MOHAMMED BIN RASHID UNIVERSITY
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FACIAL SOFT TISSUE THICKNESS IN CAUCASIAN CHILDREN WITH DIFFERENT SKELETAL CLASSES AND SOFT TISSUE PROFILE: A RETROSPECTIVE STUDY

Mohd Noor Kebbe War
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ABSTRACT

Facial soft tissue thickness in Caucasian children with different skeletal Classes and soft tissue profile: a retrospective study

Mohd Noor Kebbe War

Supervisor: Associate Professor Ahmed Ghoneima

Background: Facial soft tissue influences orthodontic treatment, and is essential for facial reconstruction in forensics. Its position is determined by the underlying hard tissue. Facial soft tissue thickness of midline components is conventionally measured using a two-dimensional (2D) lateral cephalometric radiograph.

Aim: This retrospective three-dimensional (3D) cone beam computed tomography (CBCT) imaging study investigates and compares midline and bilateral facial soft tissue thickness (FSTT) in patients with different skeletal Classes and soft tissue profiles.

Materials and Methods: Following Institutional Review Board (IRB) approval, a convenient sample of CBCT images was obtained for 55 Caucasian subjects (28 males and 27 females) with the mean age of 11.1 years (SD: ± 1.99 years). Two cephalometric measurements and twenty-two facial soft tissue thickness (FSTT) parameters were selected and measured. The sample was divided into three skeletal Classes and soft tissue profile groups based on the ANB angle measurement: Class I (ANB ≤ 3.5° and ≥ 1.5°), Class II (ANB > 3.5°) and Class III (ANB < 1.5°). The intraclass correlation coefficient (ICC) was measured to assess the intraobserver reliability ≥ 0.9. ANOVA test was used to compare the means of the selected parameters and P-value ≤ 0.05 was considered significant in all statistical analyses.

Results: In Class I group, the correlation coefficient between ANB angle and FSTT parameters showed statistically significant differences for points: Glabella, Nasion, right mid-supraorbital, left mid-supraorbital, right posterior anterior ramus, left posterior anterior ramus, right Gonion, and left Gonion. The correlation coefficient between the soft tissue profile and all FSTT showed statistically significant differences for point B and Pogonion point.

In Class II group, the correlation coefficient between soft tissue profile and all FSTT parameters showed statistically significant differences for points: B, Pogonion, right zygomaticofrontal medial suture, and left zygomaticofrontal medial suture.

Conclusion: Differences of soft tissue depth between skeletal Classes and soft tissue profile were observed. Most of the statistically significant differences were found in skeletal Class I group, while skeletal Class II group showed less statistically significant differences.

DEDICATION

I am thankful to Almighty Allah for his generous blessings in life which empowered my will to accomplish my thesis. I would like to dedicate my thesis to my beloved family. I am deeply grateful to my mother for her wholehearted love and support that enabled me to pursue my ambitions. I am gratified to my father for his endorsement and guidance. To the most beautiful soul, my sister, whom I am thankful for always being there for me.

DECLARATION

I hereby declare that the dissertation entitled "*Facial soft tissue thickness in Caucasian children with different skeletal Classes and facial soft tissue profiles: a retrospective study*" submitted by me for the partial fulfillment of the Master of Science in Orthodontics at the Hamdan Bin Mohammed College of Dental Medicine (HBMCDM), Mohammed Bin Rashid University of Medicine and Health Sciences (MBRU) is my original work under the direct supervision of Associate Professor Ahmed Ghoneima, and that the thesis has not previously formed the basis for the award to me of any degree, diploma, fellowship, or any other title in this university or any other institution.

Name:

Signature:

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1 INTRODUCTION

The treatment planning of facial esthetics can be challenging to orthodontists. Angle (1907) believed that the form and beauty of the mouth as well as the harmony and balance of the face depend greatly on the dental relationship of teeth. Furthermore, he reported that the retention of a full complement of teeth was necessary if the desired harmony and balance of the face was to be achieved. However, the perception of beauty may also be influenced by factors such as culture or society and time (Angle, 1907; Burstone, 1967).

The form and dimension of the human face is influenced by multiple factors such as growth, congenital anomalies, genetics, ethnicity, gender, and environmental factors. (Gatliff, 1984; Sforza et al., 2013; Taylor, 2000). According to Nanda et al. (1990), clinicians should recognize treatment objectives and estimate the amount and direction of the remaining growth in order to reach a predictable change in facial esthetics (Nanda et al., 1990).

One of the principal goals of orthodontic treatment is to achieve optimally harmonious soft tissue profile and improved facial esthetics with maximal functional occlusion with respect to treatment limitations (Burstone, 1959). Nanda et al. (1990) stated that the main components that influence facial harmony and balance are the nose, lips and chin. It has been reported that changes in relationship of soft tissue to skeletal tissues and teeth during orthodontic treatment can affect the soft tissue morphology of the patients. On the other hand, soft tissue sets the limitation for orthodontic treatment of the dental arches and mandibular position. Also, post-treatment stability is dependent on the adaptability of soft-tissue to the teeth and skeletal tissue changes (Ackerman and Proffit, 1997). Soft tissue analysis has always been a fundamental part of diagnosis and treatment planning (Melsen and Athanasiou, 1987; Nanda et al., 1990).

2 LITERATURE REVIEW

2.1 Soft Tissue Profile

Soft tissue profile is influenced by three interacting factors that include the underlying skeletal base (maxilla and mandible), the supporting teeth, and the soft tissue mask (formed by the nose, lip tonicity and thickness, and chin) (Ackerman and Proffit, 1997).

Multiple soft tissue analyses introduced by Ricketts (1957), Steiner (1960), Burstone (1967) Sushner (1977), Holdaway (1984) were developed to help clinicians evaluate facial morphology quantitatively. Holdaway (1984) suggested that during orthodontic treatment planning, clinicians should consider changes in soft-tissue point of view to achieve ideal profile for the patient and evaluate the needed tooth movement to establish that goal. Welcker (1883) was the first to introduce soft tissue thickness tables for any application in the 19th century (Valentine and Davis, 2015).

The nose is one of the main components that influences soft tissue profile form and convexity. Its size, shape, position and symmetry influence facial expressions (Pochedly et al., 2012) and attractiveness (Roxbury et al., 2012). It is the only component that cannot be directly influenced by orthodontic treatment, although it may be affected indirectly by altering the position of the lips and/or chin. Thus, an ideal facial morphology is strictly dependent on harmony of the nose with the other features of the face (Allam et al., 2018; Czarnecki et al., 1993; Schendel and Carlotti, 1991).

Another main component of the soft tissue profile are the lips, which is the only component directly supported by teeth. Depending on the position they are in, closed or relaxed, lips require thorough diagnosis and analysis by clinical examination and cephalometric analysis before initiating orthodontic treatment (Burstone, 1967). Lips posture may favor or affect the position of anterior teeth (Burstone, 1967). Depending on the malocclusion present and orthodontic treatment done, lips can retain teeth in a favorable or unfavorable position as they form one of the boundaries that maintain teeth in their neutral zone (Burstone, 1967). In soft tissue profile analysis, clinicians are interested in analyzing the relaxed lips position, and the harmonious relationship between them and to the nose and chin, in order to achieve a balanced facial profile. For instance, greater lips protrusion was reported as being acceptable for individuals with larger nose or chin (Nanda et al., 1990). In contemporary society, greater lip thickness and fullness is recognized as a primary component of facial attractiveness (Auger and Turley, 1999). In spite of ethnic differences, retruded lips position has overall been perceived as a sign of unattractiveness and aging (Byrne and Hilger, 2004; Fanous, 1984).

2.2 Aging

Aging is a natural consequence of genetically determined continuous remodeling of the underlying hard tissue, and shrinkage of soft tissues over time (Mokos et al., 2018). This remodeling process is complex and it is reflected by structural, functional, and esthetic changes (Mokos et al., 2018). The residual growth of the nose and chin leads to a progressively flatter facial profile with age (Anderson et al., 1973; Rudee, 1964). Skin elasticity, distribution of subcutaneous adipose tissue and facial muscles are the factors responsible for aging changes of the soft tissue (Ramos-e-Silva et al., 2013; Sadick et al., 2009). Therefore, progression of aging leads to a continuous alteration of facial proportions affecting facial soft tissue thickness and profile (Farkas and Posnick, 1992; Farkas et al., 2004; Nanda et al., 1990).

With age, the upper lip undergoes morphological changes such as reducing its projection and volume, but increasing its height (Lambros and Amos, 2016; Penna et al., 2009; Penna et al., 2017; Raschke et al., 2014; Rohrich and Pessa, 2009; Sadick et al., 2009). These changes occur due to multiple factors, including the quantity and quality of underlying bone and perioral tissues (Bartlett et al., 1992; Shaw and Kahn, 2007; Zadoo and Pessa, 2000).

Morphological aging changes of the nose include drooping of nasal tip, reduction of nasal tip projection, and increase in bulbosity (Helal et al., 2018; Rohrich et al., 2004). These changes are attributed by the supporting skeletal, cartilaginous, and soft tissue structures (Helal et al., 2018; Rohrich et al., 2004).

Chin protrusion tends to increase with age due to the decrease of skin elasticity, the thinning of subcutaneous adipose tissue, and the resorption in the mandible at the prejowl (Sadick et al., 2009). In addition, dental attrition that occurs throughout life tends to decrease the lower facial vertical dimension and autorotate of the mandible forward inducing relative increase of chin prominence in relationship to the facial profile.

