds (s).

Kwong et al (88) found that mA and kVp could be reduced in order to reduce the radiation for the equipment studied without a significant loss of image quality.

(II) Field of View (FOV) and Collimation:

The FOV is a cylindrical or spherical volume and determines the shape and size of the reconstructed image. FOVs may vary from a few centimeters in height and diameter to a full head reconstruction.

The size of the FOV is associated with radiation dose to the patient and staff (69). X-ray beam should be reduced to the minimum size needed to image the object of interest,

(III) Filtration:

Aluminum filtration is an established component of medical X-ray equipment. Some dental CBCT units are equipped with copper filtration. Filtration removes lower energy X-ray photons, which results in skin dose reduction.

Loftag-Hansen et al (62) and Kwong et al (88) found that addition of a copper filter did not affect overall image quality on the CBCT equipment studied, for that reason, adding the filtration system will help in decreasing the radiation dose to the patient.

(IV) Digital detector:

Dental CBCT units are equipped with digital receptors where the image is captured and formed. Two types of digital detectors have been used for dental CBCT units (65).

The first type involves conventional image intensifiers, the second type involves flat panel detectors (FPDs).

FPD have greater sensitivity to X-rays than image intensifiers and therefore have the potential to reduce patient dose (83) .They have higher spatial and contrast resolution and fewer artifacts than image intensifiers but, in general, image intensifiers are cheaper than flat panel detectors.

(V) Voxel size:

The volume element (voxel) represents a three-dimensional (3D) quantity of data and it can be pictured as a 3D pixel.

The voxel size in CBCT systems may vary from less than 0.1 mm to over 0.4 mm (65). Scanning protocols with smaller voxel size, are associated with better spatial resolution but with a higher radiation dose to the patient.

Multipurpose dental CBCT equipment should offer a choice of voxel sizes and examinations should use the largest voxel size (lowest dose) consistent with acceptable diagnostic accuracy.

(VI) Number of projections:

The rotation of the X-ray tube and the detector around the patient's head produces multiple projection images.

The total number of acquired projections depends on the rotation time, frame rate (number of projections acquired per second) and on the completeness of the trajectory arc. A high number of projections is associated with increased radiation dose to the patient, higher spatial resolution and greater contrast resolution.

Therefore, reducing the number of projections, while maintaining a clinically acceptable image quality, results in patient dose reduction (63).

(VII) Shielding devices:

An alternative way of reducing patient dose is by using shielding devices containing high attenuation materials, such as lead.

The thyroid gland is a radiosensitive organ which may be affected by scattered radiation and, occasionally, primary beam in dental CBCT.

Tsiklakis et al (138) observed a 20% decrease in effective dose by protecting the thyroid gland during CBCT, although this was with a large FOV scanner.

4.14 Clinical Implication

In the past, much attention has been given to the diagnosis and treatment of anteroposterior malrelationships of the dental arches. However, the cases that have proved most difficult to treat and which have the least favorable prognosis are frequently those in which there is a vertical discrepancy. This was amply demonstrated by the fact that relapse in the vertical dimension of a treated case is the first sign to be noted.

Prediction of growth pattern through the analysis of the mandibular morphology of an individual had clinical implications in treatment planning for the patient.

Extraction decision, type of anchorage preparation, mechanics, and retention period are influenced by the growth pattern, which an individual possesses.

In addition, the size and shape of the mandibular symphysis is an important consideration in evaluation of orthodontic patients. With a larger symphysis, more protrusion of the incisors is esthetically acceptable and therefore chances of a nonextraction treatment approach are greater.

Ricketts suggested that preferred incisal positions and angulations at the end of active treatment might vary depending on the underlying vertical facial type, with brachyfacial patients tolerating more protrusive and proclined incisors than dolichofacial patients. It has been suggested that brachyfacial patterns might allow greater expansion of the arches during treatment, in contrast to dolichofacial patterns with generally weaker mandibular muscle forces that might allow less expansion during treatment (120, 156).

On the other hand, Patients with greater symphysis height and a small chin would be candidates for an extraction treatment plan to compensate for arch length discrepancies (95).

The anteroposterior position of the mandibular incisors affects the fullness of the lips, ideal incisor inclination contributes to an attractive facial appearance in addition to playing an important functional role in overbite stability (5).

For that reason, clinician must consider the ideal and most stable incisor inclination according to the facial growth type of his patient.

It is widely accepted that the labiolingual inclination of the central incisor significantly correlates with the labiolingual inclination of the associate alveolar bone (153).

Numerous studies have shown that if the incisor root apex is moved against the cortical plate of the alveolar or beyond the alveolar, severe root resorption and bony dehiscence may occur (8, 119).

Therefore, it is important to consider the existing shape and bone thickness of the symphysis to evaluate the precise position of the lower incisor root apex within the alveolar bone before orthodontic treatment.

Another clinical application of estimating the shape and the bone quality of the lower jaw is related to success of stability of mini screw. Mini-implants do not osseointegrate like traditional endosseous implants. The retention and stability of the mini-implant is derived from mechanical interdigitation between the cortical bone and the mini-implant interface (71). Because mini-screw implants (MSIs) are being placed in various locations, knowledge of cortical bone thickness of the mandible is important clinically, as well as didactically. Numerous sites for MSI placement have been presented. Cortical bone thickness has been linked to both primary and secondary stability of MSIs and dental osseous-implants.

A study by Miyawaki et al in 2003 showed with statistical significance that orthodontic mini-screw implants fail more often in patients with high mandibular plane angles than they do in low-angle patients. Here, fifty-one orthodontic patients who had previously received MSIs or miniplates were retrospectively analyzed for causes of implant success and failure. Among a few other identifiable factors, a high mandibular plane angle proved to be a significant factor in MSI failure (99).

Similarly, Moon et al retrospectively looked at 778 MSIs in 306 patients and used multiple logistic regression analysis to determine that subjects with long vertical skeletal patterns had lower MSI success rates than those with average or short vertical skeletal patterns (101).

From what has been reviewed, however, it stands to reason that theoretically, one cause for failure may be due to the fact that patients with high mandibular plane angles have less cortical bone thickness.

It has been suggested that MSIs require at least 1 mm of cortical thickness to ensure success (103).

Based on this finding, Miyawaki (99) suggested using a 1.5 mm diameter screw in hypo-divergent patients and screws with a diameter of 2.3 mm in hyper-divergent patients. The reasoning was that since cortical bone was thinner in hyper-divergent individuals, the compensation to increase the success rate of the MSI would have been to increase the diameter of the screw. If the length of the MSI must have been shortened due to a lack of cortical bone, then increasing the diameter would increase the retentiveness.

5. MATERIAL AND METHODS

5.1. Patient selection

For this study, CBCT images of Seventy-four patients (46 female and 28male) with normal and high-angle mandibular growth pattern were selected from the archives of Department of Orthodontics, Faculty of Dentistry, University of Marmara. Based on the Mandibular Plane Angle measurement of Steiner Cephalometric Analysis (the angle between the Sella – Nasion and Mandibular planes) the patients were divided into 2 groups: High angle mandibular growth pattern group with the mandibular plane angle above 36 degrees (1st Group) and Normal mandibular growth pattern group with the mandibular plane angle between 28-36 degrees (2nd Group)(132). …

In the 1st group 30 of the patients were female (mean age=15.7 years ± 2.52 SD) and 16 of them were male (mean age=19.8 years ± 10.04SD). In the 2nd group, 16 of the patients were female (mean age=16 years± 2.8SD), and 12 of them were male (mean age=17.75 years ± 2.0SD) (Table 5.1).

Table 5.1: Gender and age distribution of the study

	High Angle group		**Normal Angle group**	
	female	**male**	**female**	**male**
Mean age	15.7 years ± 2.52 SD	19.8 years ± 10.04 SD	16 years ± 2.8 SD	17.75 years ± 2.0 SD
Number	30	16	16	12

The patients, whose images were used in the study, were selected according to the following criteria:

(1) No pathologic or syndromic deformities in the head and neck region

(2) No previous orthodontic treatment

(3) Intact lower permanent dentition.

5.2 Data gathering

All CBCT images were obtained at NET Radiology and Diagnostic Center, Nisantasi, Istanbul by using Iluma Imtec imaging LLC, (3M Company Ardmore. Oklahoma. USA-2007).

All the images were acquired while the patient was sitting upright with the Frankfort Horizontal plane parallel to the floor. The patient's head position was adjusted with the help of two laser beams, one parallel to the floor, coinciding with the Frankfort Horizontal plane, and one vertical beam passing through the patient's facial midline. The patients were asked not to swallow and not to move their heads or tongues during exposure.

5.3 Machines and software used in the study

The technical properties of the Cone Beam machine, that was used, were:

1. Focal Spot: 0.3mm x 0.3mm
2. X-ray tube voltage: 120 KV
3. X-ray tube current: 1-4mA
4. Detector size: 19.5 x 24.5cm
5. Scanning with 360 degrees rotation
6. Radiation: 376 microsieverts maximum

The data obtained from CBCT images were transferred to a workshop computer workstation, where our objective parameters were measured using Materialize Interactive Medical Image Control Systems (MIMICS) 14.0 software launched by Materialise (Materialise Europe, World Headquarters, Leuven, Belgium).

(MIMICS) is an interactive tool for the visualization and segmentation of CT images as well as MRI images and 3D rendering of objects. Therefore, the medical field of MIMICS can be used for diagnosis, operation planning or rehearsal purposes. The software divides the screen into four views (fig 5.1).

- The axial view.
- The coronal view (made up by the resliced data).
- The sagittal view (made up by the resliced data).
- The 3D view

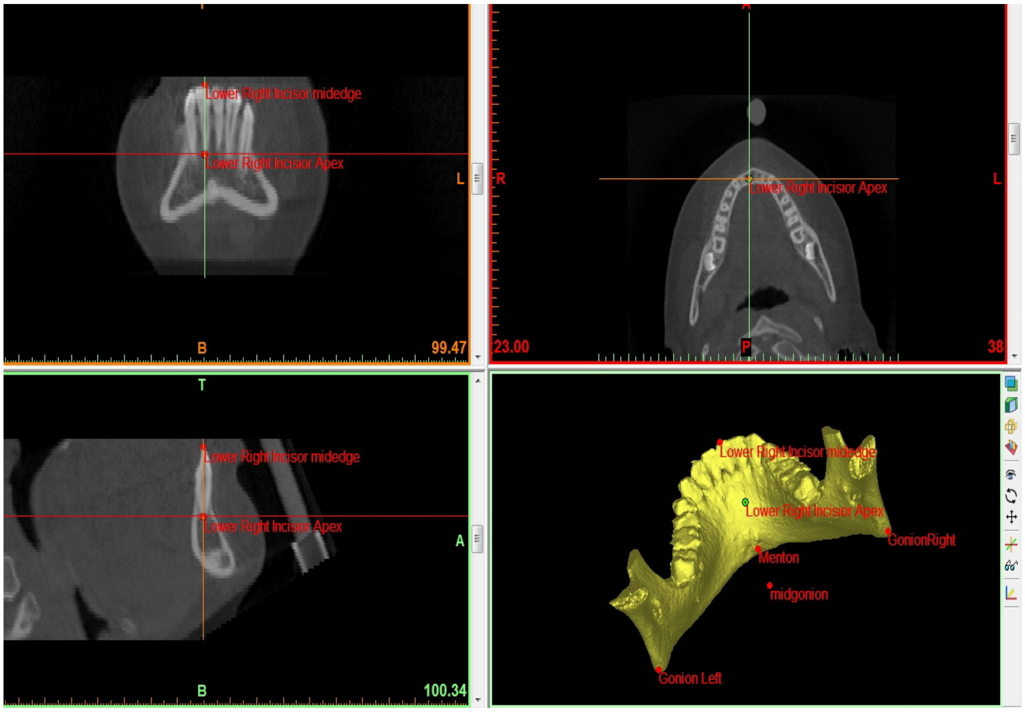


Fig 5.1 Sagittal, Coronal, Axial and 3D screen view on MIMCS software

5.4 Definitions of the Anatomical Landmarks, Constructed Landmarks, and Measurements used in the Study

Anatomical and Constructed Landmarks:

- Sella (S): Geometric center of the pituitary fossa located by inspection (Fig 5.2).
- Nasion (N): The most anterior aspect of the frontonasal suture (Fig 5.2).
- Gonion (Go): The point on the curvature of the mandibular angle by bisecting the angle formed by the two lines: one tangent to the inferior border of the mandible and the other tangent to the posterior border of the ramus (Fig 5.2).
- Menton (Me): The most anterior and inferior point of the mandibular symphysis (Fig 5.2).

- Prosthion: The most anterior and superior part of labial alveolar bone process at the lower right central incisor (Fig 5.2).
- Lingual Prosthion: The most posterior and superior part of lingual alveolar bone process at the lower right central incisor (Fig 5.2)

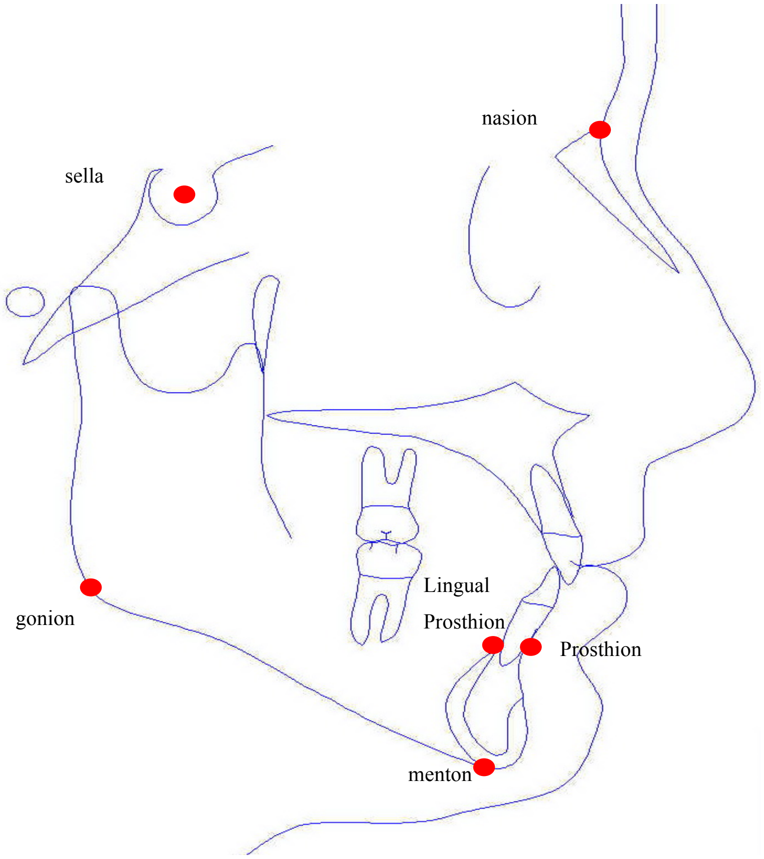


Fig 5.2 Anatomical and constructed landmarks

Angles:

- Mandibular Plane Angle (MP Angle): The MP was drawn between Go and Me.The MP angle was formed by relating the MP (Go-Me) to the anterior cranial base (S-N). The mean reading for this angle was 32-degrees. Excessively high or low mandibular plane angles suggested unfavorable growth patterns in individuals (Fig 5.3).

- Lower Right Incisor Inclination Angle: The lower right incisor inclination Angle was measured by the intersection of the mandibular plane with the axis of the lower right central incisor, a line passing through the incisal edge and the apex of the mandibular right central incisor (79)(Fig 5.3).