2.3 Gender

Facial soft tissue thickness differs between genders. Numerous studies showed that males have thicker tissues compared to females (Abeltins and Jakobsone, 2011; Simpson and Henneberg, 2002; Hamdan, 2010; Basciftci et al., 2003; Celikoglu et al., 2015; Cha, 2013; Jazmati et al., 2016; Perovic and Blazej, 2018; Pithon et al., 2014; Anam et al., 2018) .

2.4 Orthodontic Tooth Movement

Orthodontic tooth movement can influence the soft tissue profile. For instance, the retraction of upper incisors alters upper lip position (Alkadhi et al., 2019; Ramos et al., 2005; Yasutomi et al., 2006;). The relationship of upper incisors retraction and corresponding upper lip retraction depends on treatment modality, age, gender, and ethnicity (Hershey, 1972; Rains and Nanda, 1982; Talass et al., 1987; Wisth, 1974).

Posterior teeth movement affects the occlusion as well as the sagittal and vertical position of the mandible, thus affecting the soft tissue profile. The extrusion, distalization or expansion of posterior teeth induces downward and backward rotation of the mandible. On the contrary, mesialization or intrusion of posterior teeth induces upward and forward rotation of the mandible.

2.5 Facial Symmetry

Facial esthetics has always been a subject of paramount importance in several fields of research and particularly in orthodontics. Facial esthetic disharmony can lead to social and psychological disorders having a direct and great effect on a person's confidence and quality of life (Siqueira de Lima et al., 2019). Ideal facial esthetics can be attained only by mirroring various structures of the craniofacial complex on both sides of the face, thus achieving symmetry. However, such a symmetry does not seem to exist. Generally, facial asymmetry may be expressed in soft tissues, hard tissues, or both (Kim et al., 2013).

In fact, Nur et al. (2016) reported that faces classified as symmetric have showed mild asymmetries that are compensated for by hard tissue surface modifications or soft tissue adaptations. Another study by Masuoka et al. (2007) reported that symmetric faces might reveal skeletal asymmetries that are enhanced by or concealed by the soft tissue. According to a previous study conducted about mandibular asymmetries, it was observed that soft tissue thickness appears to be less on the deviated side compared to the contralateral side (Lee et al., 2013). Thus, the thickness of soft tissues can relatively camouflage skeletal asymmetry (Lee et al., 2013).

2.6 Craniofacial Anomalies

2.6.1 Cleft Lip and Palate

In cleft lip and palate (CLP) embryological and genetic differences affect the craniofacial complex growth and development. The functional and esthetic surgical grafts and/or corrections can result in scarring, muscle pull, and changes to nasal form and function, that have an impact on the thickness of the facial soft tissue (Starbuck et al., 2014).

Soft tissue in CLP is asymmetric and thicker on the congenital cleft side of the face (Starbuck et al., 2014). It was found that the congenital cleft disrupts the ordinary position and formation of the muscle by changing the insertion and length of nasolabial muscles (Bell et al,. 2014; Starbuck et al., 2014). Furthermore, it disrupts the development of the lateral incisor on the cleft side of the face and reforms asymmetry of the underlying skeletal base where the soft tissue is attached to (Starbuck et al., 2014).

2.6.2 Treacher Collins Syndrome

Treacher Collins syndrome (TCS) is a congenital craniofacial disorder characterized by malar and mandibulomaxillary hypoplasia and periorbital anomalies (Aljerian and Gilardino, 2019). The treatment of patients affected with TCS treatment constitutes of craniofacial surgery followed by plastic surgery to achieve proper soft tissue reconstruction, and to improve function and esthetics which are essential for normal facial tissues growth. Extra-oral soft tissue features of TCS are mainly concentrated in periorbital region which appear to be hypoplastic (Aljerian and Gilardino, 2019). Other extra oral soft tissue features include decreased midfacial width, loss of normal protrusion of the cheeks, colobomata of the lower eyelids and iris, ectropion, and absence of eyelashes in the medial aspect of the lid (Aljerian and Gilardino, 2019).

2.6.3 Craniofacial Microsomia

Craniofacial microsomia (CFM) has been the preferred term used to describe the craniofacial disorder which is characterized by underdevelopment of facial structures arising from the first and second embryonic pharyngeal arches (Converse et al., 1973; Rollnick and Kaye, 1983; Stark and Saunders, 1962; Bennun et al., 1985). Other terms for CFM are often used, including: first and second branchial arch syndrome, otomandibular dysostosis, oculoauriculovertebral syndrome and hemifacial macrosomia (Cohen et al., 1989). In CFM, hypoplasia of facial structures occurs due to the disruption of mesenchymal cells communication which is essential to support the development of the skeletal, muscular, and neural (Fariña et al., 2015; Johnston and Bronsky, 1991; Johnston and Bronsky, 1995; Ohtani et al., 2012). This disruption might be caused by vascular injury, teratogen exposure, or genetic causes (Birgfeld and Heike, 2019). The resulting soft tissue and skeletal anomalies can affect feeding, compromise the airway, alter facial movement, disrupt hearing, and alter facial appearance (Birgfeld and Heike, 2019)

The soft tissue deficits can be classified into four main categories: auricular, ocular, preauricular, and temporal (Parameswaran and Ramanathan, 2018). The auricular problems include anotia, microtia, and dysmorphic ears (Parameswaran and Ramanathan, 2018). The preauricular abnormalities include preauricular skin tags, blind sinus tracts in the cheek and in many few individuals, macrostomia or lateral facial clefts (Parameswaran and Ramanathan, 2018). Ocular anomalies range from anophthalmia or microphthalmia to coloboma of the eyelids, absence of the lateral canthi, and epibulbar dermoid cysts (Parameswaran and Ramanathan, 2018). Temporal hollowing due to hypoplastic temporalis may also be evident in the affected (Parameswaran and Ramanathan, 2018).

2.7 Orthognathic Surgery

The aim of orthognathic surgery is to achieve stable functional and esthetic results. To attain such results, it is important to understand the relationship between the movements of the underlying skeletal bases beneath the facial soft tissue envelope. Since the soft tissue form and position will determine the esthetic outcome of surgical treatment. Unfortunately, prediction of soft tissue response is difficult due complex factors. These factors include the variation in the thickness of the facial soft tissues between individuals, variation in muscular tone between individuals, anatomical variations in the position and size of muscular attachments, and the extent of the skeletal movement (Gill et al., 2017). In general, individuals with thicker soft tissues are able to conceal more hard tissues movements (Abeltins and Jakobsone, 2011; Hu et al., 1999). Therefore, considering the soft tissue thickness can help predict the outcomes more precisely (Park et al., 2013).

Another paramount factor is the timing of surgery. Especially at young age, where it is dependent on its effect on function, appearance and alteration of body image (Maisels, 1967). To attain the desired outcome, clinicians take into consideration the remnant growth periods or maturation and their impact on the desired results (Farkas et al., 1992). Orthognathic surgery has various effects on nose, lips and chin in all three planes of space depending on the type of modality (Altman and Oeltjen, 2007; Schendel and Carlotti, 1991; Park et al., 2013; Soncul and Bamber, 2004).

Accessory nasal procedures during orthognathic surgery range from concomitant soft-tissue reconstruction to complete rhinoplasty. The surgery may be beneficial or detrimental, depending on the preexisting nasal anatomy (Schendel and Carlotti, 1991). The treatment is decided by functional and esthetic clinical examination, proper diagnosis and comprehensive treatment plan (Schendel and Carlotti, 1991). Evaluation of the pre-existing nasal structure and how it diverges from the ideal and how the ideal may be achieved is necessary. Nevertheless, the nose should be evaluated as part of the overall facial balance, symmetry and proportion. This is considered more important than evaluating the individual nasal components only and planning the treatment based solely on them (Schendel and Carlotti, 1991).

In Le Fort I osteotomy, which is commonly performed to correct maxillary congenital or acquired deficiency or retroposition. Anterior repositioning or advancement of the maxilla affects nasal morphology. In maxillary advancement, elevation of the nasal tip, reduction in the nasal length and nasofrontal angle, and increase in nasal tip protrusion are expected (Abeltins and Jakobsone, 2011; Mommaerts et al., 2000; Rosen, 1988; Vasudavan et al., 2012). In addition, there will be an increase of the supratip depression leading to lowering the columella (Gill et al., 2017) and shortening of its length (Rauso et al., 2011). If inferior maxillary repositioning is planned, dropping of the nasal tip, alar base, and columella are expected (Rauso et al., 2011).

The anatomic and morphologic nature of the upper lip along with its elasticity and proximity to the alveolar bone allow the upper lip to dictate the soft tissue spatial position in relation to the underlying skeletal tissue (Soncul and Bamber, 2004). In maxillary advancement, an increase of lip length is observed, most likely from the unrolling of the upper lip (Abeltins and Jakobsone, 2011; Chew, 2005; Rosenberg et al., 2002; Vasudavan et al., 2012), and decrease in its thickness according to several studies (Abeltins and Jakobsone, 2011; Bailey et al., 2007; Mobarak et al., 2001; Rosen, 1988). A similar finding of decreased thickness of upper lip is evident in maxillary inferior repositioning surgery (Gill et al., 2017). In addition, nasolabial angle may increase if subnasale advances more than labrale superius, and shortening of upper lip is expected due to periosteal dissection (Gill et al., 2017). In cases of maxillary expansion or setback, retraction of upper lip might occur (Gill et al., 2017).

Chin position can be altered either as a result of bilateral sagittal split osteotomy (BSSO) or by performing genioplasty, with the latter not affecting dental occlusion. The main indications for BSSO are the correction of retrognathism, prognathism, and asymmetry of the mandible. When BSSO is performed to achieve mandibular advancement, clinicians can expect a downward and forward repositioning of the chin, consequent reduction of facial convexity, increase of lower anterior facial height, and a reduction of the lower lip-chin-submental plane angle (Gill et al., 2017). An alternative approach to alter chin position and improve facial profile without affecting the occlusion is genioplasty (Gill et al., 2017). It can be executed separately or in junction with orthognathic surgery. Resultantly, effects include increase of the submental length, a reduction of submental soft tissue sag, a decrease in the lower lip-chin-submental plane angle, deepening of the labiomental fold, and reduction in relative nasal prominence (Gill et al., 2017).

In addition, chin position can be altered as a result mandibular autorotation in relationship to the spatial repositioning of the maxilla (Gill et al., 2017). In cases of maxillary superior repositioning, the mandible autorotates anticlockwise resulting in increased prominence of the chin, and reduction of anterior lower facial height and soft tissue profile convexity (Gill et al., 2017). Alternatively, inferior maxillary repositioning causes clockwise autorotation of the mandible resulting in decreased prominence of the chin, and increased anterior lower facial height and soft tissue profile convexity (Gill et al., 2017).

2.8 Methods to Measure Soft Tissue Thickness

Various methods were developed to measure soft tissue thickness, such as the use of puncture (Domaracki and Stephan, 2006; Shimofusa et al., 2009; George, 1987), lateral cephalometric radiography (Burstone, 1959; Holdaway, 1983; Nanda et al., 1990; Kurkcuoglu et al., 2011; Lopatiene et al., 2016b; Perovic and Blazej, 2018; Utsuno et al., 2010; Pithon et al., 2014; Kamak and Celikoglu, 2012; Utsuno et al., 2014), magnetic resonance imaging (Chen et al., 2011; Vander Pluym et al., 2007; Sahni et al., 2008; Sandamini et al., 2018; Kaur et al., 2017), ultrasonography (De Greef et al., 2005; Severt and Proffit, 1997; Jia et al., 2016), multislice computed tomography (Kim et al., 2005; Phillips and Smuts, 1996) and cone-beam computed tomography (Fourie et al., 2010; Gomez et al., 2017; Hwang et al., 2015; Jazmati et al., 2016; Lee et al., 2013; Hwang et al., 2012b; Hwang et al., 2012a; Masoume et al., 2015; Nur et al., 2016; Kau et al., 2005; Scarfe et al., 2017, Siqueira et al., 2019).

2.8.1 Puncture

Needle puncture technique is the oldest method used for measuring soft tissue thickness. Needles were inserted into cadaver faces at various anthropological and anatomical landmarks, and then the depth of penetration was measured (Domaracki and Stephan, 2006).

According to previous studies, use of puncture was not deemed accurate because it was difficult to measure directly perpendicular to the skin due to the irregular surface of the underlying bone (Kim et al., 2005; Fourie et al., 2010). In addition, postmortem tissue changes (dryness, shrinkage and hardness) of the cadavers did not permit any manipulation of the skin that interfered with the caliper placement during measuring (Kim et al., 2005).

2.8.2 Lateral Cephalometric Radiographs

In Orthodontics, lateral cephalometric radiographs are of great use for diagnosis, treatment planning and monitoring treatment progress. Through comprehensive cephalometric analysis great information can be obtained, such as the assessment of skeletal discrepancies between both jaws, inclination of incisors, aid in localization of unerupted or misplaced teeth (Isaacson et al., 2015), evaluating skeletal maturation using cervical vertebral maturation method (McNamara and Franchi, 2018).

Lateral cephalometric soft tissue analysis is composed of ratios, linear and angular measurements in relationship to landmarks in the skeletal base, dentition and soft tissue itself. Thus, the determination of soft tissue profile type, position and thickness is attained. Initially, various cephalometric soft tissue analysis studies were conducted on Caucasians samples of European-American ancestry which resulted in the development of norms (Joshi et al., 2015). Many studies have concluded that individuals of different ethnicity have significant differences in the cephalometric soft tissue profile thickness norms (Ayoub et al., 2019; Hamid and Abuaffan, 2016; Jeelani et al., 2015; Wang et al., 2016).

Evaluation of different soft tissue structures of the facial profile such as nose, lips, and chin along with the facial proportions using a three-dimensional (3D) image in vertical, transverse and sagittal planes is an essential part for obtaining a successful orthodontic treatment, diagnosis and planning. However, lateral cephalometric analysis has many drawbacks, such as magnification, superimposition, distortion, and it is a only two-dimensional (2D) image of a

3D structure. Other limitations involve low resolution, artifacts and errors as a result of X-ray projection and faulty patient positioning, and cephalometric measurement errors related to difficulties in landmarks identification (Scarfe et al., 2017). Also, examination of soft tissue in detail and asymmetrical assessment cannot be made due to overlap with skeletal structures (Scarfe et al., 2017). Despite that, lateral cephalometric radiographs have less radiation exposure compared to multi-slice and cone-beam computed tomography which is the only advantage, with an effective dose of ≤ 6 μSv (Horner and Panel, SEDENTEXCTGD, 2012).

2.8.3 Magnetic Resonance Imaging

Magnetic resonance imaging (MRI) is a non-invasive imaging technique without any exposure to ionizing radiation, while providing reliable and thorough information on soft tissues in craniofacial imaging and temporomandibular joint (Hall, 1994). According to a recent study, MRI offers equivalently comparable measurements to CBCT (Detterbeck et al., 2017) and displays good contrast ratio making it of great usage in orthodontics (Erten and Yılmaz, 2018). However, MRI presents limitations due cost and dentists lack of experience in using it (Mah and Hatcher, 2003).

2.8.4 Ultrasonography

Ultrasonography is a noninvasive technique with the advantages of low cost, accessibility and ability to measure soft tissue in an upright position. It has been utilized to measure soft tissue thickness in several studies involving craniofacial reconstruction (De Greef et al., 2006; El-Mehallawi and Soliman, 2001; Manhein et al., 2000; Wilkinson, 2002). Nevertheless, this effective tool has several limitations. Ultrasonography is technique sensitive when measuring soft tissue thickness. For accurate recording, the transducer must be oriented perpendicular to the bone to record the deepest thickness, and care must be taken not to compress or indent the soft tissue during the procedure (Hwang et al., 2015). Therefore, investigators are required to record multiple readings and choose the highest peak corresponding to the deepest thickness

(Hwang et al., 2015). Also, there is an inability of adding measurements at a later date (Hwang et al., 2015).

2.8.5 Multislice Computed Tomography

Multislice computed tomography (MSCT) allows clinicians to navigate through the patient's anatomy to identify and precisely localize any pathology, abnormalities and lesions (Mischkowski et al., 2007). Nowadays, some clinicians consider MSCT the standard diagnostic and treatment planning tool for maxillofacial surgery as it provides numerous information about different tissues and their relation to one another in 3D imaging and in high resolution. Additionally, it can be utilized to explore airway volume, temporomandibular joint anatomical variations, and craniofacial syndromes (Erten and Yılmaz, 2018). Unfortunately, those advantages come with the expense of high radiation dose which makes it impractical to be used routinely in orthodontics (Erten and Yılmaz, 2018). MSCT effective dose = 280-1410 μSv (Horner and Panel, SEDENTEXCTGD, 2012). Moreover, measuring soft tissue thickness using MSCT will not present correct thickness due to the supine position of the patient resulting in deforming of soft tissue due to gravity (Manhein et al., 2000, Lee et al., 2012).

2.8.6 Cone-beam Computed Tomography

Cone-beam computed tomography (CBCT) has become a progressively significant source of 3D volumetric data in dentistry and especially in clinical orthodontics. The increasing availability and utilization of 3D CBCT technology allows clinicians and researchers a significant amount of data at their disposal for analysis. One scan provides the ability to generate images from limitless perspectives, and clinicians are no longer limited to a single 2D perspective. Treatment planning for orthodontic patients can be expanded to plan improvements to the whole facial complex from a 3D background. Various orthodontic applications of CBCT were identified and reviewed, including cleft palate assessment, tooth position and localization, resorption related to impacted teeth, measuring bone dimensions for mini-implant placement, assessment of rapid maxillary expansion, 3D cephalometry, surface imaging integration, airway assessment, age assessment, investigation of orthodontic-associated paresthesia and assessment of skeletal components of temporomandibular joint (Horner and Panel, SEDENTEXCTGD, 2012). In addition, previous study confirmed that CBCT soft tissue measurements can be used to establish a database for soft tissue thickness (Fourie et al., 2010).

The interpretation of the information obtained from CBCT requires notable level of expertise. Otherwise, misinterpretation leading to false-positive or even missed diagnosis if done by untrained clinicians (Kapila et al., 2011). Radiation doses of CBCT are generally higher than conventional dental radiography, but lower than MSCT imaging of the dental area. Radiation dose is determined by exposure parameters, especially the field of view selected, and equipment type. CBCT effective dose for dento-alveolar (small and medium field of View <10 cm) imaging = 11-675 μSv, and effective dose for craniofacial (large field of view >10 cm) imaging = 30-1073 μSv (Horner and Panel, SEDENTEXCTGD, 2012). CBCT scanners are capable of obtaining images in an upright position avoiding any soft tissue distortion due to gravity and body posture unlike MSCT and MRI. Furthermore, CBCT images can be used for facial soft tissue thickness measurements for the purpose of craniofacial reconstruction (Hwang et al., 2012b). CBCT images allow measurements to be repeated, and added in accordance to research requirements (Lee et al., 2012). Cost-wise, CBCT scanners have lower cost compared to MSCT (Poeschl et al., 2013).