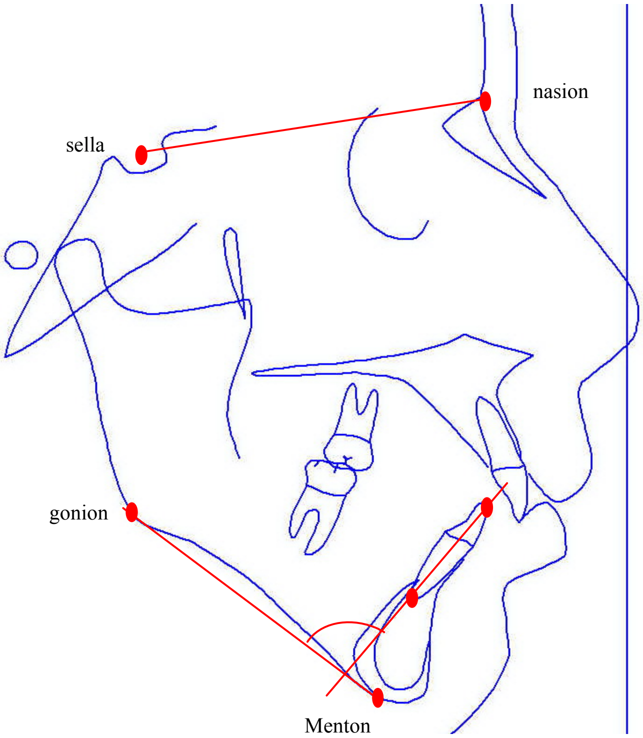


Fig 5.3 The construction of mandibular plane angle and Lower Right Incisor Inclination Angle

5.5 Assessment of the Symphysis

All CBCT images were processed and analyzed by the same operator (T.G).

The method that was applied is the following:

Initially, the object was resliced so only the mandible would be seen on the sagittal view, the reslicing procedure was applied parallel to the long axis of the lower right central incisor (Image width 200 mm – Image Height 200 mm – Slice Pixel 0.29)(fig 5.4). Then ‘‘thresholding’’ was applied with a minimum limit of -1346 HU and a maximum of -4095 HU to be able to create the3D image of the mandible (fig 5.5).

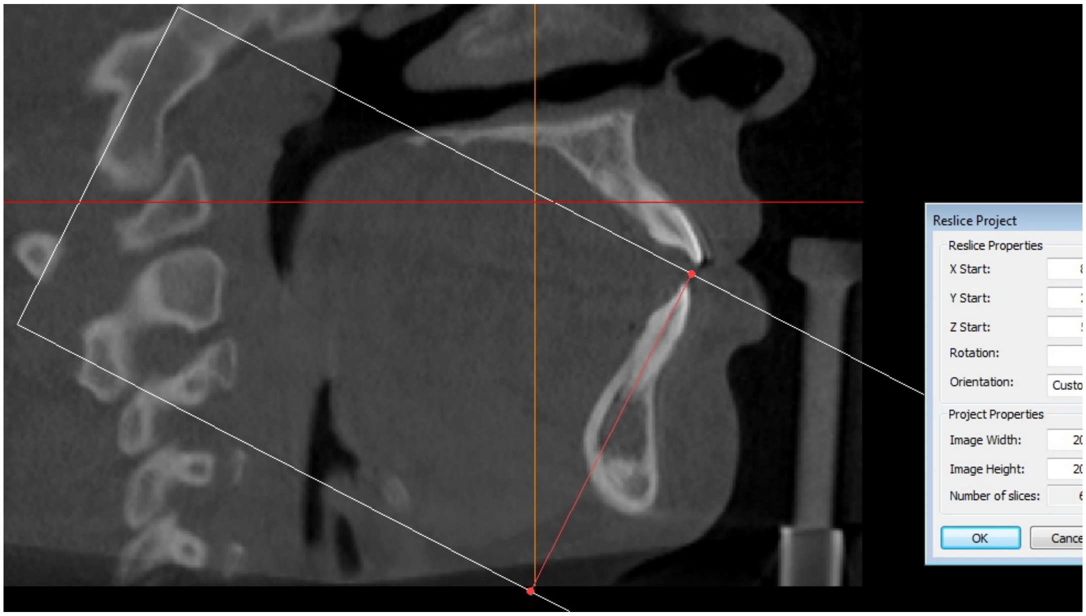
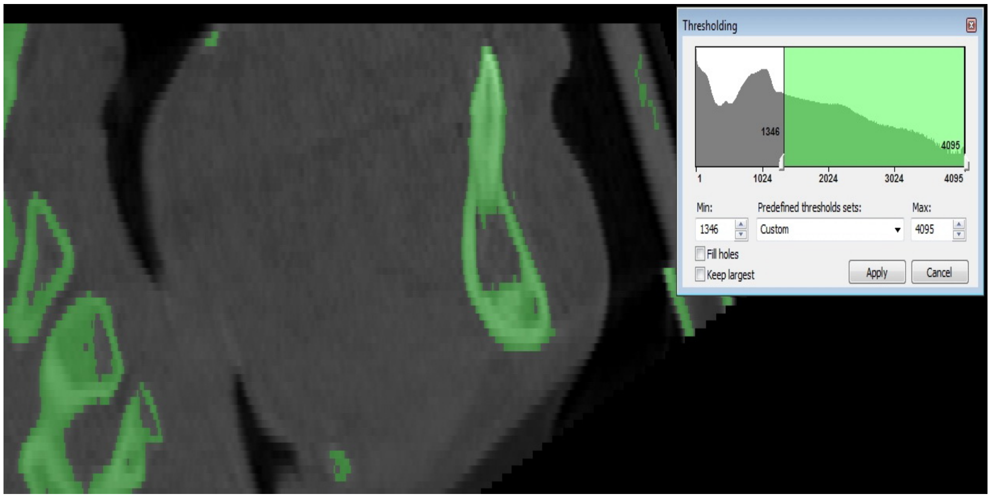


Fig 5.4 Reslicing the sagittal view along the long axis of lower right central incisor



Min: 1346
Predefined thresholds sets: Custom
Max: 4095
☐ Fill holes
☐ Keep largest

Fig 5.5 Thresholding the image to create 3D image of the mandible

Later ''region growing'' procedure was performed which made it possible to split the segmentation created by the thresholding into several objects and to remove any connected structure to the lower jaw on the 2D image such as upper cervical vertebra (Fig 5.6). As a result, a clear 3D image of the mandible could be seen on the 3D view screen (fig 5.7).

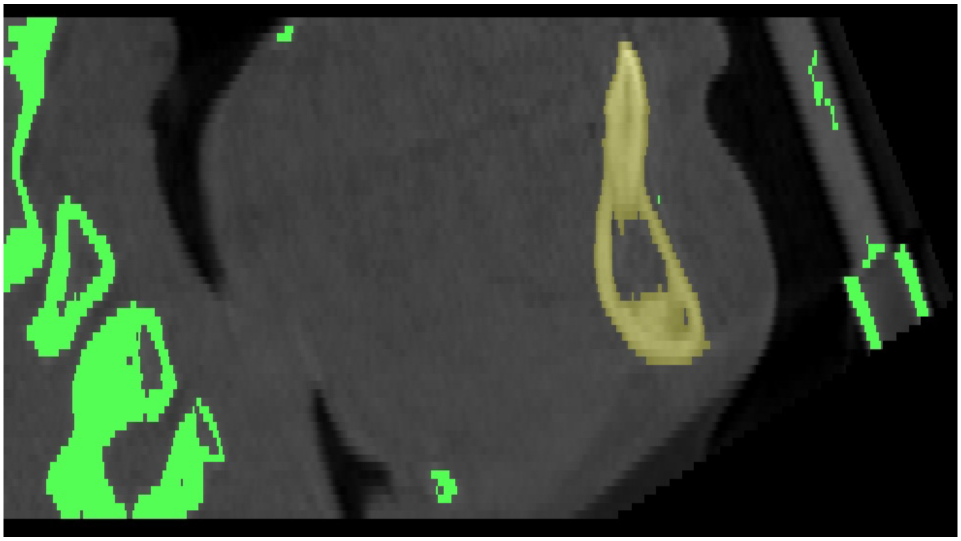


Fig 5.6 Region growing to split the mandible from other surrounding organs like upper jaw, vertebra ..etc

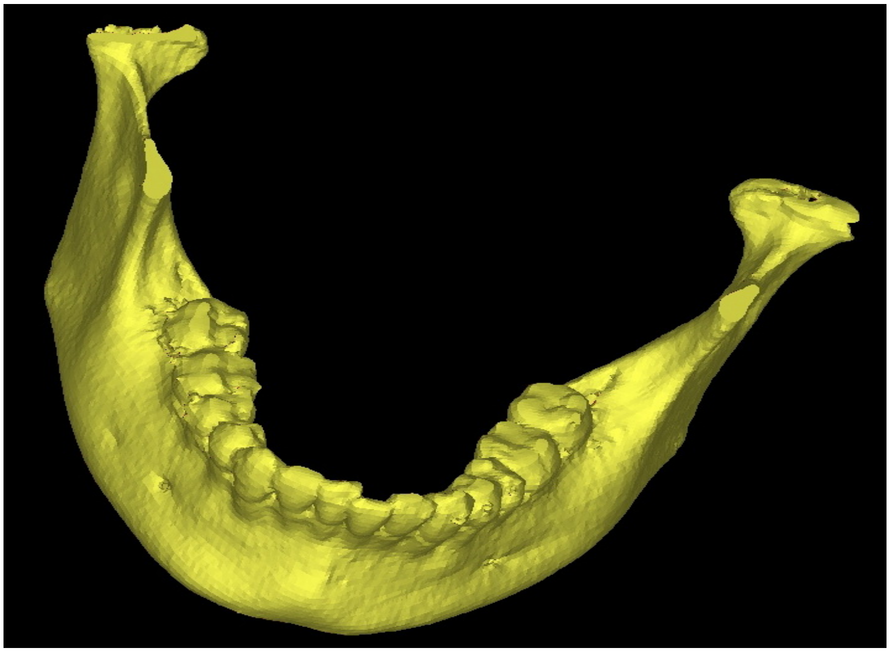


Fig 5.7 3D image of the mandible created after image reslicing and region growing

On the 3D image of the mandible, the following points were located and marked on the screen:

- Right Gonion
- Left Gonion
- Menton
- Mid Gonion: A point located at the mid distance between the right and the left Gonion (fig 5.8).

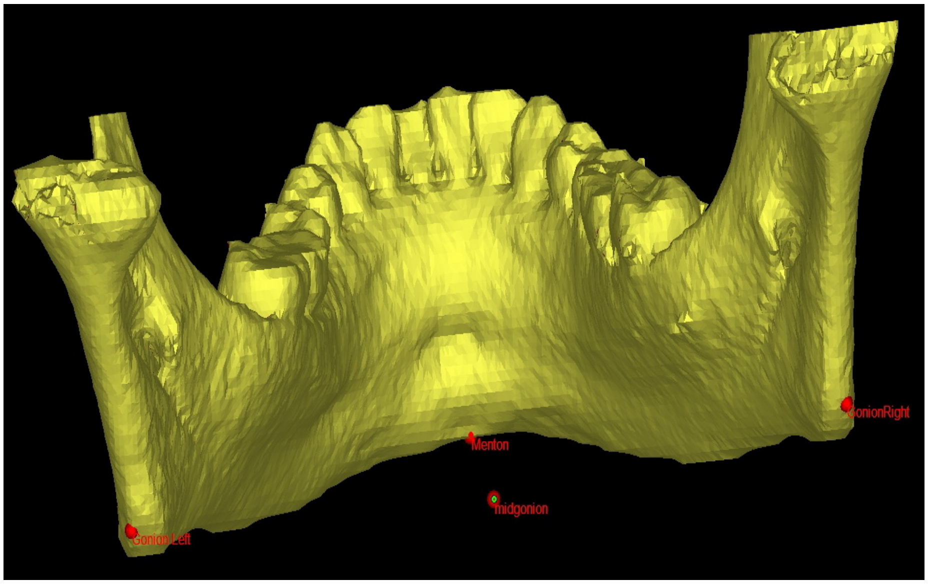


Fig 5.8 Mid Gonion, Menton, Right and left Gonion

On the sagittal, axial and coronal view, following points were located:

- The mid incisal edge point of the lower right central incisor (fig 5.9).
- The incisor apex of the lower right central incisor (fig 5.9).

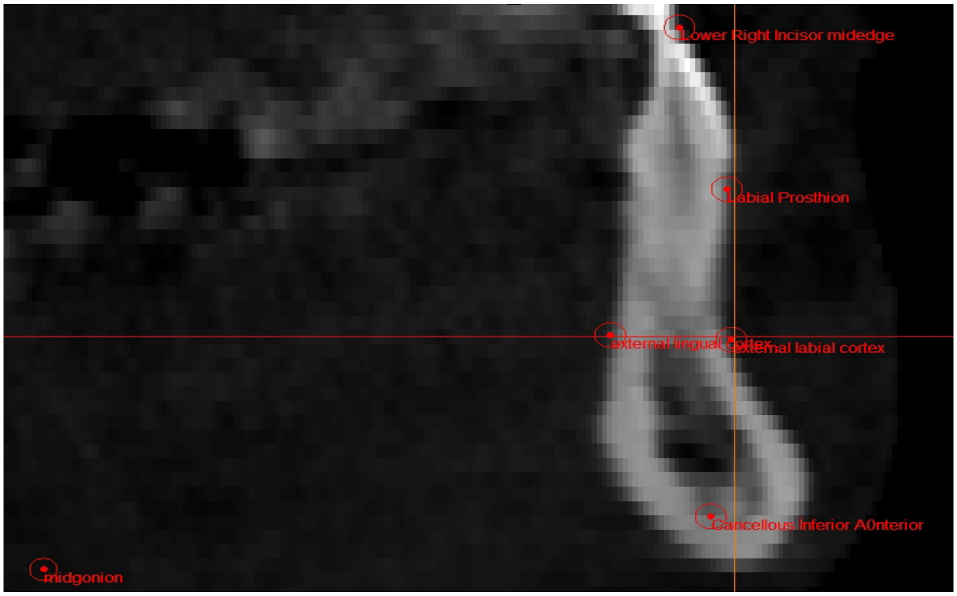


Fig 5.9 locating mid incisal edge and root apex on sagittal plane

After that, two Planes were constructed from the identified and above-mentioned points:

- The Mandibular Plane, which was constructed from the Menton, Right and Left Gonion (fig 5.10).

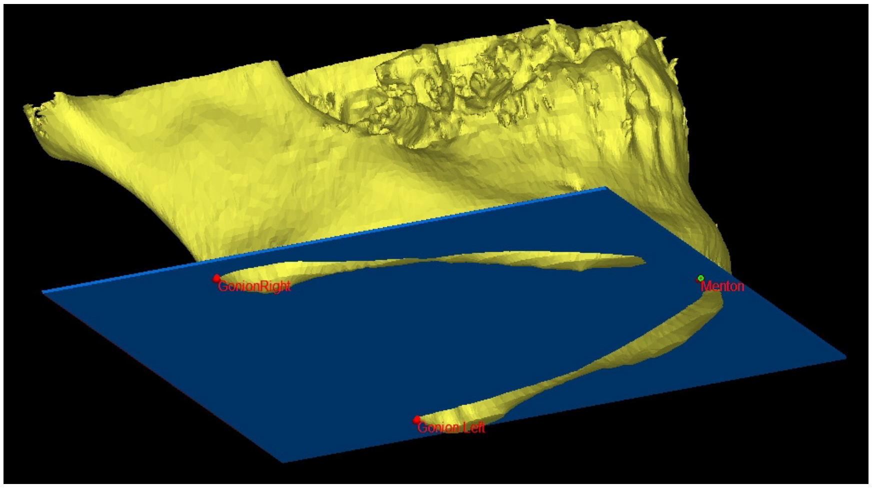


Fig 5.10 Mandibular plane constructed from Menton, right and left Gonion

- The Mid sagittal Plane, which was constructed from the Mid Incisal Edge point, Apex point and the Mid Gonion (fig 5.11).