2.9 Forensics

Besides treatment planning in orthodontics, soft tissue thickness is imperative for facial reconstruction. Facial reconstruction is a technique of rebuilding facial soft tissues of an unidentified skull based of specific skeletal landmarks (Hwang et al., 2015), and it is considered as one of the secondary methods of identification of a deceased (Pithon et al., 2014).

For accurate and reliable facial reconstruction, several essential parameters have to be taken into consideration as they greatly affect FSTT. These parameters include age, gender, body mass index (De Greef et al., 2009; Dong et al., 2012; Gibelli et al., 2016; Shrimpton et al., 2014; Wang et al., 2016), and skeletal pattern (Ferrario and Sforza, 1997). As CBCT provides plenty of information for both soft and skeletal tissues with high reproducibility, and it is one of the ideal methods to be used for this purpose in forensics (Hwang et al., 2012a).

3 AIM

The aim of this study was to evaluate and compare the soft tissue thickness in patients with different skeletal Classes and soft tissue profiles.

4 HYPOTHESIS

Hypothesis: there are significant differences in the facial soft tissue thickness among subjects with different skeletal Classes and soft tissue profiles.

Null hypothesis: there are no significant differences in facial the soft tissue thickness among subjects with different skeletal Classes and soft tissue profiles.

5 MATERIALS AND METHODS

A convenience sample of CBCT images was obtained for this study from pre-existing orthodontic records at a private orthodontic office in Indiana, USA. The subject pool consisted of images collected from records of 55 Caucasian subjects (28 males and 27 females), with the mean age of 11.1 years (SD: ±1.99 years). The study was approved by the Institutional Review Board of the university. The patients were selected according to the following inclusion criteria: no cleft lip and palate or any craniofacial anomalies, no facial asymmetry, no maxillofacial trauma, no previous orthodontic or prosthodontic treatment, and no surgical treatment.

All CBCTs were taken with the same scanner, i-CAT (Imaging Sciences, Hatfield, PA, USA). All CBCT scans were taken with full 13 cm field of view, 20 seconds scanning time, and a resolution of 0.4 mm voxel size. The CBCT data were exported in Digital Imaging and Communications in Medicine (DICOM) format, and Dolphin Imaging software, version 11.7 (Dolphin Imaging and Management Solutions, Chatsworth, CA, USA) was used for collecting the selected parameters. Threshold level of the constructed 3D imaging was set and standardized for each structure using the software rendering segmentation feature of bone and soft tissue structures. Soft tissue segmentation was performed by adjusting the range of the lower and upper density boundaries between the patient's air and soft tissue with grey scale range of 500 to 520, while hard tissue segmentation was performed by adjusting the lower and upper density boundaries between the patient's soft tissue and hard tissue with grey scale range of 500 to 1100.

The coded CBCT images were analyzed using 3D Dolphin Imaging software by the author of this thesis on the same computer and monitor. All CBCT images were oriented for standardization purposes according to the following: the coronal plane was oriented by passing a line through crista galli and anterior nasal spine (Figure 1), the sagittal plane was oriented by

Frankfort Horizontal plane (Figure 2), and the axial plane was oriented by a line passing through anterior nasal spine and posterior nasal spine (Figure 3).

A lateral cephalometric radiograph was extrapolated from the CBCT scans and digitally traced using Dolphin Imaging software. Two cephalometric measurements were recorded on each image (Figure 4) (Table 1). The sample was divided into three skeletal Classes and soft tissue profile groups based on the ANB angle measurement: Class I (ANB $\leq 3.5°$ and $\geq 1.5°$), Class II (ANB $>3.5°$) and Class III (ANB $< 1.5°$).

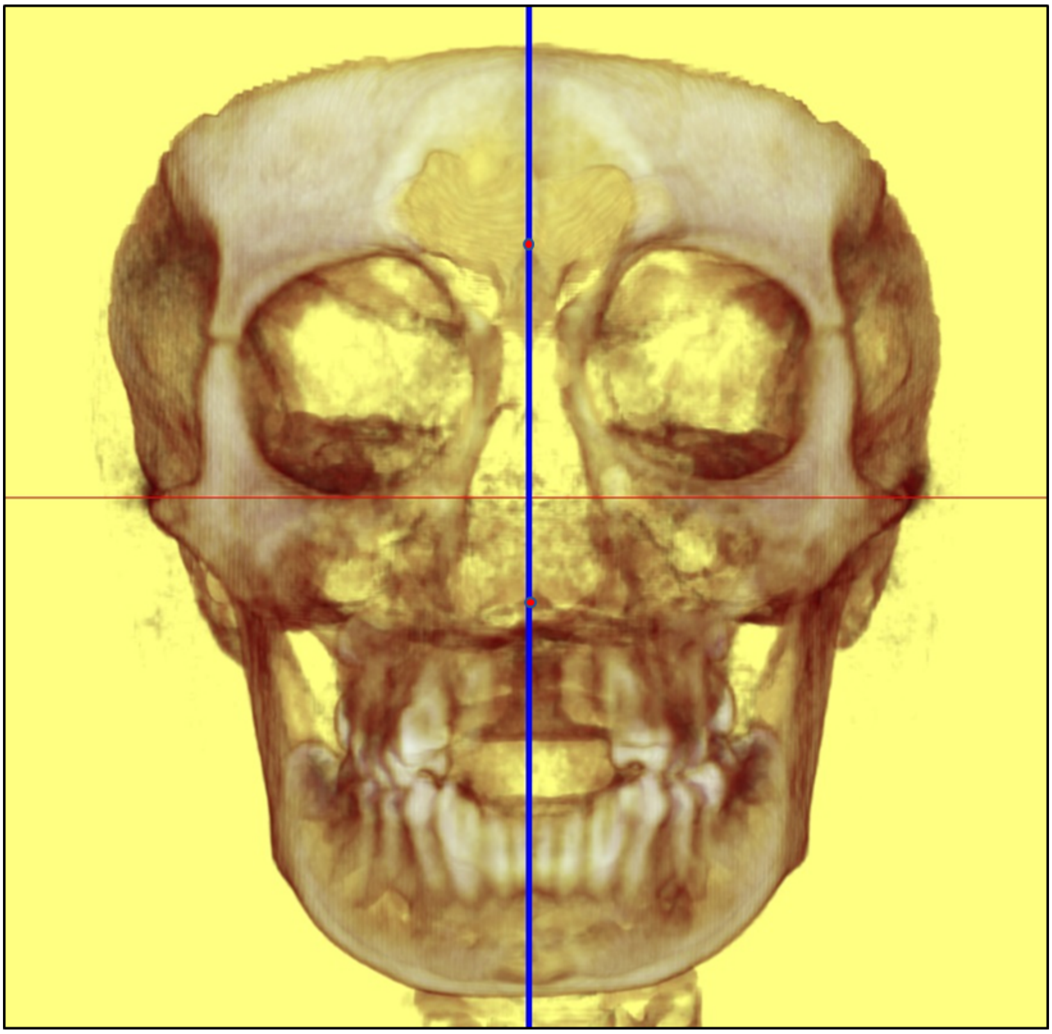

Figure 1. Orientation of coronal plane and midline using line passing through crista galli, the most superior point of the perpendicular plate of the ethmoid bone (viewed in coronal clipping), and anterior nasal spine.

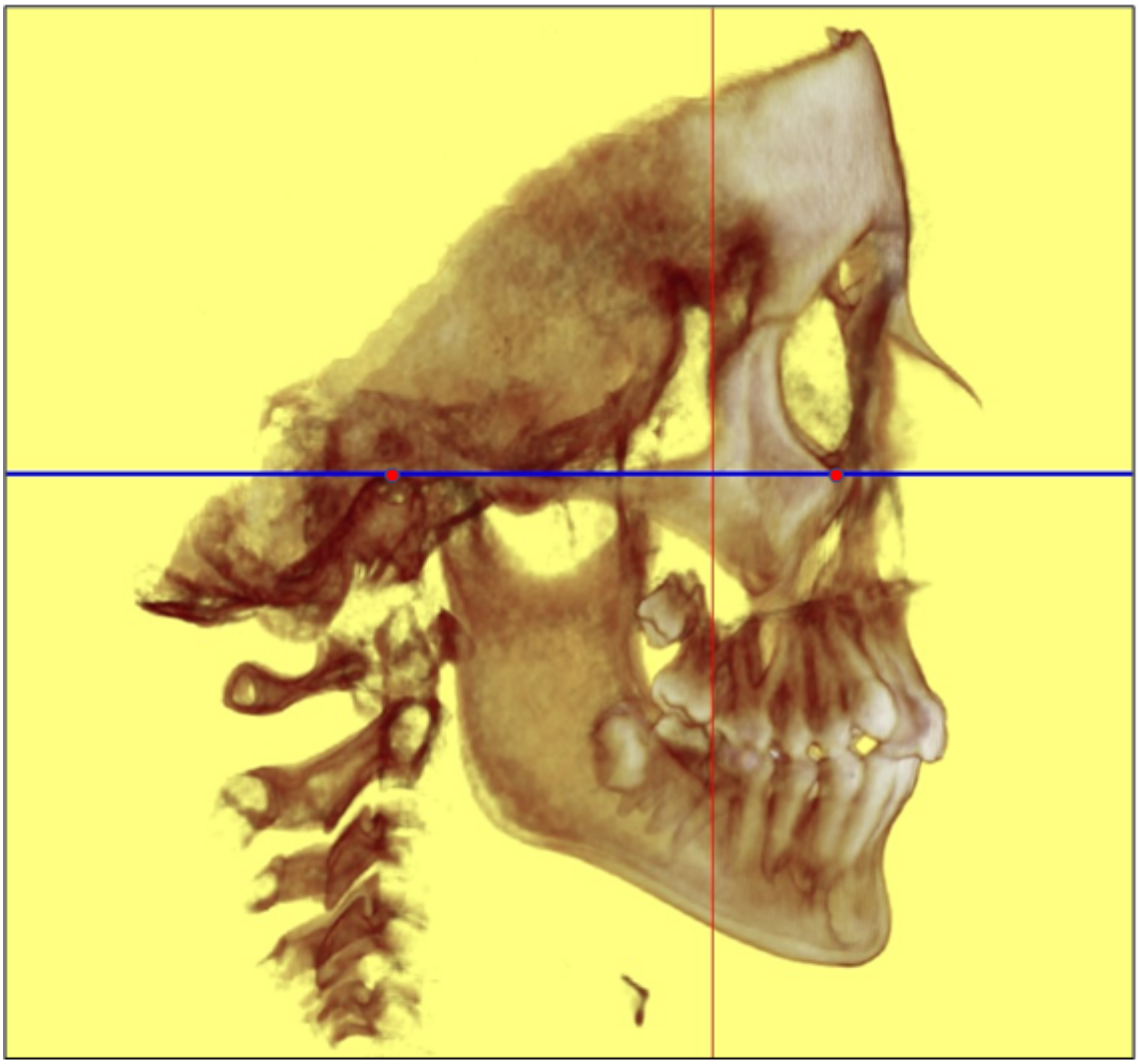

Figure 2. Orientation of sagittal plane using Frankfort Horizontal plane.

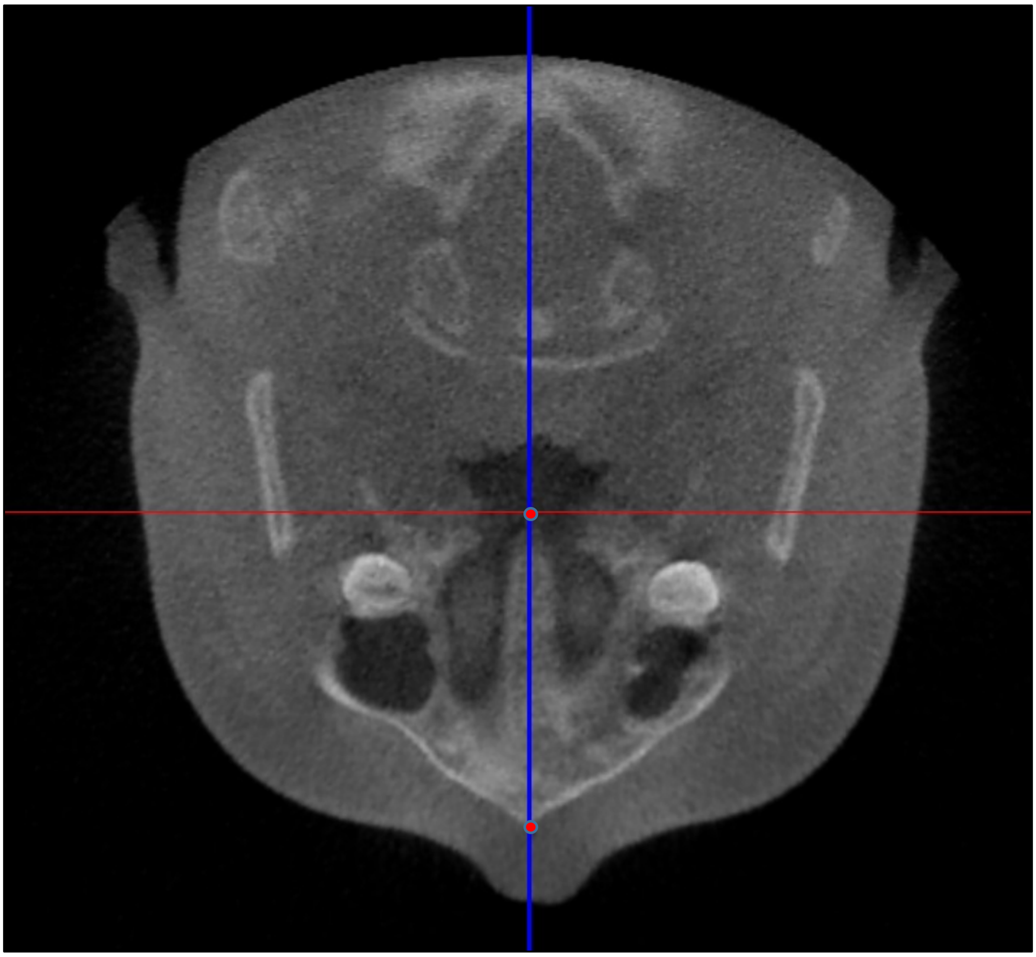

Figure 3. Orientation of axial plane using a line passing through anterior nasal spine and posterior nasal spine (viewed in axial slice for better landmarks identification).

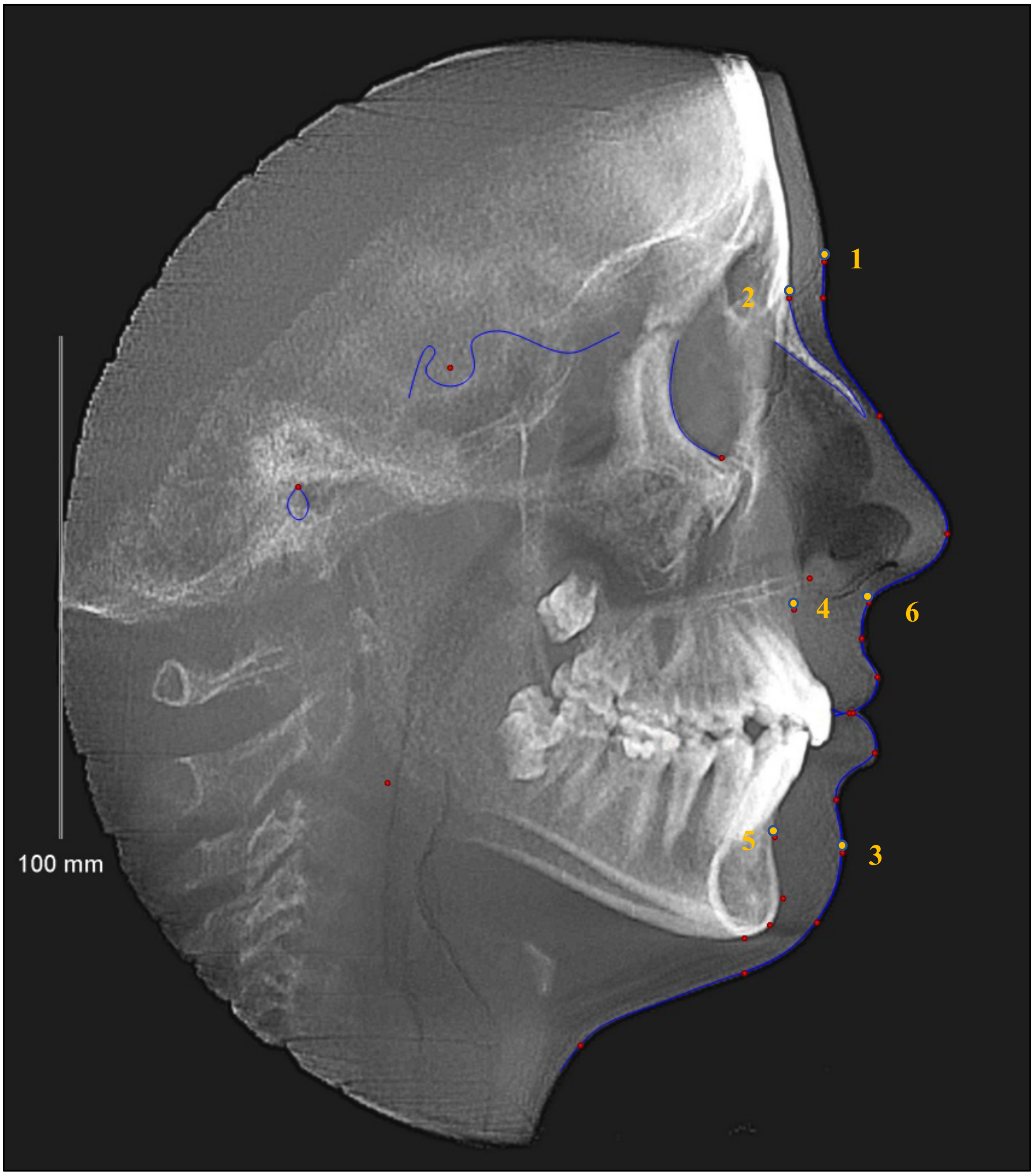

Figure 4. Lateral cephalometric landmarks that were used for measurements.

Table 1. Description of lateral cephalometric landmarks and measurements that were used.

No.	Landmark	Description
1.	Glabella (G)**	The most anterior point of forehead in midsagittal plane.
2.	Nasion (N)*	The most anterior point of frontonasal suture in the midsagittal plane.
3.	Soft tissue Pogonion (Pos)**	The most anterior point on the soft tissue contour of the chin.
4.	Point A (A)*	The deepest point in the concavity in the anterior border of the maxilla between anterior nasal spine and prosthion in the midsagittal plane.
5.	Point B (B)*	The deepest point in the concavity in the anterior border of the mandible between infradentale and pogonion in the midsagittal plane.
6.	Subnasale (Sn)**	The point where the lower border of the nose meets the outer contour of the lips.
Measurement (Unit)		**Description**
ANB (º)		Angular cephalometric measurement of A point – nasion (N) – B point.
G-Sn-Pos (º) Soft Tissue Profile		Angular cephalometric measurement formed by the intersection of a line through Glabella (G) – subnasale (Sn) with a line through point subnasale (Sn) – soft tissue pogonion (Pos).