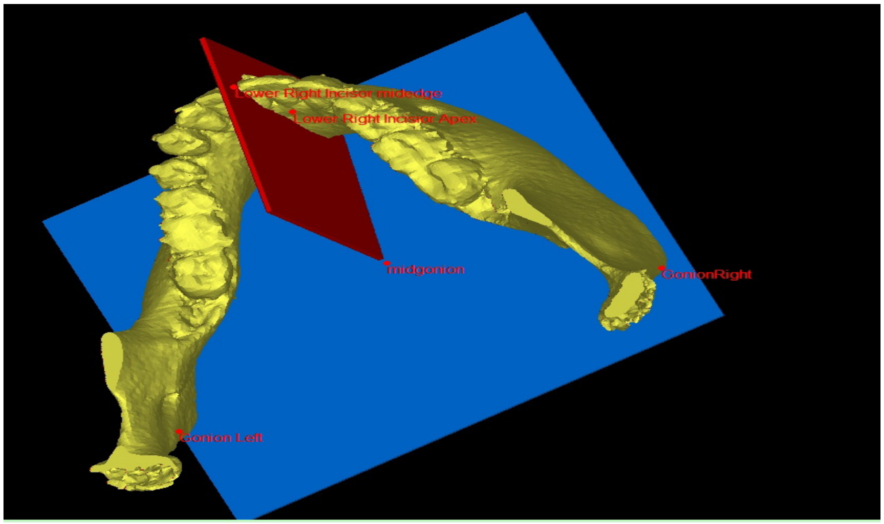


Fig 5.11 Mid sagittal Plane constructed from the Mid Incisal Edge point, Apex point and the Mid Gonion

On the sagittal view screen, we moved through the image slice by slice until the mid incisal edge point, incisal apex point and the mid sagittal plane were visible, on that slice analysis of the mandibular symphysis and incisor inclination measurement were performed. For that purpose, following points were identified and marked (fig 5.12).

1. Prosthion: the most superior and anterior point of labial alveolar bone process.
2. Lingual Prosthion: the most superior and posterior point of lingual alveolar bone process.
3. Superior Cancellous: the most superior point of cancellous bone on the labial alveolar bone.

4. Inferior Cancellous: the most inferior point of cancellous bone along a line starting from superior cancellous and parallel to the long axis of lower right central incisor.

5. Symphysis Base: the most inferior point of symphysis bone along a line starting from prosthion and parallel to the long axis of the lower right central incisor.

6. External Labial Cortex: the most anterior point of labial alveolar bone along a line that passes through the incisor apex and perpendicular to the long axis of lower right central incisor.

7. Internal Labial Cortex: the most posterior point of labial alveolar bone along a line that passes through the incisor apex and perpendicular to the long axis of lower right central incisor.

8. External Lingual Cortex: the most posterior point of lingual alveolar bone along a line that passes through the incisor apex and perpendicular to the long axis of lower right central incisor.

9. Internal Lingual Cortex: the most anterior point of lingual alveolar bone along a line that passes through the incisor apex and perpendicular to the long axis of lower right central incisor.

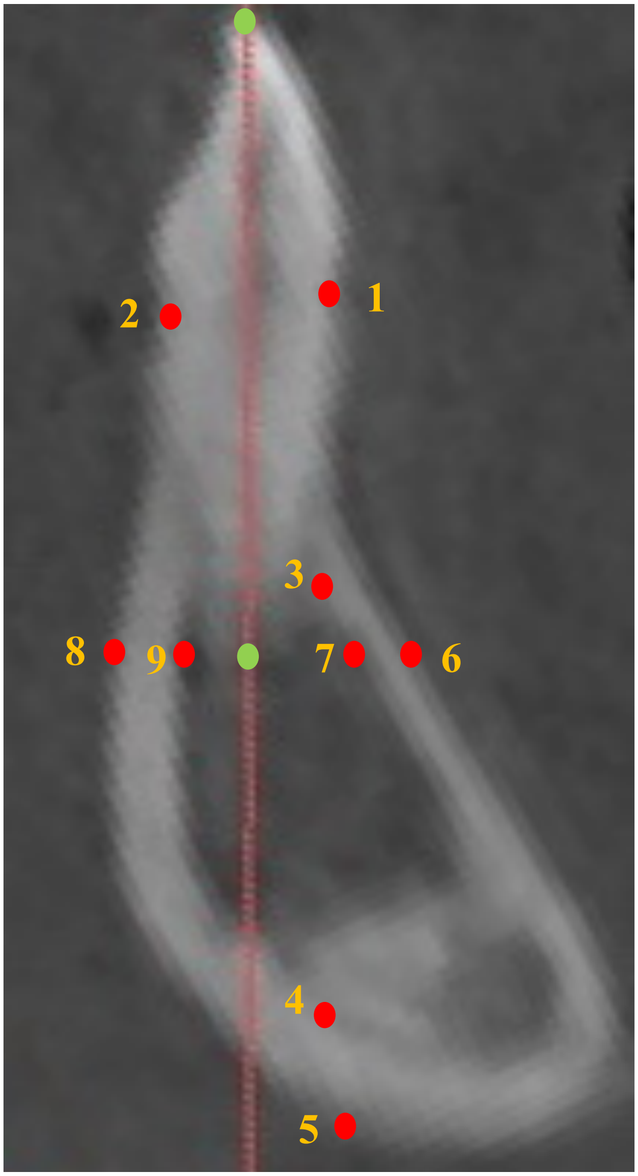


Fig 5.12 sagittal slice where the following points identified : 1 Prosthion, 2 Lingual prosthion, 3 Superior Concellous, 4 Inferior concellous, 5 Symphysis Base, 6 External labial cortex, 7 Internal Labial Cortex,8 External lingual cortex, 9 Internal lingual cortex, 10 mid incisal edge, 11 root apex

From the above-mentioned points, following linear (Fig 5.13) and angular (Fig 5.14) measurements were done by using the MIMICS 14.0 software launched by Materialise (Materialise Europe, World Headquarters, Leuven, Belgium):

Linear Measurements:

- Symphysis Height (mm): the distance from Prosthion to Symphysis Base
- Symphysis Thickness (mm): the distance from External Labial Cortex point to External Lingual Cortex point.
- Canceollus Bone Height (mm): the distance from Superior Cancellous Point to the Inferior Cancellous Point.
- Canceollus Bone Thickness (mm): the distance from Internal Labial Cortex point to Internal Lingual Cortex point.
- Labial Cortex Thickness (mm): the distance from the External Labial Cortex point to Internal Labial Cortex point.
- Lingual Cortex Thickness (mm): the distance from the internal lingual cortex point to the External Lingual Cortex point.

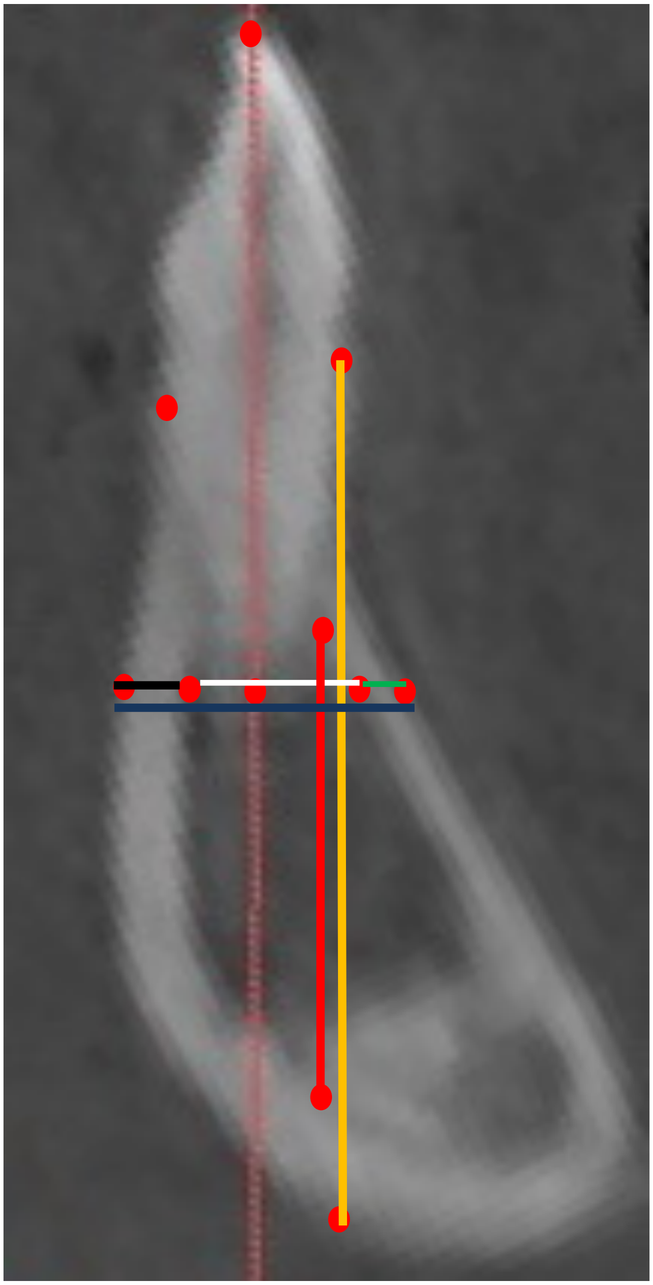


Fig 5.13 sagittal slice showing the following measurement: symphysis bone height (yellow), symphysis bone thickness (blue), cancellous bone height (red), cancellous bone thickness (white), labial cortex thickness (green), lingual cortex thickness (black).

Angular Measurements:

1. The lower right central incisor inclination: the angle between the Mandibular plane and a line passes through the long axis of lower right central incisor from the Mid Incisal Edge Point and Incisor Apex.
2. The Labial Alveolar Inclination: the angle between the mandibular plane and a line passes from Prosthion and External Labial Cortex.
3. The Lingual Alveolar Inclination: the angle between the Mandibular plane and a line passes from Lingual prosthion and External Lingual Cortex

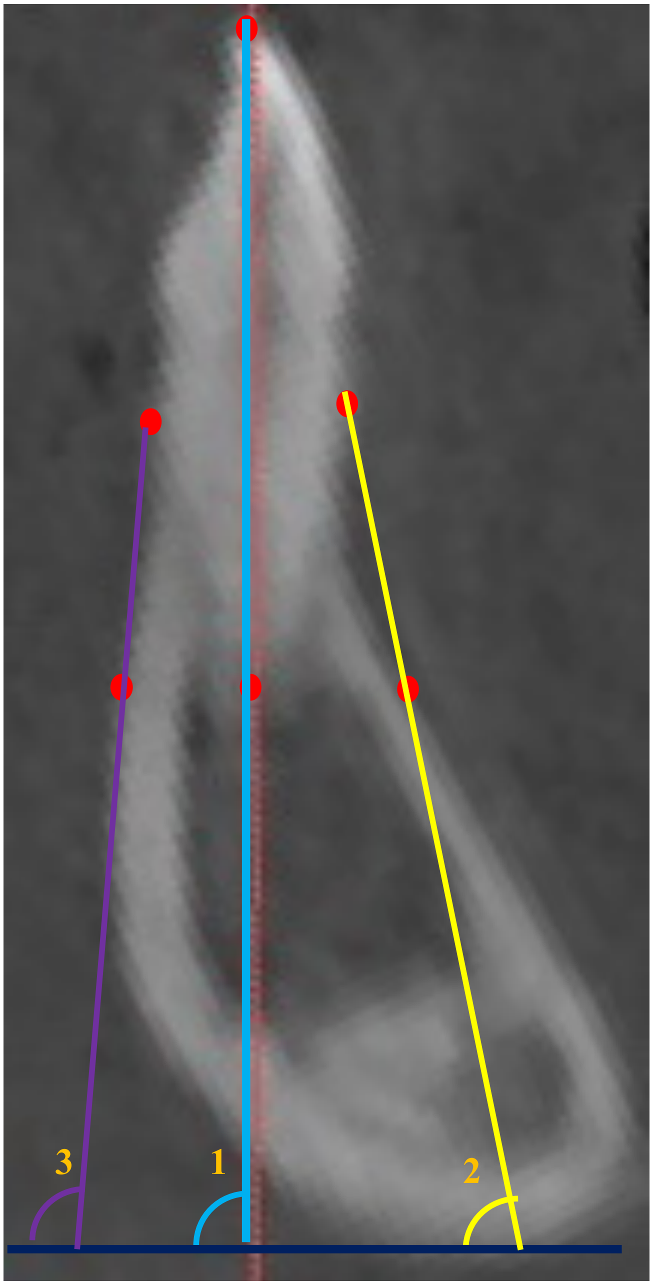


Fig 5.14 sagittal slice showing the following measurement: 1 lower right central incisor inclination, 2 Labial Alveolar Inclination, 3 Lingual Alveolar Inclination

5.6 Statistical Method

SPSS (Statistical Package for Social Sciences) for Windows 15.0 program was used for statistical analysis of the data. Means and standard deviations for all parameters were calculated. Conformity of the parameters to the normal distribution was assessed by the Kolmogorov–Smirnov test and it was determined that the parameters were conformed to the normal distribution. In both groups, the initial values of all the parameters used in the study, were evaluated for gender differences using Student t-test. In neither of the groups, there was no statistically significant difference between the two genders. Therefore, intergroup comparisons were made for the whole group, by using student-t test. Linear regression analysis was used for multivariate analysis. Pearson's correlation analysis was used for investigation of relationships between parameters. Significance was evaluated at a level of $p<0.05$.

6 RESULTS

6.1 Evaluation of the reliability of the method

Table 6.1: Evaluation of method error for the measurement

	ICC	95% CI	p
lower right central incisor inclination	0,912	0,814-0,960	0,001**
Lingual Alveolar Inclination	0,939	0,869-0,972	0,001**
Labial Alveolar Inclination	0,971	0,936-0,987	0,001**
Symphysis Height	0,977	0,949-0,989	0,001**
Cancellous Bone Height	0,975	0,945-0,989	0,001**
Cancellous bone thickness	0,974	0,943-0,988	0,001**
Lingual cortex thickness	0,958	0,908-0,981	0,001**
Labial cortex thickness	0,929	0,849-0,968	0,001**
Symphysis thickness	0,979	0,955-0,991	0,001**

The data presented on table 6.1 demonstrated a high agreement between the duplicate measurements conducted by the same examiner (T.G). The Interclass Correlation Coefficient of all the measurements for 28 randomly selected cases showed a high rate of consonance between measurements.

The highest Intraclass Correlation Coefficient was observed in symphysis thickness measurement (0.979), while the lowest was observed in the lower right central incisor inclination measurement (0.912).

6.2 Intragroup Comparisons for gender differences

The age of the patients for this study ranged between 12 and 56 years. Forty six patients (60.8%) were female and twenty-eight (39.2%) were male, in 74 patients. The mean age of the study group was 16.9 years ± 5.3 SD (table 6.2).

Table 6.2: Gender and age distribution of the study

	n	**%**
Age		
<18	52	70,3
≥18	22	29,7
Gender		
Female	46	60,8
Male	28	39,2
Type of vertical growth		
High angle	46	60,8
Normal angle	28	39,2

When the measurements were compared between males and females in the Long Face Group (table 6.3) differences were not found to be significant ($p>0.05$). Only, the symphysis height in females was significantly higher than the symphysis height in males ($p<0.05$).

Table 6.3: Comparison of measurements between males and females in the Long face group

	Male (n=30)	Female (n=16)	p
Long Face	**Mean±SD**	**Mean±SD**	
Lower right central incisor inclination	85,18±4,40	83,06±5,59	**0,165**
Labial Alveolar Inclination	81,37±4,41	78,64±6,41	**0,095**
Lingual Alveolar Inclination	84,45±4,93	83,44±5,69	**0,532**
Labial cortex thickness	1,46±0,35	1,47±0,28	**0,928**
Symphysis thickness	7,24±1,77	7,12±1,52	**0,820**
Cancellous bone thickness	4,09±1,41	4,14±1,25	**0,914**
Lingual cortex thickness	1,69±0,42	1,52±0,33	**0,168**
Symphysis height	27,84±2,43	29,96±3,66	**0,049***
Cancellous Bone Height	17,81±2,81	18,44±3,36	**0,500**

Student t-test ** p<0, 05*

When the measurements were compared between males and females in the Normal Face Group (table 6.4) differences were not found to be significant ($p>0.05$). Only, the symphysis height in females was significantly higher than the symphysis height in males ($p=0.05$).