The number which precedes the landmark name corresponds to the number represented in Figure 4.
*Athanasiou AE. Orthodontic Cephalometry. Mosby-Wolfe: London, 1995:46-47.
**Athanasiou AE. Orthodontic Cephalometry. Mosby-Wolfe: London, 1995:49-50.

Twenty-two facial soft tissue thickness parameters were collected from each CBCT image by locating eight midline and fourteen bilateral landmarks on the skull and projected on the face using the same software (Table 2) (Figures 5-7). Nasion (N) point was located on the skeletal tissue on the 3D CBCT image, and the FSTT was measured in the sagittal plane by extending a line from Nasion (N) point to the corresponding border of the soft tissue. This line was measured parallel to the Frankfort Horizontal plane anterioposterioly (Figure 8). The same method was applied to locate and measure all midline FSTT parameters. Zygomaticofrontal medial suture (zfms) point was located on the skeletal tissue on the 3D CBCT image, and the FSTT was measured in the axial plane by extending a line from zygomaticofrontal medial suture (zfms) point to the corresponding border of the soft tissue. This line was measured parallel to the Frankfort Horizontal plane anterioposterioly (Figure 9). The same method was applied to locate and measure all bilateral FSTT, except Gonion (Go) points and posterior anterior ramus (par) points (Figures 10 and 11). The FSTT of posterior anterior ramus (par) point was measured in the axial plane by extending a line from the landmark to the corresponding soft tissue border. This line was measured parallel to the Frankfort Horizontal plane transversely (Figure 10). The FSTT at Gonion (Go) point was measured using the same method.

Prior to data collection, a reliability test was performed for all selected parameters. All cephalometric and FSTT measurements were taken on 10 coded images on two separate occasions with two weeks between each measurement session to avoid memory bias. The order of cases was randomized for each measurement using the randomization function in Excel file. The intraclass correlation coefficient (ICC) was calculated to assess intra-observer reliability across two repeatability trials. The ICC value of 0.9 or greater was considered acceptable.

Table 2. Definition of skeletal landmarks that were used for facial soft tissue thickness measurements.

No.	Skeletal Landmark	Definition
Midline Landmarks		
1.	Glabella (G)	The most prominent point between the supraorbital ridges in the midsagittal plane
2.	Nasion (N)*	The most anterior point of frontonasal suture in the midsagittal plane.
3.	Rhinion (Rhi)	The most anterior point on the tip of the nasal bones in the midsagittal plane.
4.	Anterior Nasal Spine (ANS)*	The most anterior pointed projection of the bony anterior nasal spine in the midsagittal plane.
5.	Prosthion (Pr)*	The most inferior and anterior point of the alveolar ridge between the maxillary central incisors in the midsagittal plane.
6.	Infradentale (Id)*	The most superior and anterior point of the alveolar ridge between the mandibular central incisors in the midsagittal plane.
7.	Point B (B)*	The deepest point in the concavity in the anterior border of the mandible between infradentale and pogonion in the midsagittal plane.
8.	Pogonion (Pog)	The most anterior point on the mental eminence of the mandible in the midsagittal plane.
Bilateral Landmarks		
9.	Mid-supraorbital (mso)	The most superior and anterior point that bisects the supraorbital margin (Figure 12).
10.	Mid-Infraorbital (mio)	The most inferior and anterior point that bisects the infraorbital margin.
11.	Zygomaticofrontal medial suture (zfms)	The most medial point of the frontomaxillary suture in the lateral orbital rim.
12.	Lateral border nasal aperture (lbna)	The most lateral point of the lateral border of the nasal aperture.
13.	Maxillare (mx)**	The intersection of the lateral contour of maxillary alveolar process and the lower contour of maxillozygomatic process of maxilla.

14.	Posterior anterior ramus (par)	The most posterior point along the curved anterior margin of the ascending ramus.
15.	Gonion (Go)	The constructed point located on the angle of the mandible by a line bisecting the angle formed between a line tangent to the posterior border of the ramus and mandibular plane †.

The number which precedes the landmark name corresponds to the number represented in Figure 5.
*Athanasiou AE. Orthodontic Cephalometry. Mosby-Wolfe: London, 1995:46-47.
**Athanasiou AE. Orthodontic Cephalometry. Mosby-Wolfe: London, 1995:148-149.
† Mandibular plane: line tangent to the most inferior point of the symphysis and tangent to lower border of the mandible posteriorly.

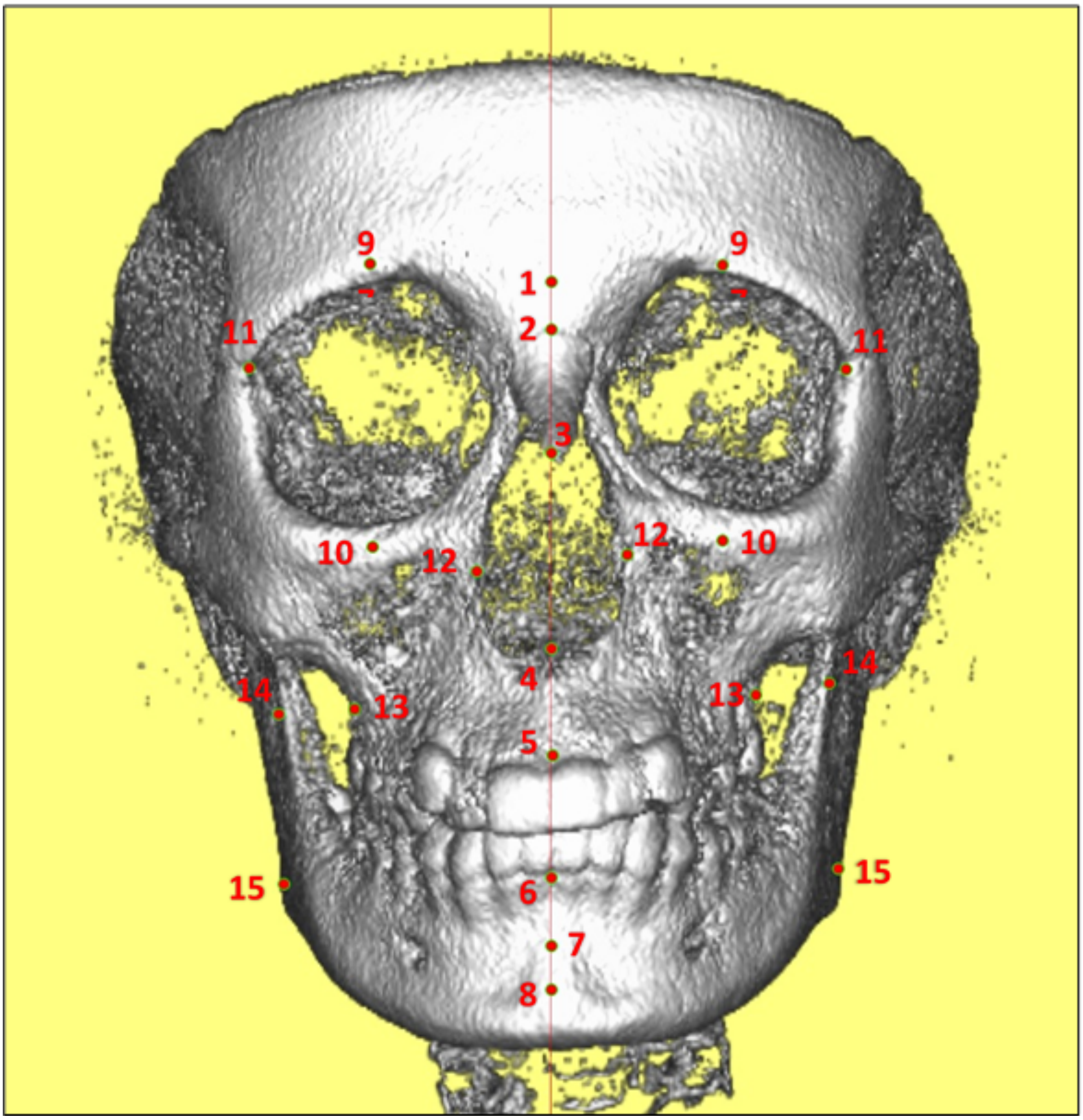

Figure 5. All skeletal landmarks that were used to measure facial soft tissue thickness.