Table 6.4: Comparison of measurements between males and females in the Normal face group

Normal face	Male (n=16) Mean±SD	Female (n=12) Mean±SD	p
Lower right central incisor inclination	86,82±1,69	86,14±3,15	**0,509**
Labial Alveolar Inclination	80,25±5,43	76,45±8,09	**0,149**
Lingual Alveolar Inclination	83,30±3,41	83,94±5,72	**0,737**
Labial cortex thickness	1,69±0,44	2,02±0,45	**0,066**
Symphysis thickness	9,10±2,02	9,92±1,72	**0,270**
Cancellous bone thickness	5,37±1,30	5,94±1,41	**0,277**
Lingual cortex thickness	2,04±0,59	1,97±0,34	**0,700**
Symphysis height	25,87±1,89	27,75±2,95	**0,050***
Cancellous Bone Height	16,34±2,32	17,64±2,68	**0,182**

Student t-test ** p<0, 05*

6.3 Intergroup Comparison of Parameters

In neither of the groups, there was no statistically significant difference between the two genders. Therefore, intergroup comparisons were made for the whole group

Table 6.5: Intergroup comparison of means of measurements

	Long face (n=46)	**Normal face (n=28)**	**p**
	Mean±SD	**Mean±SD**	
Lower right central incisor inclination	84,44±4,89	86,53±2,40	**0,017***
Labial Alveolar Inclination	80,42±5,29	78,62±6,84	**0,208**
Lingual Alveolar Inclination	84,10±5,16	83,58±4,46	**0,658**
Symphysis thickness	7,20±1,67	9,45±1,91	**0,001****
Labial cortex thickness	1,4±0,32	1,83±0,47	**0,001****
Cancellous bone thickness	4,11±1,34	5,61±1,35	**0,001****
Lingual cortex thickness	1,63±0,40	2,01±0,49	**0,001****
Symphysis height	28,58±3,05	26,67±2,53	**0,007****
Cancellous Bone Height	18,03±2,99	16,89±2,52	**0,098**

Student t-test ** p<0,05* *** p<0,01*

The data in Table 6.5, which shows the comparison of the means of measurements between the long face and normal, face group demonstrated the following results:

(I) The mean values of the lower right central incisor inclination ($p<0.05$), the labial cortex thickness ($p<0.01$), the cancellous bone thickness ($p<0.01$), the lingual cortex thickness ($p<0.01$), the symphysis thickness ($p<0.01$) measurements were statistically significantly lower in the Long Face group than the mean values of the Normal face group ($p<0.05$).

(II) There were not statistically significant differences between the mean values of labial alveolar Inclination ($p>0.05$), lingual alveolar Inclination ($p>0.05$), and the cancellous bone height ($p>0.05$) measurements between the Long Face and the Normal Face groups.

(III) The mean value of the symphysis height measurement was statistically significantly higher in the Long Face group than the mean value in the Normal face group ($p<0.01$).

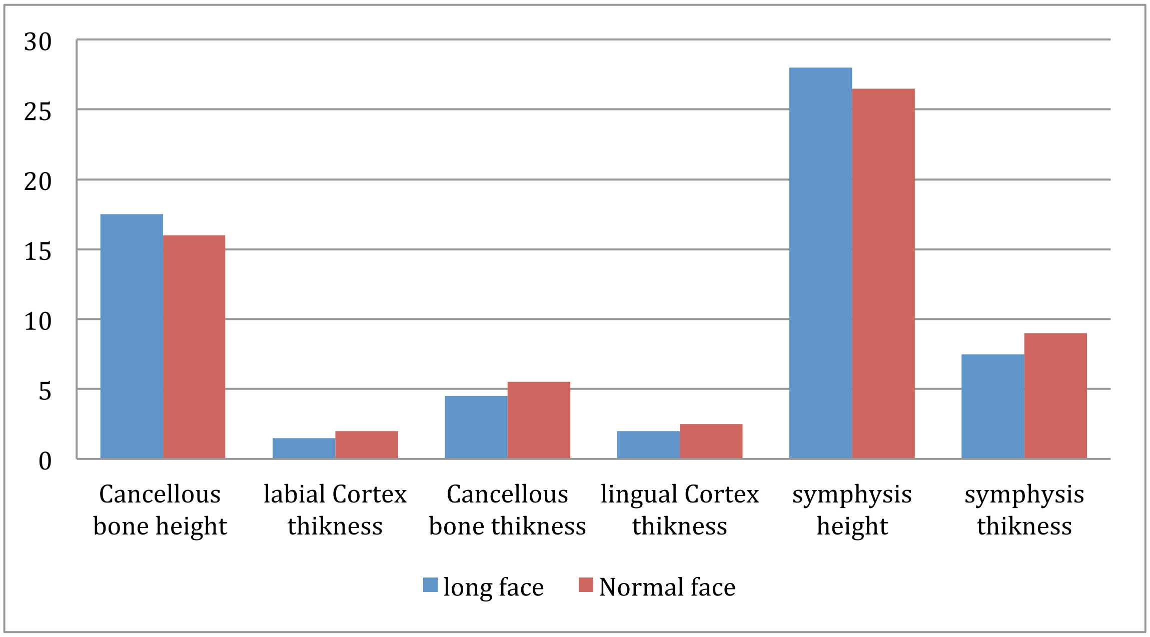


Fig 6.1: Distribution graph for intergroup comparison of means of measurements

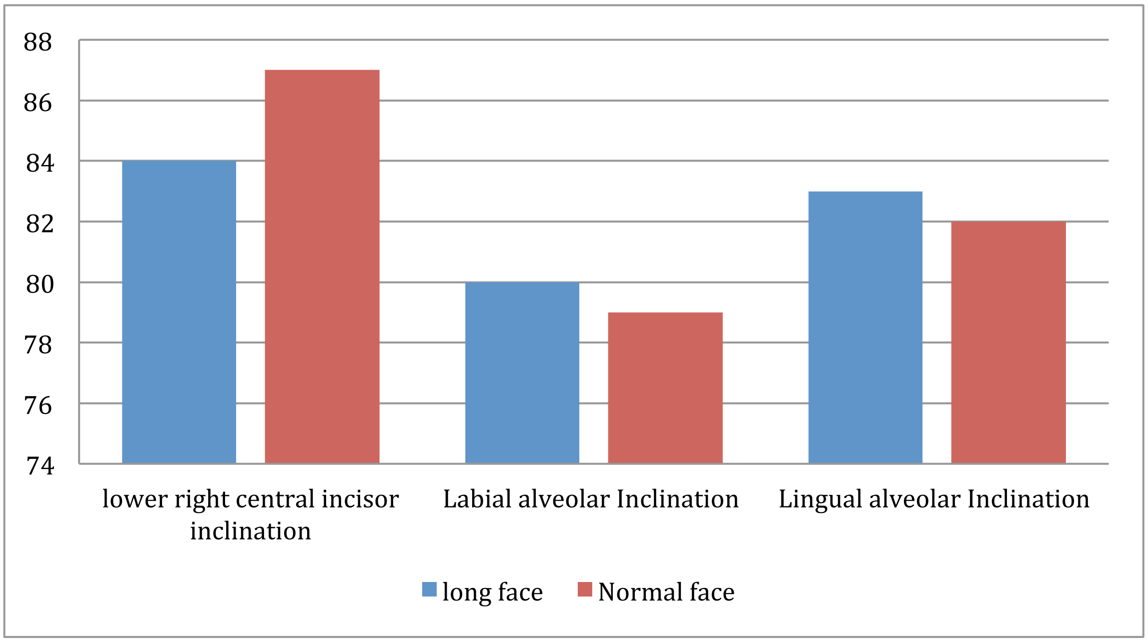


Fig 6.2: Distribution graph for intergroup comparison of means of measurements

6.4 Correlation between the Lower Right Central Incisor Inclination and the other parameters

The results of the Pearson`s Correlation test between the lower right central incisor inclination and the other parameters in the long face group demonstrated the following (Table 6.6):

(I)There were no statistically significant correlations between the lower right central incisor inclination and the measurements of Cancellous Bone height (p>0.05), the Labial Cortex Thickness (p>0.05), and the symphysis height (p>0.05).

(II) The positive correlation between the measurement of right lower central incisor inclination and the measurement of Labial alveolar inclination was highly significant at a level of 48.5% (strength of the correlation) (p<0.01).

(III) The positive correlation between the measurement of right lower central incisor inclination and the measurement of Lingual alveolar inclination was highly significant at a level of 73.6% (strength of the correlation) (p<0.01).

(IV) The positive correlation between the measurement of right lower central incisor inclination and the measurement of cancellous bone thickness was highly significant at a level of 42.4% (strength of the correlation) (p<0.01).

(V) The positive correlation between the measurement of right lower central incisor inclination and the measurement of Lingual cortex bone thickness was highly significant at a level of 42.8% (strength of the correlation) (p<0.01).

(VI) The positive correlation between the measurement of right lower central incisor inclination and the measurement of symphysis thickness was highly significant at a level of 47.8% (strength of the correlation) (p<0.01).

Table 6.6: The result of the Pearson`s Correlation test between the lower right central incisor inclination and the other parameters in the Long Face group

	Lower right central incisor inclination	
Long face	**r**	**p**
Lingual Alveolar Inclination	0,736	**0,001****
Labial Alveolar Inclination	0,485	**0,001****
Labial cortex thickness	0,171	**0,256**
Symphysis thickness	0,478	**0,001****
Cancellous bone thickness	0,424	**0,003****
Lingual cortex thickness	0,428	**0,003****
Symphysis height	-0,119	**0,432**
Cancellous Bone Height	-0,164	**0,275**

Pearson's Correlation test ** p<0,05* *** p<0,01*

The results of the Pearson`s Correlation test between the lower right central incisor inclination and the other parameters in the normal face group demonstrated the following (Table 6.7):

(I) There were no statistically significant correlations between the lower right central incisor inclination and the measurements of Cancellous Bone height ($p>0.05$), the labial alveolar Inclination ($p>0.05$), the Labial Cortex Thickness ($p>0.05$), the lingual alveolar Inclination ($p>0.05$), the lingual cortex thickness ($p>0.05$) and the symphysis thickness ($p>0.05$).

(V) The negative correlation between the right lower central incisor inclination and the measurement of cancellous bone thickness was highly significant at a level of 44.2% (strength of correlation) ($p<0.05$).

(VII) The positive correlation between the measurement of right lower central incisor inclination and the measurement of symphysis height was highly significant at a level of 37.6% (strength of correlation) ($p<0.01$).

Table 6.7: The result of the Pearson`s Correlation test between the lower right central incisor inclination and the other parameters in the Normal Face group

	right lower central incisor inclination	
Normal face	**r**	**p**
Lingual Alveolar Inclination	0,344	**0,073**
Labial Alveolar Inclination	0,158	**0,423**
Labial cortex thickness	-0,137	**0,487**
Lingual cortex thickness	-0,047	**0,813**
Cancellous bone thickness	-0,442	**0,019***
Symphysis thickness	-0,359	**0,061**
Symphysis height	0,376	**0,048***

Cancellous bone Height	0,253	**0,194**

Pearson's Correlation test ** p<0,05*

6.5 The Results of Regression Analysis

Table 6.8: Evaluation of regression analysis in the Long Face group

	Unstandardized Coefficients		**Standardized Coefficients**			**95% CI for B**	
Step 4	**B**	**Std. Error**	**Beta**	**t**	**p**	**Lower**	**Upper**
Constant	16,003	7,603		2,105	0,041*	0,649	31,357
Cancellous Bone Height	-0,303	0,132	-0,186	2,300	0,027*	-0,570	-0,037
Labial Alveolar Inclination	0,428	0,094	0,463	4,555	0,001**	0,238	0,618
Lingual Alveolar Inclination	0,362	0,101	0,383	3,600	0,001**	0,159	0,566
Symphysis thickness	1,249	0,295	0,426	4,241	0,001**	0,654	1,844

Dependent Variable: lower right central incisor mandibular plane angle

Evaluation of regression analysis in the Long Face group: the effects of the measurement of lower right central incisor inclination (Dependent Variable) and all other (Independent Variable) were evaluated with linear regression analysis using backward selection method. In this step, as data in table (6.8) showing that Cancellous bone height, Labial alveolar inclination, Lingual alveolar inclination and symphysis thickness parameters remain in the model (p<0.05; p<0.01). Model was found to be meaningful (p: 0.001; p<0.01) and R-squared value was determined to be 0.741. This value shows that 74.1% of the change in the measurement of lower right central incisor inclination is explained by the parameters added to the model. While one more unit increase in the measurement of Cancellous bone height has a 0.303-fold lowering effect on the measurement of lower right central incisor inclination, one more unit increase in the measurement of Labial alveolar inclination has a 0.428-fold increasing effect on the measurement of lower right central incisor inclination, one more unit increase in the measurement of Lingual alveolar inclination has a 0.362-fold increasing effect on the measurement of lower right central incisor inclination and one more unit increase in the measurement of symphysis thickness parameter has a 1.249-fold increasing effect on the measurement of lower right central incisor inclination.

Table 6.9: Evaluation of regression analysis in the Normal Face group

	Unstandardized Coefficients		**Standardized Coefficients**			**95% CI for B**	
Step 5	**B**	**Std. Error**	**Beta**	**t**	**p**	**Lower**	**Upper**
Constant	83,777	3,095		27,067	0,001**	77,389	90,165
Cancellous Bone Height	0,493	0,173	0,517	2,848	0,009**	0,136	0,850
Labial cortex thickness	2,401	1,245	0,469	1,929	0,006**	-0,168	4,970
Symphysis thickness	-1,055	0,319	-0,840	-3,303	0,003**	-1,715	-0,396

Dependent Variable: lower right central incisor mandibular plane angle

Evaluation of regression analysis in the Normal Face group: the effects of the measurement of lower right central incisor inclination (Dependent Variable) and all other parameters (Independent Variable) were evaluated with linear regression analysis using backward selection method. In this step, as data in table (6.9) shows that

Cancellous height, Labial cortex thickness and symphysis thickness parameters remained in the model ($p<0.01$). Model was found to be meaningful (p: 0.011; $p<0.05$) and R-squared value was determined to be 0,368. While one more unit increase in the measurement of Cancellous bone height has a 0.493-fold increasing effect on the measurement of lower right central incisor inclination and one more unit increase in the measurement of labial cortex thickness has a 2.401-fold increasing effect on the measurement of lower right central incisor inclination, one more unit increase in the measurement of symphysis thickness parameter has a 1.055-fold lowering effect on the measurement of lower right central incisor inclination.

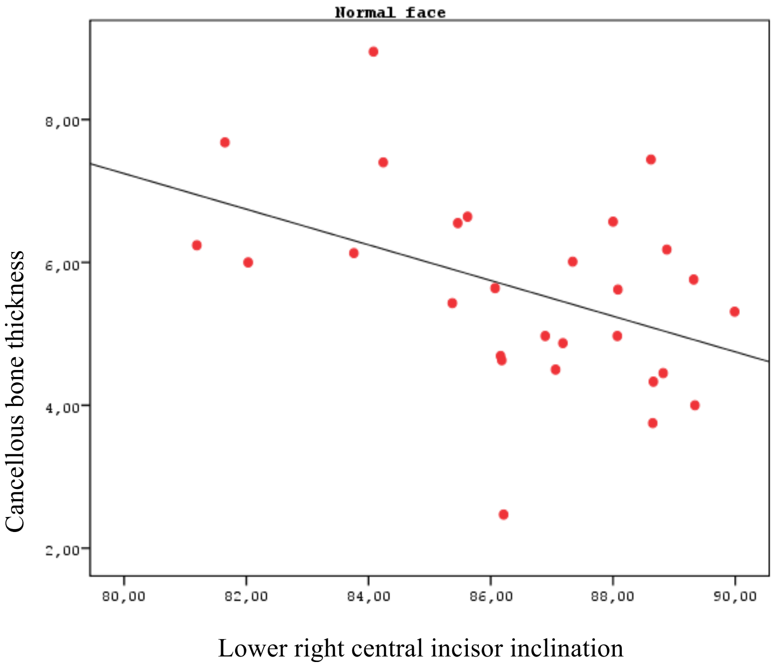


Fig 6.3: The linear regression plots for the right lower central incisor inclination and concellous bone thickness in normal face group

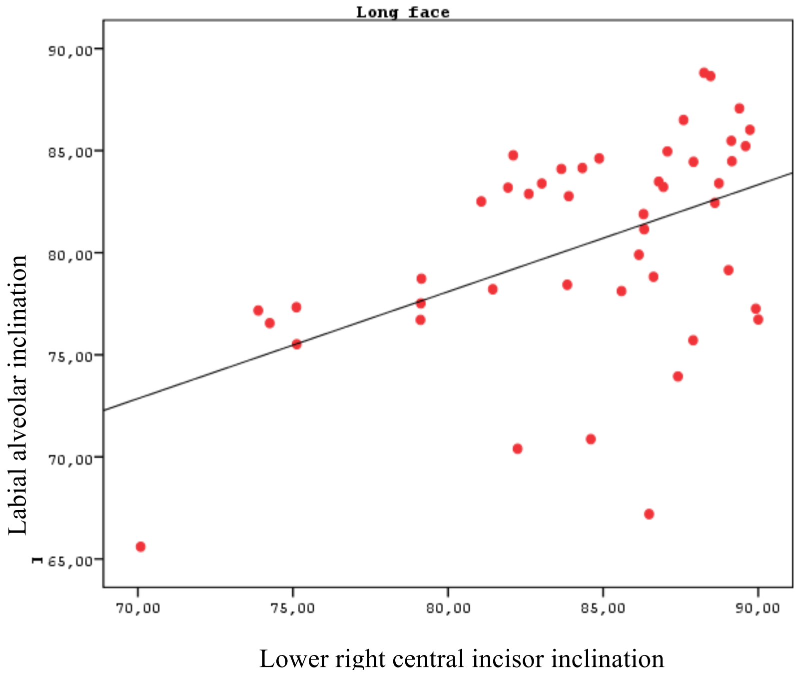


Fig 6.4: The linear regression plots for the right lower central incisor inclination and Labial alveolar inclination in long face group

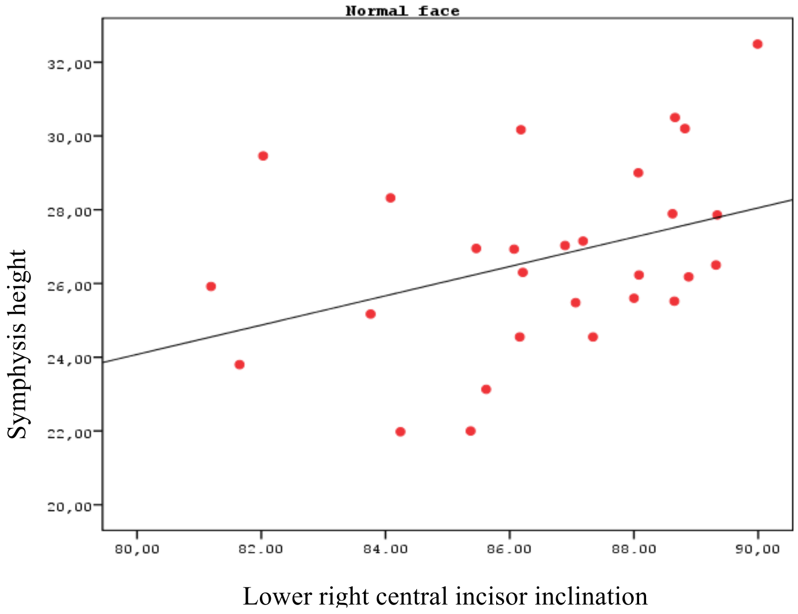


Fig 6.5: The linear regression plots for the right lower central incisor inclination and symphysis height in normal face group

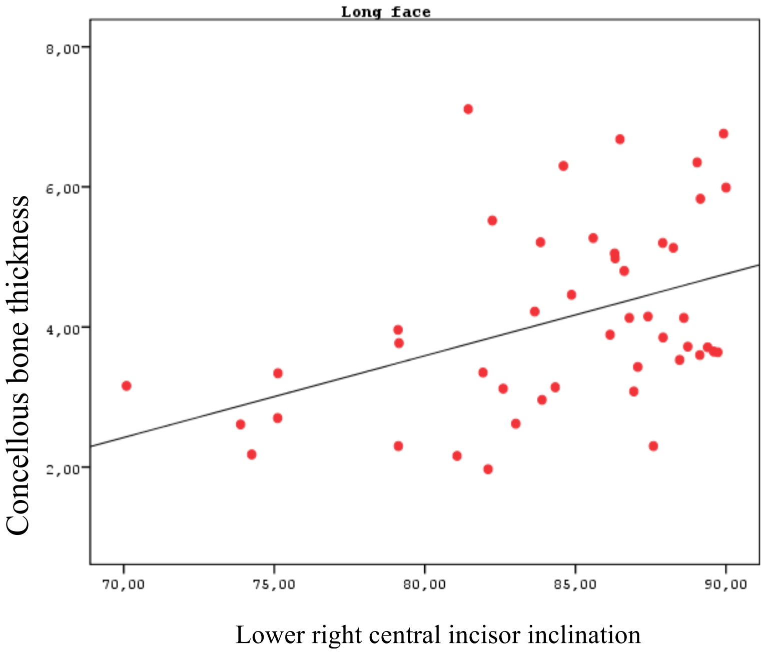


Fig 6.6: The linear regression plots for the right lower central incisor inclination and concellous bone thickness in long face group

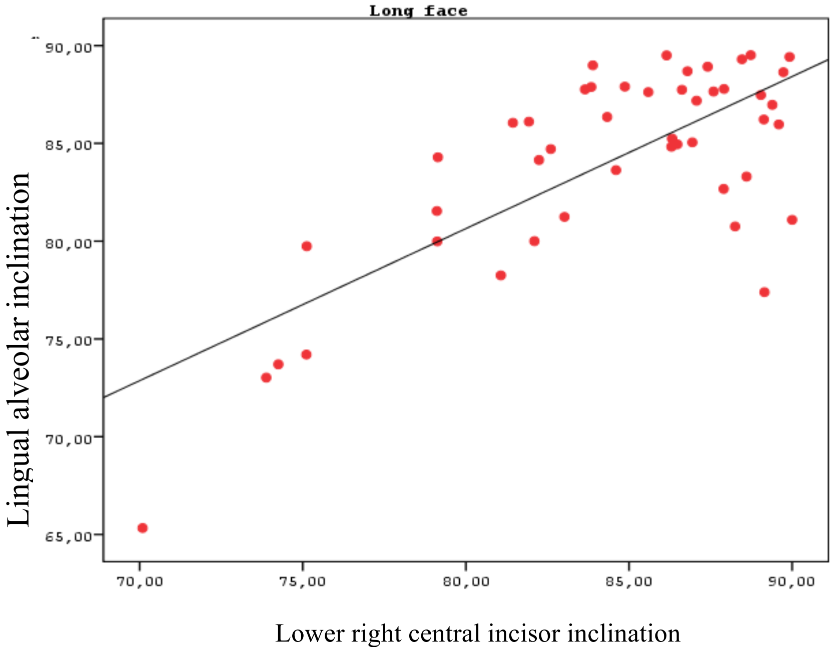


Fig 6.7: The linear regression plots for the right lower central incisor inclination and Lingual alveolar inclination in long face group

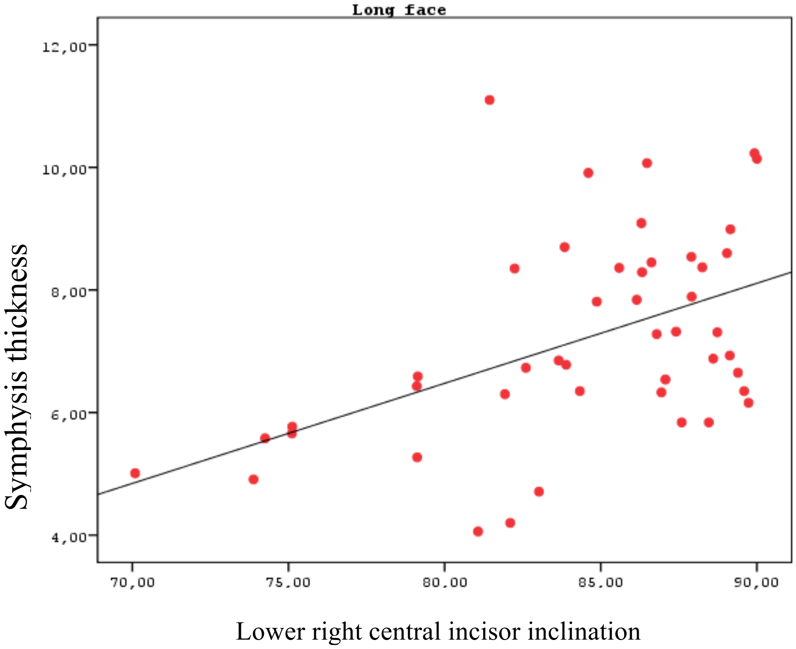


Fig 6.8: The linear regression plots for the right lower central incisor inclination and Symphysis thickness in long face group

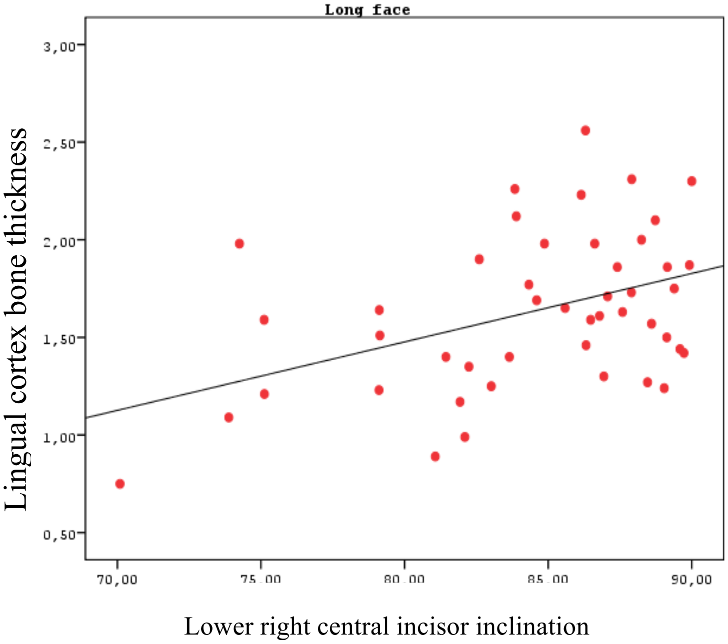


Fig 6.9: The linear regression plots for the right lower central incisor inclination and Lingual cortex bone thickness in long face group

7 DISCUSSION

7.1 Discussion of the materials and methods

The purpose of this study was to elucidate any differences in the cross-sectional morphology's of the mandibular symphysis, the thickness of cortical and cancellous bones, the height of cortical and cancellous bones and lower incisor teeth inclination among different subjects with normal and long facial growth pattern.

All CBCT images used in this study were from the archives of the Department of Orthodontics of Faculty of Dentistry of Marmara University.Our patients sample were gathered after excluding the patients with the following criteria:

(I) the patients should not have any pathologic or syndromic deformities in their head and neck region, because those diseases may affect the normal bony growth and maturation.

(II) The patients should not have any previous orthodontic treatment, since the orthodontic treatment may change the natural incisor inclination.

(III) The patients should have intact lower permanent dentition, because missing teeth may cause a change in the normal position and inclination of lower anterior teeth.

The CBCT images of 74 patients were used in this study, the mean age of the sample was 16.9± 5.3 SD years.

These patients were divided according to their Mandibular plane angle into 2 groups: High angle group (their mandibular plane angle above 36 degrees) and Normal angle group (their mandibular plane angle range between 28-36 degrees) these ranges were chosen according to Steiner cephalometric analysis (132).

In this study each vertical sample were divided into male and female groups. 30 of these patients were high angle female patients (mean age=15.7± 2.52 SD), 16 of them were normal angle female patients (mean age=16± 2.8 SD), 16 of them were high angle male patients (mean age=19.8 ± 10.04 SD) and 12 of them were normal angle male patients (mean age =17.75 ± 2.0 SD).

In the past, many researchers tried to explore the relationship between the mandibular symphysis morphology and vertical facial growth pattern and/or lower incisor inclination. Most of these studies were based on 2D x-rays images (lateral cephalogram) (61, 105, 85, 118, 3).

However, 2D-cephalometry is a projection image of 3D-structures, and has several disadvantages, such as non-homogenous enlargement, distortion on lateral structures and inaccurate landmark locations due to overlapping structures (145). Therefore, the precise identification of specific tooth and its supporting bony apparatus becomes very difficult since it is most likely superimposed by nearby structure.

In addition, using a 2D method for linear measurements of tiny bone structure was not found to be accurate enough compare to 3D image, which was more precise and gave 4-5 times more accurate results than the 2D approach (2).

Therefore, we chose to conduct our study using Cone Beam Computed Tomography due to their advantages over other 3D image techniques such as Multi Spiral-Computed Tomography scans, the most important being its lower radiation dose, reduced artifacts and lower costs (43, 92).

In addition, CBCT 3D image has unique ability to produce accurate representation of small tiny details of the mandibular bony tissue, Also, it provides the option of viewing and recording those details from any view angle on multiple anatomical planes (axial, coronal and sagittal) (134).

Also, It is important to mention that many researchers have proved that there was no statistically significant difference between CBCT and direct craniometric measurements and it was reported that CBCT craniometric measurements were accurate to a subvoxel size and therefore it was recommended to be the optimal diagnostic tool for future investigations (68, 59).

.

In this investigation after all the data were collected, MIMICS 14.0 software was incorporated in order to process the CBCT images and to investigate the morphological feature of the mandibular symphysis at the lower right central incisor region (fig 5.13, fig 5.14).

First, 3 dimensional image of the lower jaw was constructed in order to accurately locate Menton, right and left Gonion. These 3 points were used to construct the mandibular plane, which was used later as the horizontal reference for measuring lower right central incisor and its associated alveolar bone inclination (fig 5.10).

After that, by using the mid gonion, mid incisal edge and incisor root apex, the mid sagittal plane was constructed. By the help of this plane, it was possible to perform the analysis through the mid sagittal plane of the lower right central incisor (fig 5.11).

In previously published studies (85, 56), which investigated the morphological changes of alveolar bone around the incisor without constructing a guiding plane, the measurements could be performed on a sagittal plane which might have been placed slightly oblique or deviated from the true sagittal plane of the targeted incisor, which would affect the statistical reliability and results of those studies.

The importance of constructing a reliable mid-sagittal plane to be able to evaluate the incisor position, was also emphasized by Yamada (154), who investigated the morphological changes of the alveolar bone around the lower central incisor in mandibular prognathism patients by constructing a sagittal plane between central incisal edge, central incisor root apex and central incisor basal tubercle and he called it central incisor mid-sagittal plane .

However, it is important to mention that accurate identification of the central incisor basal tubercle is difficult to achieve since there is no anatomic guidance and it is highly subjected to low intra-observer reliability.