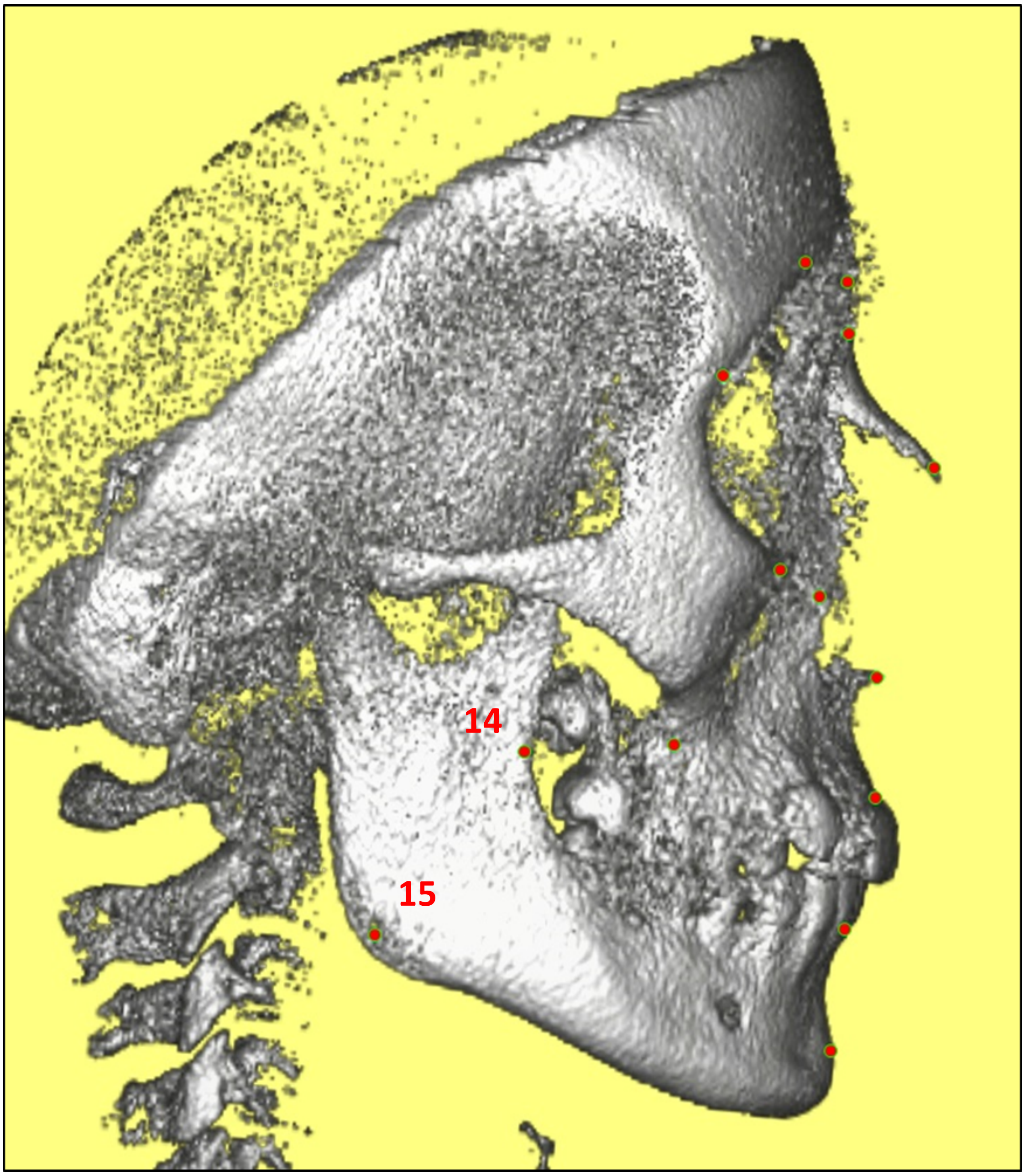

Figure 6. Skeletal landmarks that were measured transversely (points 14 and 15).

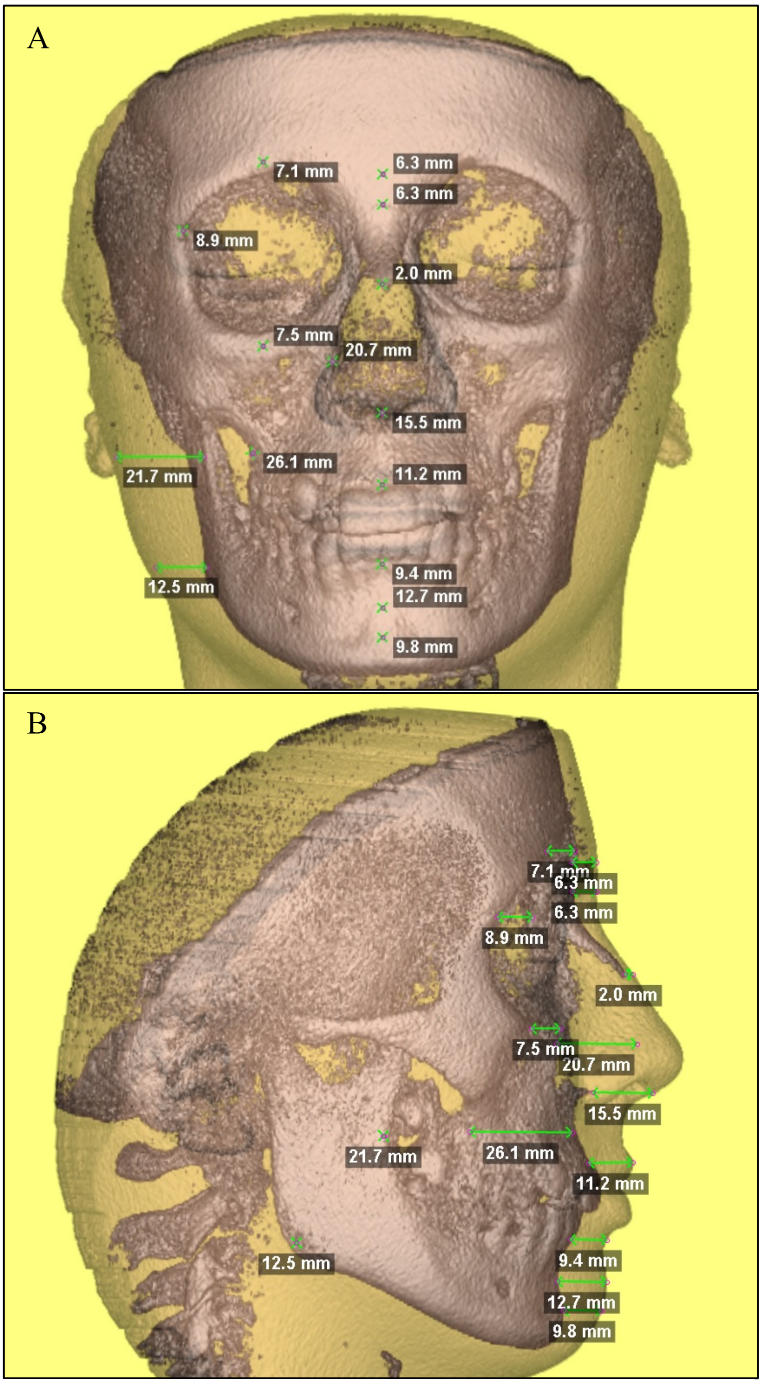

Figure 7. Midline and bilateral (one side) facial soft tissue thickness measurements that were used. (A) Frontal view. (B) Lateral view.

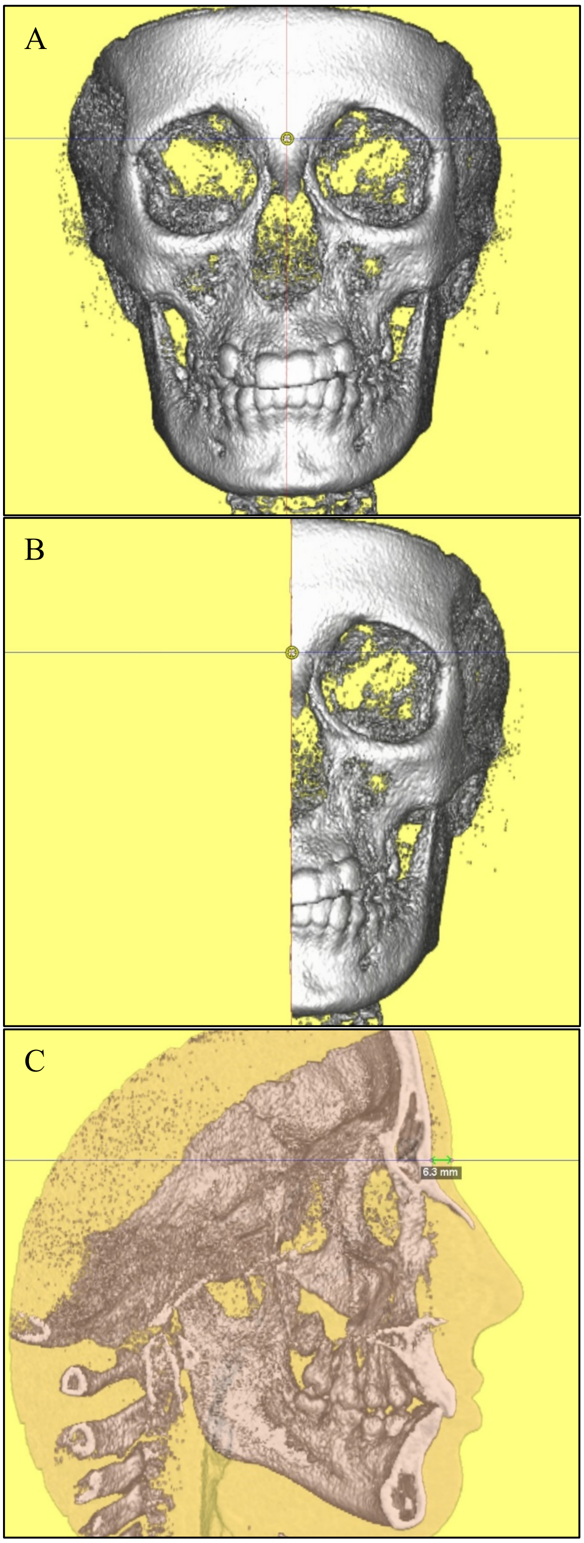

Figure 8. Nasion (N) point. (A) Locating Nasion (N) point. (B) Sagittal clipping. (C) Sagittal view, adding soft tissue component and measuring the corresponding soft tissue thickness in the sagittal plane.