Therefore, in the current study, to guarantee the reliability of the calculations, the analysis was performed on a sagittal plane, which called mid-sagittal plane that was constructed through the mid Incisal edge point, apex point and the mid Gonion, those anatomic landmark are easily recognizable and demonstrates high intra-observer reliability (fig 5.11).

On the right lower central incisor mid-sagittal plane, specific points will be identified and digitized (fig 5.12) in order to perform the measurements through the MIMICS software.

Previously, studies (4,5 6, 135, 85, 144, 147) were performed to evaluate the symphysis shape and/or lower incisor inclination and vertical malocclusion relationship, the anatomical landmark and measurement criteria used in these studies were different and some of these anatomical points were difficult to locate and could subject the study to low intra-observer reliability. Therefore, we chose to perform our measurements relying on anatomical landmarks that are easy to identify.

Uysal and Gracco (56, 144), used CBCT to investigate the relationship of symphysis morphology with vertical malocclusion. In their research a similar anatomical guidance and measurements criteria were used. Since both the landmarks were easily recognizable and the selected measurements demonstrated high intra-observer reliability, we chose to adapt their method for the calculation of the symphysis and cancellous bone height and thickness.

However, they calculated the cancellous bone height from the internal labial cortical point at the level of the incisor root apex to cancellous bone base along a line parallel to the long axis of the incisor, yet the cancellous bone above that area was not included (fig 5.13)(56, 144). In our study, we decided to calculate the small portion of cancellous bone between the internal labial cortex point and cancellous superior, which was ignored by Uysal and Gracco. Therefore, we measured the cancellous bone height from the cancellous bone base point to the most superior cancellous bone area on the internal labial cortex along a line parallel to the long axis of the incisor, which we called superior cancellous (fig 5.13).

Yamad and Yu (154, 118) used CBCT to investigate the relationship between the lower central incisor and its supporting alveolar bone. The anatomical landmarks and angular measurements that they used were easily recognizable. They used the most posterior point of the labial and lingual alveolar bone as the second point to be able to construct the planes to measure the labial and lingual alveolar bone inclination angles.

It is important to mention, however, that accurate identification of the most posterior point of the labial and lingual alveolar bone are difficult to achieve since there is no anatomic guidance and it is highly subjected to low intra-observer reliability.

Therefore, in our study to guarantee the reliability of landmark identification and measurement's accuracy, simple and clearly visible points were used. For that reason, we chose the external labial and lingual alveolar cortex points to construct the labial and lingual alveolar inclination planes (fig 5.14).

7.2 Discussion of result

means of measurements of cancellous bone height, cancellous bone thickness, labial cortex thickness, lingual cortex thickness and symphysis thickness were not significantly different between the Normal Face and the Long Face groups for both genders (p>0.05) (table 6.3 & 6.4).

These findings were compatible with the results of the study done by Farnsworth who stated that, there was no sex differences in cortical bone thickness at sites commonly used for MSI placement (44). Also, Swasty reported the same result in his study which was performed on CBCT images (135).

On the other hand, Uysal evaluated the thickness of the alveolar bone support of the lower incisors on cone beam computed tomographic sections and reported that the mandibular bone measurements were greater in the male subjects than the female (144).

He supported his finding based on the fact that male had a greater bite force than female and therefore the male bony structure would be larger due to the compensatory phenomenon of bone remodeling in response to higher strain. However, other researchers have claimed that maximum bite forces were not physiological because they were rarely attained in every day life (27, 143). Since males and females eat essentially the same types of food, the strains produced during mastication might be expected to be similar, as would cortical bone thickness.

The data of our study indicated that in both Normal and Long Face groups the means of measurements of symphysis height were found to be statistically significantly higher in females than the measurements of the males ($p<0.05$) (table 6.3&6.4).

This result, which contradicts the belief, that male and female bony measurements are similar, might be explained by the fact that vertical facial growth continue after puberty, and the circumpubertal facial growth in the vertical plane is completed substantially after the growth in the horizontal plane (52, 77). Since the age of the subjects used in this study in both gender is young adult and it is widely known that female usually mature much earlier than male (136), their vertical facial growth will temporarily exceed the male before the male vertical facial growth will catch up later.

Our statitical analysis of lower right central incisor and its bony support inclination did not indicate any significant difference between genders in both Normal and long face groups ($p>0.05$) (table 6.4 & 6.3). These findings were consistent with the results of previous report that documented by Yamada (154), who examined the mandibular central incisor and its associated alveolar bone in adult with mandibular prognathism using computed tomography images of the mandible. He did not find any significant difference between men and women for any variable.

The same conclusion was also published by Yu (118), who did a similar investigation on pre-orthodontic treatment Cone Beam images of young adolescent subjects.

In our study, we found that the long face cases had statistically significantly thinner alveolar bony support and symphysis than the subjects with Normal vertical growth pattern (table 6.5, fig 6.1).

These results are supported by many researches (70, 42, 3, 139), which demonstrated that hyperdivergent or Long face subjects had slightly less thick mandibular cortical bone and thinner symphysis than the subjects with Normal and Short vertical growth pattern..

These finding might be explained by the fact that Long face Subjects had weaker muscles of mastication when it is compared to the other vertical growth pattern groups (120, 93).

There is evidence that the form of the mandible and maxilla, specifically the density and thickness of the cortical plate, adapts to the function of the masticatory apparatus (148).

Frost's mechanostat hypothesis provides an explanation of this adaptive process. It suggests that there are a range of strain values, in which the form and mass of the bone can be maintained. Strains above this range induce bone production, strains below the maintenance range leads to bone loss (51).

The results of our study showed that the symphysis height was increased in the Long face subjects compare to the Normal face subjects (table 6.5, fig 6.1). Numerous investigations had confirmed our finding (15, 135, 3).

Possible explaination for long face subjects to have longer symphysis height than the other vertical growth groups might have been related to the fact that most of the hyperdivergent individuals have open bite tendencies either due to nasal airway problem, tongue thrust or increased posterier facial height due to weak muscle of mastication (108, 116, 54). All these conditions will disrupt the incisal contact providing a space for lower incisors to over erupt and elongating the mandibular sympysis (137).

Regarding the inclinations of the Lower right central incisor and its bony support, our data revealed that the Lower right central incisor teeth were more retroclined in the long face group than the Normal face group (table 6.5, fig 6.2).

Similar results were published in previous investigations (67, 12), which studied the relationship between the lower incisors inclination and vertical malocclusion.

These findings are in accordance with the analysis of Tweed (13), who suggested that the change in Vertical pattern of the patient could affect the Lower incisor inclination.

However, there are other investigators (16, 47) who found the lower incisors to be more proclined in patients with long facial growth pattern. They stated that this position of the lower incisors could be considered as a dental compensation to mandibular retrusion, i.e, to the clockwise rotation of the mandible.

In our study sample most of the subjects in Long Face group were Class III or Class I with Class III tendency. We believed that the retroclination of the lower incisor teeth in this group was related with the sagittal malocclusion as well.

It is widely known that in class III malocclusion the dentoalveoler compensatory adaptation is influenced by the surrounding soft tissue pressure, the neighbouring and opposing teeth during occlusion will move the incisors lingually to compensate for the reverse overjet (7, 128).

In our study, the lower incisor inclination showed a significant positive correlation with the labio-lingual inclinations of the associated mandibular symphyseal alveolar bone in Long Face subjects (table 6.6) ($p<0.01$). Therefore, we can conclude that the shape of the alveolar bone seems to correspond to the incisor inclination for patients with Long Facial growth pattern.

These findings were consistent with the results of the previous reports, which documented that the morphology of the alveolar bone in the central incisor region was associated with the inclination of the central incisor teeth (154, 82, 85, 118).

On the other hand, the measurement of the lower incisor inclination was not found to be corralated with the measurements of labial and lingual alveolar Inclination in normal face subjects (table 6.7)($p>0.05$).

This finding maight be related to the sample size variation between the long and normal facial growth subjects (table 6.2), which could effect the statistical analysis results comparing the groups.

This also could be explained by the fact that in generl, normal face subjects have wider symphysis base and therefore the lower incisor root has plenty of space to move through the cancellous bone while they procline without affecting the inclination of their supporting alveolar bone. This is opposite in the long face subjects who have a thinner symphysis base where lower incisor root apex has limited cancellous bone space to move while it proclines. Therefore, changes in the lower incisor inclination will affect the inclination of their supporting alveolar bone.

8. CONCLUSION

1. The labial cortical bone thickness, the lingual cortical bone thickness, the cancellous bone thickness and mandibular symphysis thickness at the lower right central incisor root apex region are thinner in the long facial growth subjects compared to normal facial growth subjects in both genders.

2. The symphysis height at the lower right central incisor region is longer in the long facial growth subjects compared to the normal facial growth subjects in both genders.

3. There are no significant differences for the mandibular symphysis bony measurements at the lower right central incisor region between genders.

4. The lower right central incisor is more retroclined in the long facial growth subjects compared to normal facial growth subjects.

5. The morphological contour of the alveolar bone at the lower right central incisor follows their incisor inclination in the long facial growth subjects but not in the normal facial growth subjects in both genders.

9. REFERENCES

1. Aasen TO, Espeland L. (2005). An approach to maintain orthodontic alignment of lower incisors without the use of retainers. *Eur J Orthod*, 27(3): 209–214.
2. Adams GL, Gansky SA, Miller AJ. (2004). Comparison between traditional 2-dimensional cephalometry and a 3-dimensional approach on human dry skulls. *Am J Orthod Dentofacial Orthop*, 126(4):397–409.
3. Aki T, Nanda RS. (1994). Assessment of symphysis morphology as a predictorof the direction of mandibular growth.*American Journal of Orthodontic and Dentofacial Orthopedics,*V106, Issue 1, 60–69.
4. AlHadlaq A. (2010). Anterior alveolar dimensions among different classifications of sagittal jaw relationship in Saudi subjects. *The Saudi Dental Journal* 22, 69–75.
5. Al-Nimri KS. (2003). Changes in mandibular incisor position in Class Ⅱ Division 1 malocclusion treated with premolar extractions. *Am J Orthod Dentofacial Orthop,* 124(6): 708–713.
6. Alves M, Silva G, Wolf U. (2008). Cone-beam computed tomography for routine orthodontic treatment planning: a radiation dose evaluation. *Am J Orthod Dentofacial Ortho*p, 133:640.e1-640.
7. Anwar, N. , Fida, M. (2009). Evaluation of dentoalveolar compensation in skeletal class II malocclusion in a Pakistani University Hospital setting. *Journal of the College of Physicians and Surgeons Pakistan*, 19(1), 11-6.
8. Apajalahti S, Peltola JS. (2007). Apical root resorption after orthodontic treatment-a retrospective study. *Eur J Orthod*, 29(4): 408–412.

9. Aronson L . (1970). Adenoids: their effect on mode of breathing and nasal airflow and their relationship to characteristics of the facial skeleton and dentition. *Acta Oto-laryngol Suppl*, 26: 5-132.

10. Aronson L . (1975). Effect of adenoidectomy on the dentition and facial skeleton over a period of five years. In: Cook JT ed. Transaction of the Third international Orthodontic Congress. The C.V Mosbey Co. st.louis.

11. Aronson L . (1979). Respiratory function in relation to facial morphology and the dentition. *Br J Orthod*, 6:59-71.

12. Asad S, Naeem S, Hamid W. (2009). Relationship between Lower Incisor Inclination, Lower Lip Prominance & Vertical Patteren Of The Patient. *Pakistan Oral & Dental Journal.* Vol 29, No. 1.

13. Barreto MB, Fonseca EM, da Cunha AJLA.(2006). A computerized system to conduct the Tweed-Merrifield analysis in orthodontics. *Braz Oral Res*, 20(2):167-71.

14. Baumgaertel S, Palomo JM, Palomo L, Hans M. (2009). Reliability and accuracy of cone-beam computed tomography dental measurements. *Am J Orthod Dentofacial Orthop,* 136:19-28.

15. Beckmann SH, Kuitert RB, Prahl-Andersen B. (1998). Alveolar and skeletal dimensions associated with lower face height. *Am J Orthod Dentofacial Orthop*, 113:498-506.

16. Bell WH, Creekmore TD, Alexander RG. (1977). Surgical correction of the long face syndrome. *Am J Orthod*, 71(1):40-67.

17. Berco M, Rigali PH Jr, Miner RM, DeLuca S, Anderson NK, Will LA. (2009). Accuracy and reliability of linear cephalometric measurements from cone-beam computed tomography scans of a dry human skull. *Am J Orthod Dentofacial Orthop,* 136:17 e11–e19; discussion 17–18.

18. Bernard G. Sarnat. (1963). Postnatal Growth of the Upper Face: Some Experimental Considerations. *The Angle Orthodontist, Vol.* 33, No. 3, pp. 139-161.

19. Biewener AA, Swartz SM, Bertram JE. (1986). Bone modeling during growth: dynamic strain equilibrium in the chick tibiotarsus. *Calcif Tissue Int*, 39:390-5.

20. Bishara SE. (2001). Text Book of Orthodontic -Section. Saunders Company.

21. Bjork A, Skieller V .(1972). Facial growth and development an implant study at the age of puberty. *Am J Orthod*, 48:61-74.

22. Bjork A, Skieller V .(1983). Normal and abnormal growth of the mandibule. A synthesis of longitudinal cephalometric implant studies over a periode of 25 years. *Eur J Orthod*, 5:1-46.

23. Bjork A. (1955). A facial growth in man, studied with the aid of metallic implant .*Act Odontol scand*, 13:9-34.

24. Bjork A. (1969). Prediction of mandibular growth rotation. *Am J Orthod*, 55:585-99.

25. Bloom RA. (1980). A comparative estimation of the combined cortical thickness of various bone sites. *Skeletal Radiol.* 5:167-70.

26. Bloomer HH. (1963). Speech defects in relation to orthodontist. *Am J Orthod,* 49:920-929.

27. Braun S, Hnat WP, Freudenthaler JW. (1996). A study of maximum bite force during growth and development. *Angle Orthod*, 16:261-4.

28. Brenner DJ, Doll R, Goodhead DT, Hall EJ, Land CE, Little JB. (2003). Cancer risks attributable to low doses of ionizing radiation: assessing what we really know. *Proc Natl Acad Sci U S A,* 100(24):13761-6.

29. Burger EH, Klein-Nulend J. (1999). Mechanotransduction in bone--role of the lacuno-canalicular network. *FASEB J, 13 Suppl*:S101-12.

30. C.H.Kau, S. Richmond, J.M Palomo, M.G.Hans. (2005). Current Products and Practice Three-dimensional cone beam computerized tomography in orthodontics. *Journal of Orthodontics, Vol* 32 282–293.

31. Cohnen M, Kemper J, Mobes O, Pawelzik J, Modder U. (2002). Radiation dose in dental radiology. *Eur Radiol*, 12(3):634–7.

32. Cowin SC, Moss-Salentijn L, Moss ML. (1991). Candidates for the mechanosensory system in bone. *J Biomech Eng*, 113:191-7.

33. Danforth RA, Dus I, Mah J. (2003). 3-D volume imaging for dentistry:a new dimension. *J Calif Dent Assoc,* 31:817–823.5.

34. Deguchi T, Nasu M, Murakami K, Yabuuchi T, Kamioka H, Takano-Yamaoto T. (2006). Quantitative evaluation of cortical bone thickness with computed tomographic scanning for orthodontic implants. *Am J Orthod Dentofacial Orthop,* 129:721.e7-12.

35. Demes B, Preuschoft H, Wolff J.E.A. (1984). Stress-strength relationships in the mandibles of hominoids. In Chivers D.J.,Wood B.A., and Bilsborough A. (eds.), Food Acquisition and Processing in Primates. *Plenum Press, New York, pp*. 369–390.

36. Dodd JS, Raleigh JA, Gross TS. (1999). Osteocyte hypoxia: a novel mechanotransduction pathway. *Am J Physiol,* 277 Pt 1:C598-602.

37. Donahue HJ, McLeod KJ, Rubin CT. (1995). Cell-to-cell communication in osteoblastic networks: cell line-dependent hormonal regulation of gap junction function. *J Bone Miner Res*, 10:881-9.

38. Donald H.Enlow. (1966). A morphogenetic analysis of facial growth. *American Journal of Orthdontics,*Volume 52. Issue 4. 283-299.

39. Durham L. (2007). Genetic predisposition of facial growth patterns: Concordance among siblings. *Am J Orthod Dentofacial Orthop*, 131:692.

40. Ekestubbe A, Thilander A, Grondahl K, Grondahl HG. (1993) .Absorbed doses from computed tomography for dental implant surgery: comparison with conventional tomography. *Dentomaxillofac Radiol*, 22:13–17.

41. Enlow DH, Hans MG. (1996). Overview of craniofacial growth and development: the three principal regions of facial and neurocranial development In: Enlow DH, Hans MG, editors. Essentials of facial growth. Philadelphia: W.B. Saunders Company Chap 1.

42. Esenlik E, Sabuncuoglu FA. (2012). Alveolar and symphysis regions of patients with skeletal class II division 1 anomalies with different vertical growth patterns.*Eur J Dent*, 6(2):123-32.

43. Farman AG, Scarfe WC. (2006). Development of imaging selection criteria and procedures should precede cephalometric assessment with cone-beam computed tomography. *Am J OrthodDentofacial Orthop*, 130:257–265.

44. Farnsworth D, Rossouw PE, Ceen FR, Buschang PH . (2011). Variation in cortical bone thickness at common mini-screw implant sites. *American journal of orthodontics and Dentofacial orthopedics,* volume 13. 9 issue 4. 495-503.

45. Ferrari SL, Traianedes K, Thorne M. (2000). A role for N-cadherin in the development of the differentiated osteoblastic phenotype. *J Bone Miner Res*, 15:198-208.

46. Fields HW. (1984). Facial pattern differences in long faced children and adults.*Am J Orthod*, 85:217-223.

47. Filho OG, Gleisieli C. Cardoso PB, Cardoso M, Filho LC. (2010). Study of the cephalometric features of Brazilian long face adolescents. *Dental Press J Orthod*, 35.e,15(4):35.e1-12.

48. Frank B. (1955). A rational for closer cooperation between orthodontist and speech and hearing therapist .*Arch OralBiol*, 41:571-582.

49. Frankle R, Frankle C. (1983). A functional approach to treatment of Skeletal open bite. *Am J Orthod*, 84:54-68..

50. Frankle R, Frankle C. (1989) .Orofacial orthopedics with the function regulator .Munich :S Karger.

51. Frost HM. (1987). the mechanostat: a proposed pathogenic mechanism of osteoporoses and the bone mass effects of mechanical and nonmechanical agents. *Bone and Miner*. 2:73-85.

52. Fudalej P, Vincent G, Kokich A, Leroux B. (2007). Determining the cessation of vertical growth of the craniofacial structures to facilitate placement of single-tooth implants. *Am J Orthod Dentofacial Orthop*, 131:00.

53. Fukase H. (2007). Functional significance of bone distribution in the human mandibular symphysis. *Anthropological Science* Vol 115, 55–62.

54. Garliner D. (1971). Myofunctional therapy in dental practice. Abnormal swallowing habits, Diagnosis and treatment. A course of study for the dental practitioner and speech pathologist. Brooklyn :Baretal Book Co.

55. Gibbs SJ. (2000). Effective dose equivalent and effective dose: comparison for common projections in oral and maxillofacial radiology. *Oral Surg Oral Med Oral Pathol Oral Radiol Endo*d, 90(4):538–45.

56. Gracco A, Luca L, Bongiorno MC, Siciliani G. (2010). Computed tomography evaluation of mandibular incisor bony support in untreated patients. *Am J Orthod Dentofacial Orthop,* 138:179-87.

57. Grauer D, Cevidanes LS, Proffit WR. (2009). Working with DICOM craniofacial images. *Am J Orthod Dentofacial Orthop*, 136:460–470.

58. Gray H. (2000). Gray's Anatomy of the Human Body 20th edition-New York: Bartleby.com.

59. Gribela BF, Gribel MN, Fraza˜o DC, McNamara Jr A, Manzie FR. (2011). Accuracy and reliability of craniometric measurements on lateral cephalometry and 3D measurements on CBCT scan. *Angle Orthod*, 81:28–37.

60. Guggino SE, Lajeunesse D, Wagner JA, Snyder SH. (1989). Bone remodeling signaled by a dihydropyridine- and phenylalkylamine-sensitive calcium channel. *Proc Natl Acad Sci U S A*, 86:2957-60.

61. Handelman CS. (1996). The anterior alveolus: its importance in limiting orthodontic treatment and its influence on the occurrence of iatrogenic sequelae. *Angle Orthod*, 66:95–109.

62. Hansen L , Klang T, Ekestubbe A, Helmrot E, Gröndahl K. (2008). Calculating effective dose on a cone beam computed tomography device: 3D Accuitomo and 3D Accuitomo FPD. *Dentomaxillofac Radio*, 137: 72-79.

63. Hansen L. (2010). Cone Beam Computed Tomography. Radiation Dose and Image Quality assessments. ISBN 978-91-628-8205-1 - ISSN 0348-6672 PhD thesis: Sahlgrenska Academy, University of Gothenburg.

64. Hanson ML. (1978). Oral myofunctional therapy. *Am J Orthod*, 73:59-67.

65. Hashimoto K, Yoshinori A, Kazui I. (2003). A comparison of a new limited cone beam computed tomography machine for dental use with a multidetector row helical CT machine. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod*, 95:371-7.

66. Hatcher DC, Dial C, Mayorga C. (2003). Cone beam CT for presurgical assessment of implant sites. *J Calif Dent Assoc*, 31:825–833.

67. Hernández-Sayago E, Espinar-Escalona E, Barrera-Mora JM, Ruiz-Navarro MB, Llamas-Carrera JM, Solano-Reina E. (2012). Lower incisor position in different malocclusions and facial patterns. *Med Oral Patol Oral Cir Bucal, doi*: 10.4317/*medoral.* 18434.

68. Hilgers ML, Scarfe WC, Scheetz JP, Farman AG. (2005). Accuracy of linear temporomandibular joint measurements with cone beam computed tomography and digital cephalometric radiography. *Am J Orthod Dentofacial Orthop*, 128:803-11.5.

69. Hirsch E, Wolf U, Heinicke F, Silva MA. (2008). Dosimetry of the cone beam computed tomography 3D compared with the 3D Accuitomo in different fields of view. *Dentomaxillofac Radiol*, 37: 268-273.

70. Horner KA , Behrents RG, Kim KB, Busch PH. (2012). Cortical bone and ridge thickness of hyperdivergent and hypodivergent adults. *American Journal of Orthdontics and Dentofacial Orthopedics,* Volume 124-Issue 2-170-178.

71. Huja SS, Litsky AS, Beck FM, Johnson KA, Larsen PE. (2005). Pull-out strength of mono cortical screws placed in the maxillae and mandibles of dogs. *Am J Orthod Dentofacial Orthop,* 27:307-313.

72. Hylander WL, Johnson KR, Crompton AW. (1987). Loading patterns and jaw movements during mastication in Macaca fascicularis: a bone-strain, electromyographic, and cineradiographic analysis. *Am J Phys Anthropol*, 72:287-314.

73. Hylander WL, Johnson KR, Crompton AW. (1992). Muscle force recruitment and biomechanical modeling: an analysis of masseter muscle functions during mastication in Macaca fascicularis. *Am J PhysAnthropol*, 88:365-87.

74. Inoue N. (1993). Collapse of dentition in Japan. In: Inoue N (ed.) Culture of food and oral health in Maori. Therapeia Publishing Co, Tokyo, pp. 67-77.

75. Isaacson JR,Speidel TM, Worms FW. (1971). Extreme variations in vertical facial growth and associated variations in skeletal and dental relations. *Angle Orthod,* 41:219-229.

76. Isaacson RJ, Zapfel RJ, Worms FW, Erdman AG. (1977). Effects of rotational jaw growth on the occlusion and profile. *Am J Orthod*, 72:276-286.

77. Iseri H, Solow B. (1996). Continued eruption of maxillary incisors and first molars in girls from 9 to 25 years, studied by the implant method. *Eur J Orthod*, 18:245-56.

78. Ito G. (1993). Basic and clinical consideration on the development of masticatory function and occlusion. *Journal of Tohoku Orthodontic Society*, 1:1-17.

79. Jacobson A. (1995). Radiographic Cephalometry from Basics to Videoimaging, Quintessence publishing Co.Inc - chap 5.

80. James L, Vaden E, Lloyd E, Pearson. (2002). Diagnosis of vertical dimension. *Semin Orthod*, 8:120-129.

81. Jones H H, Priest J D, Hayes W C, Tichenor C C, Nagel D A. (1977). Humeral hypertrophy in response to exercise. *Journal of Bone and Joint Surgery*, 59:179-182.

82. K Nojima, K Nakakawaji, T Sakamoto, Y Isshiki. (1998). Relationships between mandibular symphysis morphology and lower incisor inclination in skeletal class III malocclusion requiring orthognatic surgery.*Bull Tokyo Dent Coll*, 39 (3):175-81.

83. Kalender WA, Kyriakou Y. (2007). Flat-detector computed tomography (FD-CT). *Eur Radiol*, 17:2767-2779.

84. Katsumata A, Fujishita M, Maeda M, Ariji Y, Ariji E, Langlais RP. (2005). 3D-CT evaluation of facial asymmetry. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod*, 99:212–220.

85. Khan MA, Hussain SS. (2010). The Association between lower central incisal inclination and morphology of the supporting alveolar bone-A lateral cephalogram study. *Pakistan Orthodontic Journal*, vo : l2.no1-ISSN: 2074-0069.

86. Kiliaridis S, Kalebo P. (1991). Masseter muscle thickness by ultrasonography and its relation to facial morphology. *Journal of Dental Research*, 70:1262-1265.

87. Kiliaridis S, Bresin A. (2002). Dento-skeletal adaptation after bite-raising in growing rats with different masticatory muscle capacities. *Eur J Orthod*, 24 (3): 223-237. doi: 10.1093/ejo/24.3.223.

88. Kwong JC, Palomo JM, Landers MA, Figueroa A, Hans MG. (2008). Image quality produced by different cone-beam computed tomography settings. *Am J Orthod Dentofacial Orthop,* 133: 317-327.

89. Kydd WL. (1956). Quantitive analysis of forces of the tongue. *J Dental Res,* 35:171-74.

90. Lagravere MO, Carey J, Toogood RW, Major PW. (2008). Three dimensional accuracy of measurements made with software on cone-beam computed tomography images. *Am J Orthod Dentofacial Orthop*, 134:112–116.

91. Lecanda F, Towler DA, Ziambaras K. (1998). Gap junctional communication modulates gene expression in osteoblastic cells. *Mol Biol Cell*, 9:2249-58.

92. Ludlow JB, Davies-Ludlow LE, Brooks SL. (2003). Dosimetry of two extraoral direct digital imaging devices: NewTom cone beam CT and Orthophos Plus DS panoramic unit. *Dentomaxillofac Radiol*, 32:229–234.

93. Maki K, Miller A, Okano T, Shibasaki Y. (2000). Changes in cortical bone mineralization in the developing mandible: a three-dimensional quantitative computed tomography study. *J Bone Miner Res* 15:700-9.

94. Maki K, Miller AJ, Okano T, Shibasaki Y. (2001). A three-dimensional, quantitative computed tomographic study of changes in distribution of bone mineralization in the developing human mandible. *Arch Oral Biol,* 46:667-78.

95. Mangla R, Singh N, Dua V, Padmanabhan P,Man Khanna. (2011). Evaluation of mandibular morphology in different facial types. *Contemp Clin Dent*, 2(3): 200–206.

96. Marotti G. (1996). The structure of bone tissues and the cellular control of their deposition. *Ital J Anat Embryol*, 101:25-79.

97. Masumoto T, Hayashi I, Kawamura A, Tanaka K, Kasai K. (2001). Relationships among facial type, buccolingual molar inclination, and cortical bone thickness of the mandible. *Eur J Orthod*, 23:15-23.

98. Meneghini F. (2005). Clinical Facial Analysis Elements Principles Techniques-Springer -Berlin Heidelberg.

99. Miyawaki S, Koyama I, Inoue M, Mishima K, Sugahara T, Takano-Yamamoto T. (2003). Factors associated with the stability of titanium screws placed in the posterior region for orthodontic anchorage. *Am J Orthod Dentofac*, 124:373-8.

100. Moller E. (1966). the chewing apparatus. *Acta Physiol*, 69:571-574.

101. Moon C, Park H, Nam J, Im J, Baek S. (2010). Relationship between vertical skeletal pattern and success rate of orthodontic mini-implants. *Am J Orthod Dentofacial Orthop,* 138:51-7.

102. Motoyoshi M, Inaba M, Ono A, Ueno S, Shimizu N. (2009). The effect of cortical bone thickness on the stability of orthodontic mini-implants and on the stress distribution in surrounding bone. *Int J Oral Maxillofac Surg*, 38:13-8.

103. Motoyoshi M, Yoshida T, Ono A, Shimizu N. (2007). Effect of cortical bone thickness and implant placement torque on stability of orthodontic mini-implants. *Int J Oral Max Impl*, 22:779-84.

104. Mulie RM, Ten Hoeve A. (1976). The Limitation of tooth movement within the sympysis studied with Laminography and standardized occlusal films. *J Clin Orthod,* 10:882-93.

105. Nauert K, Berg R. (1999). Evaluation of Labio-Lingual Bony Support of Lower Incisors in Orthodontically Untreated Adults with the Help of Computed Tomography.*J Orofac Orthop*, 60:321-34.

106. Nauert K, Berg R. (1999). Evaluation of labio-lingual bony support of lower incisors in orthodontically untreated adults with the help of computer tomography. *J Orofac Orthop*, 60:321-34.

107. Ngan DC, Kharbanda OP, Geenty JP, Darendeliler MA. (2003). Comparison of radiation levels from computed tomography and conventional dental radiographs. *Aust Orthod J*, 19(2):67–75.

108. Nielsen L. (1991). Vertical malocclusions: etiology, development, diagnosis and some aspects of treatment. *The Angle Orthodontist*, Vol. 61 No .4.

109. Okano T, Sur J. (2010). Radiation dose and protection in dentistry. *Japanese Dental Science Review*, 46.112—121.

110. Ono A, Motoyoshi M, Shimizu N. (2008). Cortical bone thickness in the buccal posterior region for orthodontic mini-implants. *Int J Oral Maxillofac Surg*, 37:334-40.

111. Parker JH. (1971). The interception of the open bite in the early growth period.*Angle Orthod*, 41:24-44.

112. Pearson OM, Lieberman DE. (2004). The aging of Wolff's "law": ontogeny and responses to mechanical loading in cortical bone. *Am J Phys Anthropol*, 39:63-99.

113. Peterson J, Wang Q, Dechow PC. (2006). Material properties of the dentate maxilla. *Anat Rec A Discov Mol Cell Evol Biol*, 288:962-72.

114. Pinsky HM, Dyda S, Pinsky RW, Misch KA, Sarment DP. (2006). Accuracy of three-dimensional measurements using cone beam CT. *Dentomaxillofac Radiol,* 35:410–416.

115. Proffit WR, Mason RM. (1975). Myofunctioal therapy for tongue thrusting: Background and recommendations .*J Am Dent Assoc*, 90:403-411.

116. Proffit WR, Raymond P, White Jr, David M sarver. (2003). Long face problem- Chapter 15 - contemporary treatment of dentofacial deformity. Mosby, Inc.

117. Proffit WR. (2000). the development of vertical dentofacial problems: Concept from recent human studies .In: Mc-Namara JA, ed. The enigma of vertical

dimension. Ann Arbor: Monograph 36, Craniofacial Growth Series, Center for human Growth and development, The University of Michigan.

118. Quan Yu, Xiao-gang Pan, Guo-ping Ji, Gang Shen. (2009). The Association between Lower Incisal Inclination and Morphology of the Supporting Alveolar Bone — A Cone-Beam CT Study.*Int J Oral Sci*, 1(4): 217–223 – 217.

119. Richmond S, Klufas ML, Sywanyk M. (1998). Assessing incisor inclination: a non-invasive technique. *Eur J Orthod*, 20(6): 721–726.

120. Ricketts RM, Roth RH, Chaconas SJ, Schulhof RJ, Engel GA. (1982). Introduction to cephalometrics. In: Orthodontic diagnosis and planning Bioprogressive therapy—book 1. Denver: Rocky Mountain Orthodontics: 32-3.

121. Robinson S W,Speidel T M,Isaacson R J. (1972). Soft tissue profile change produced by reduction of mandibular prognathism.*Angle Orthodontist*, 42:227-235123.

122. Rubin CT, Gross TS, McLeod KJ, Bain SD. (1995). Morphologic stages in lamellar bone formation stimulated by a potent mechanical stimulus. *J Bone Miner Res*, 10:488-95.

123. Rubin CT, Lanyon LE. (1984). Regulation of bone formation by applied dynamic loads. *J Bone Joint Surg Am*, 66:397-402.

124. Ruff C, Holt B, Trinkaus E. (2006). Who's afraid of the big bad Wolff ? "Wolff's law" and bone functional adaptation. *Am J Phys Anthropol*, 129:484-98.

125. Saville P D, Whyte M P. (1969). Muscle and bone hypertrophy, Positive effect of running exercise in the rat. *Clinical Orthopedics and Related Research*, 65:81-88.

126. Scaf G, Lurie AG, Mosier KM, Kantor ML, Ramsby GR, Freedman ML. (1997). Dosimetry and cost of imaging osseointegrated implants with film-based and computed tomography. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod*, 83(1):41–8.

127. Schwartz-Dabney CL, Dechow PC. (2003). Variations in cortical material properties throughout the human dentate mandible. *Am J Phys Anthropol*, 120:252-77.

128. Solow B. (1980). The dentoalveolar compensatory mechanism: background and clinical implications. *Br J Orthod*, 7:145-61.

129. Sommerfeldt DW, Rubin CT. (2001). Biology of bone and how it orchestrates the form and function of the skeleton. *Eur Spine J*, 10 Supplement 2:S86-95.

130. Steiner C. (1953). Cephalometrics for you and me. *Am J Orthod*, 39:720-55.

131. Steiner GG, Pearson JK, Ainamo J. (1981). Changes of marginal periodontium as a result of labial tooth movement in monkeys .*J Periodontal*, 52:314-20.

132. Steiner CC. (1959). Cephalometrics in clinical practice. *Angle of Orthod*, 29:8–29.

133. Stockli PW, teuscher U. (1985). Combined activator head gear orthopedics.In Orthodontics, current principle and technique (ed.Graber TM,Swain BF). The C.V Mosby Co St .Louis.

134. Sukovic P. (2003). Cone beam computed tomography in craniofacial imaging. *Orthod Craniofac Res*, 6(Suppl 1):31–6.

135. Swasty D, Lee J, Huang J, Maki K, Gansky SA, Hatcher D, Miller A. (2011). Cross-sectional human mandibular morphology as assessed in vivo by CBCT in patients with different vertical facial dimensions. *Am J Orthod Dentofacial Orthop,* 139:e377-e389.

136. Tanner JM. (1962). Growth at adolescence. Oxford: Blackwell Scientific Publications.

137. Thomas J. Cangialosi. (1984). Skeletal morphologic features of anterior open bite. *Am.J.Orthod*. volume 85. Issue 1.28-36.

138. Tsiklakis K, Donta C, Gavala S, Karayianni K, Kamenopoulou V, Hourdakis CJ. (2005). Dose reduction in maxillofacial imaging using low dose Cone Beam CT. *Eur J Radiol*, 56: 413-417.

139. Tsunori M, Mashita M, Kasai K. (1998). Relationship between facial types and tooth and bone characteristics of the mandible obtained by CT scanning. *The Angle Orthodontist,* Vol. 68. No. 6, pp. 557-562.

140. Tsunori M, Mashita M, Kasai K. (1998). Relationship between facial types and tooth and bone characteristics of the mandible obtained by CT scanning. *Angle Orthod,* 68:557-62.

141. Tuncer BB, Atac MS, Yuksel S. (2009). A case report comparing 3- D evaluation in the diagnosis and treatment planning of hemimandibular hyperplasia with conventional radiography. *J Craniomaxillofac Surg*, 37:312–319.

142. Turner CH. (1998). Three rules for bone adaptation to mechanical stimuli. *Bone* 23:399–407.

143. Usui T, Uematsu S, Kanegae H, Morimoto T, Kurihara S. (2007). Change in maximum occlusal force in association with maxillofacial growth. *Orthod Craniofac Res,* 10:226-34.

144. Uysal T, Yagci A, Ozer T, Veli I, Ozturk A. (2012). Mandibular anterior bony support and incisor crowding: Is there a relationship? . *Amj Orthod Dentofacial Orthop,* 142(5):645-53.

145. W Bholsithi, W Tharanon, K Chintakanon, R Komolpis, C Sinthanayothin. (2009). 3D vs. 2D cephalometric analysis comparisons with repeated measurements from 20 Thai males and 20 Thai females. *Biomed Imaging Interv J,* 5(4): e21PMC3097714.

146. W.A. WEIJS, B. HILLEN. (1984). Relationships between masticatory muscle cross-section and skull shape. *J Dent Res*, 63(9):1154-1 157.

147. Wang YW, Tsai IM, Chen HL. (2009). Changes in the Morphology of Mandibular Symphysis Secondary to Pre-surgical Dental Decompensation in Class III Malocclusion. *J. Taiwan Assoc. Orthod*, 21(2): 17-23.

148. Weinmann J, Sicher H. (1955). Bone and Bones. 2nd ed. St. Louis, MO: The C.V. Mosby Company.

149. White SC. (1992). assessment of radiation risk from dental radiography. *Dentomaxillofac Radiol*, 21(3):118–26.

150. William C. Scarfe Allan G. Farman. (2008). what is Cone-Beam CT and How Does it Work. *Dent Clin N Am*, 52 707–730.

151. William C. Scarfe, Allan G. Farman, Predag Sukovic**.** (2006). Clinical application of cone-beam computed tomography in dental practice. *J Can Dent Assoc*, 72(1):75–80.

152. Worms F W,Isaacson R J,Speidel T M. (1976). Surgical orthodontic treatment planning profile analysis and mandibular surgery.*Angle Orthod*, 46:1-25.

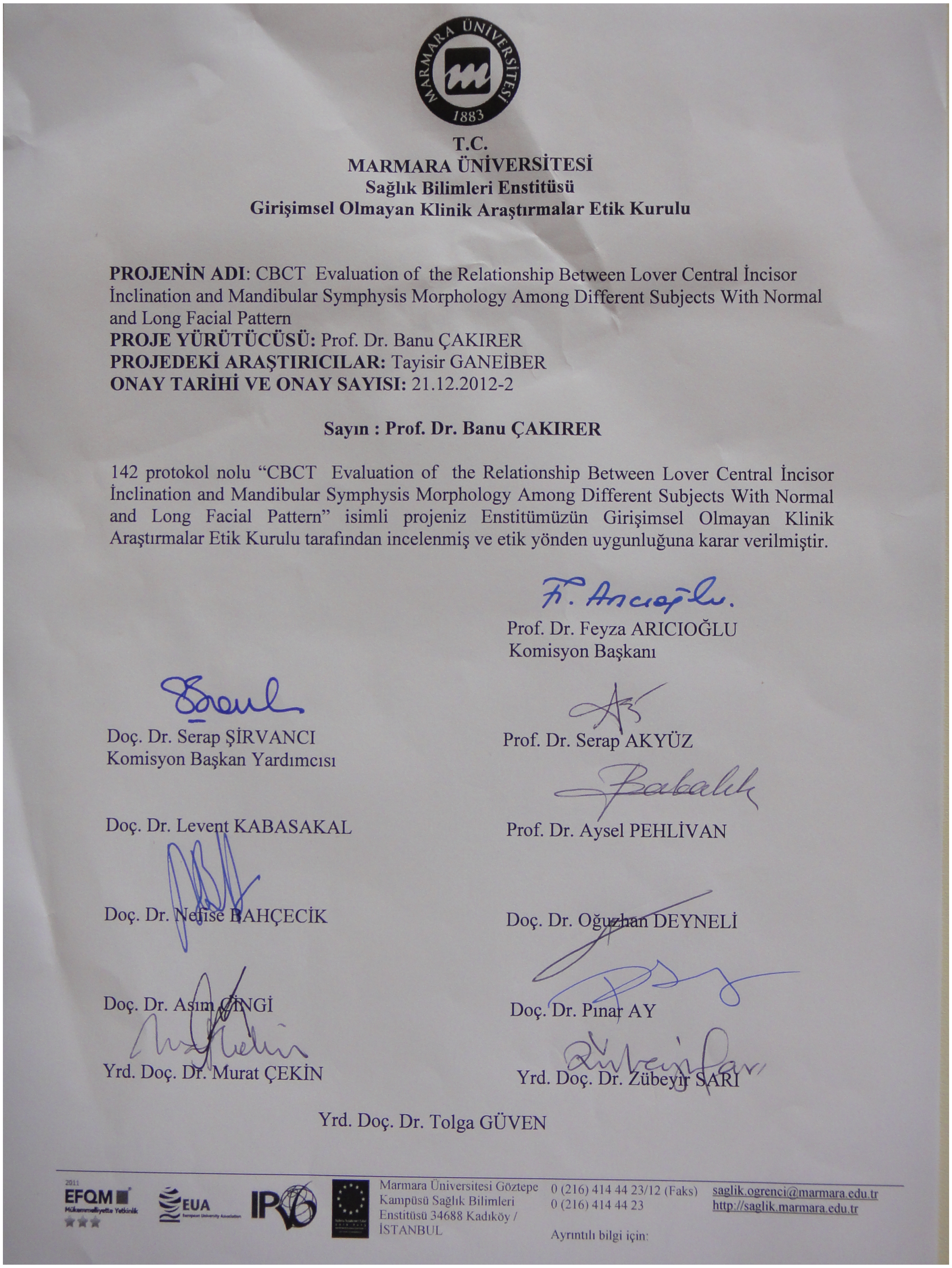
153. Yamada C, Kitai N, Kakimoto N, Murakami S, Furukawa S, Takada K. (2007). Spatial relationships between the mandibular central incisor and associated alveolar bone in adults with mandibular prognathism. *Angle Orthod,* 77(5): 766–772.

154. Yamada C, Kitai N. (2007). Spatial Relationships between the Mandibular Central Incisor and Associated Alveolar Bone in Adults with Mandibular Prognathism. *Angle Orthodontist*, Vol 77, No 5.

155. Yamada T, Tanne K, Miyamoto K, Yamauchi K. (1997). Influences of nasal respiratory obstruction on craniofacial growth in young Macaca-fuscata monkeys. *Am J Orthod Dentofacial Orthop*, 111:38-43.

156. Zaher AR, Bishara SE, Jacobsen JR. (1994). Post treatment changes in different facial types .*Angle Orthod*, 64:425–436.

157. Ziegler CM, Woertche R, Brief J, Hassfeld S. (2002). Clinical indications for digital volume tomography in oral and maxillofacial surgery. *Dentomaxillofac Radiol*, 31(2):126–30.



T.C.
MARMARA ÜNİVERSİTESİ
Sağlık Bilimleri Enstitüsü
Girişimsel Olmayan Klinik Araştırmalar Etik Kurulu

PROJENİN ADI: CBCT Evaluation of the Relationship Between Lover Central İncisor İnclination and Mandibular Symphysis Morphology Among Different Subjects With Normal and Long Facial Pattern
PROJE YÜRÜTÜCÜSÜ: Prof. Dr. Banu ÇAKIRER
PROJEDEKİ ARAŞTIRICILAR: Tayisir GANEİBER
ONAY TARİHİ VE ONAY SAYISI: 21.12.2012-2

Sayın : Prof. Dr. Banu ÇAKIRER

142 protokol nolu "CBCT Evaluation of the Relationship Between Lover Central İncisor İnclination and Mandibular Symphysis Morphology Among Different Subjects With Normal and Long Facial Pattern" isimli projeniz Enstitümüzün Girişimsel Olmayan Klinik Araştırmalar Etik Kurulu tarafından incelenmiş ve etik yönden uygunluğuna karar verilmiştir.

F. Arıcıoğlu.
Prof. Dr. Feyza ARICIOĞLU
Komisyon Başkanı

Doç. Dr. Serap ŞİRVANCI
Komisyon Başkan Yardımcısı

Prof. Dr. Serap AKYÜZ

Doç. Dr. Levent KABASAKAL

Prof. Dr. Aysel PEHLİVAN

Doç. Dr. Nefise BAHÇECİK

Doç. Dr. Oğuzhan DEYNELİ

Doç. Dr. Asım CİNGİ

Doç. Dr. Pınar AY

Yrd. Doç. Dr. Murat ÇEKİN

Yrd. Doç. Dr. Zübeyir SARI

Yrd. Doç. Dr. Tolga GÜVEN

Marmara Üniversitesi Göztepe
Kampüsü Sağlık Bilimleri
Enstitüsü 34688 Kadıköy /
İSTANBUL

0 (216) 414 44 23/12 (Faks)
0 (216) 414 44 23
Ayrıntılı bilgi için:

saglik.ogrenci@marmara.edu.tr
http://saglik.marmara.edu.tr

Biography

I was born in Benghazi, Libya in March 1978. I studied at the Dental School of Al Arab Medical University of Benghazi from September 1997, until December 2002. Since September of 2009, I have been enrolled in the MSc program at the Department of Orthodontics, Faculty of Dentistry, Marmara University, Turkey.

PERSONAL INFORMATION

Name	Tayisir	**Surname**	Ganeiber
Birth Place	Benghazi	**Birth Date**	28/03/1978
Citizen	LİBYAN	**Identity Card Number**	540509901
E-mail	TWG_1978@YAHOO.COM	**Phone**	05318602318

EDUCATION LEVEL

	The Institute Graduated From	**Graduation Year**
Doctorate		
Master		
Licence	The Dental School of Al arab Medical University of Benghazi	2002
High school	Saudi school in Ankara	1995

Work Experience

	MISSION	**INSTITUTE**	**DURATION (year - year)**
1.	DENTAL PRACTICE	Libyan Minister of Health	2004-2007
2.	DENTAL PRACTICE	PRIVATE	2003-2009

FOREIGN LANGUAGE	**COMPREHENSION ***	**SPEAKING ***	**WRITING***
ENGLISH	EXCELLENT	EXCELLENT	EXCELLENT
TURKISH	INTERMEDIATE	INTERMEDIATE	INVALID

* Evaluate as Excellent, Well, Intermediate, Invalid

FOREIGN LANGUAGE COMPETENCY								
KPDS	ÜDS	IELTS	TOEFL IBT	TOEFL PBT	TOEFL CBT	FCE	CAE	CPE
			99/120					

it is to be written all the successfull examinations

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

	Quantitative	**Equally Weighted**	**Verbal**
graduate record examination (GRE)	840		330
OTHER SCORE			

COMPUTER KNOWLEDGE

PROGRAM	**ABILITY TO USE**
MICROSOFT OFFICE	EXCELLENT

*Evaluate as Excellent, Well, Intermediate, Invalid

International and national editions/proclamations/ certificate /prizes/ other

ProQuest LLC
789 East Eisenhower Parkway
P.O. Box 1346
Ann Arbor, MI 48106 - 1346 USA