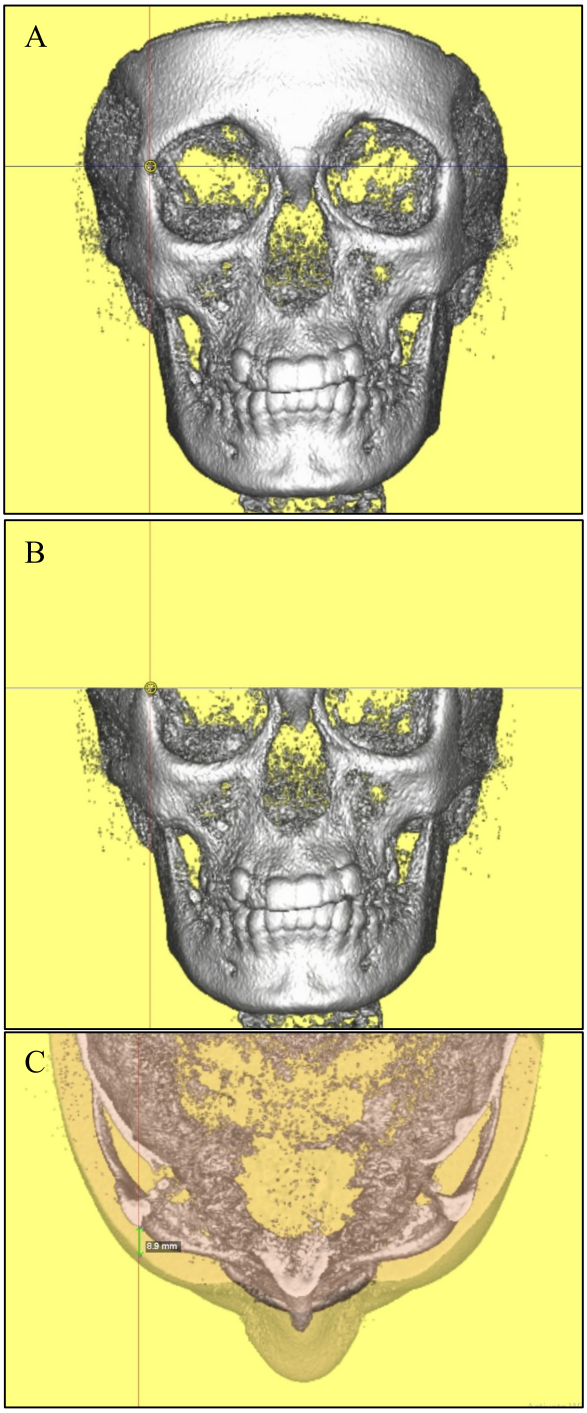

Figure 9. Zygomaticofrontal medial suture (zfms) point. (A) Locating zygomaticofrontal medial suture (zfms) point. (B) Axial clipping. (C) Axial view, adding soft tissue component and measuring the corresponding soft tissue thickness in the axial plane.

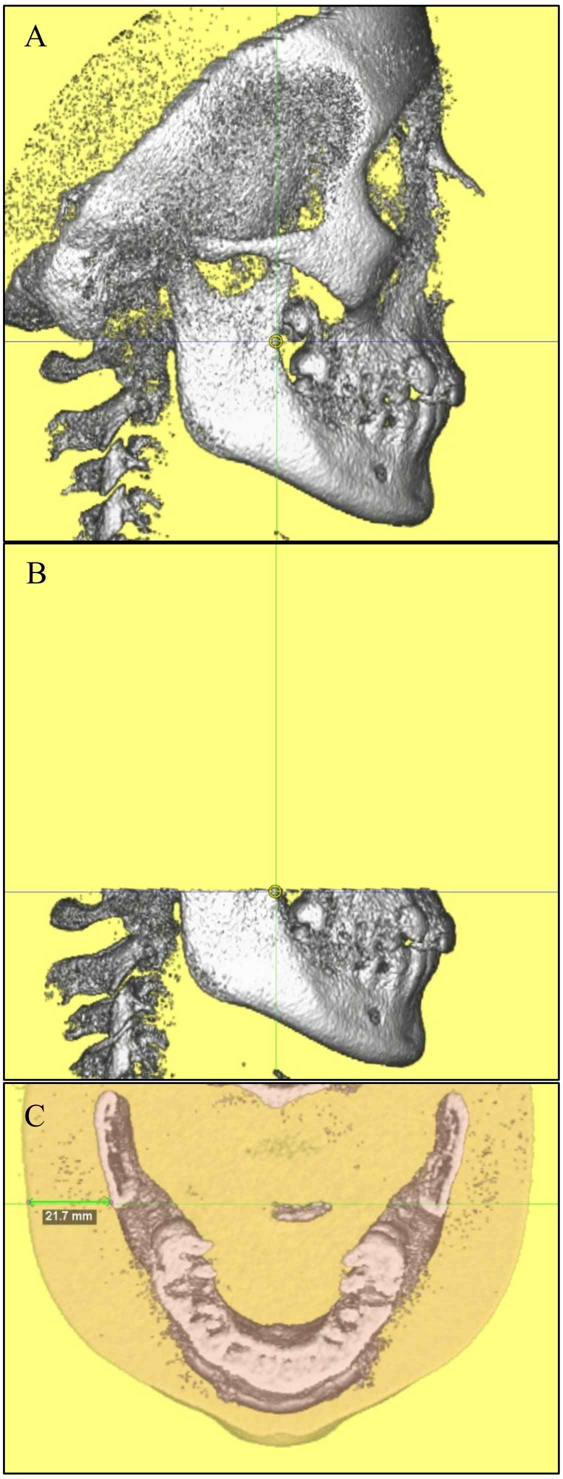

Figure 10. Posterior anterior ramus (par) point. (A) Locating posterior anterior ramus (par) point. (B) Axial clipping. (C) Axial view, adding soft tissue component and measuring the corresponding soft tissue thickness in the axial plane.

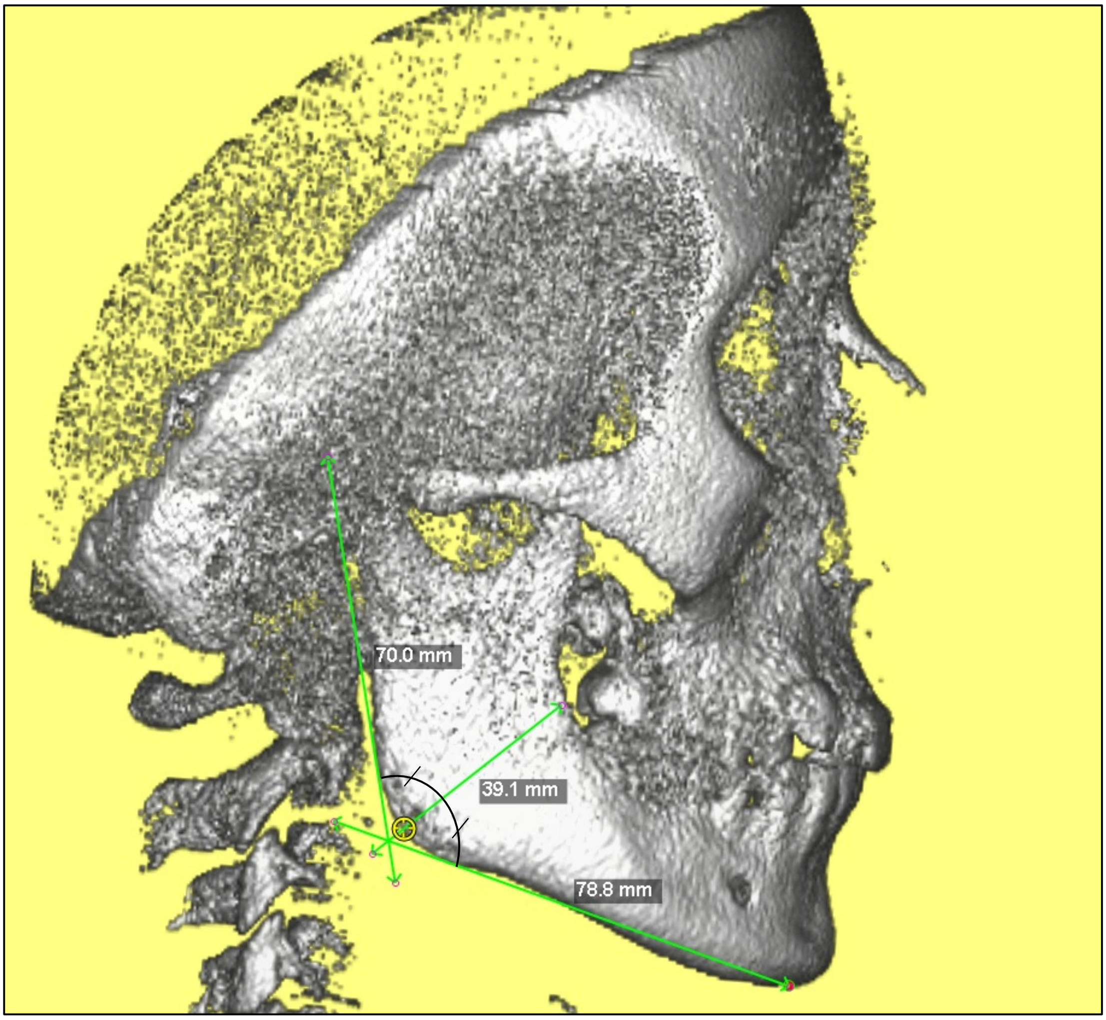

Figure 11. Locating Gonion (Go) point using a line that bisects the angle created by two lines, first one is passing from Menton and tangent to lower border of the mandible posteriorly and second one is tangent to the posterior surface of the ramus.

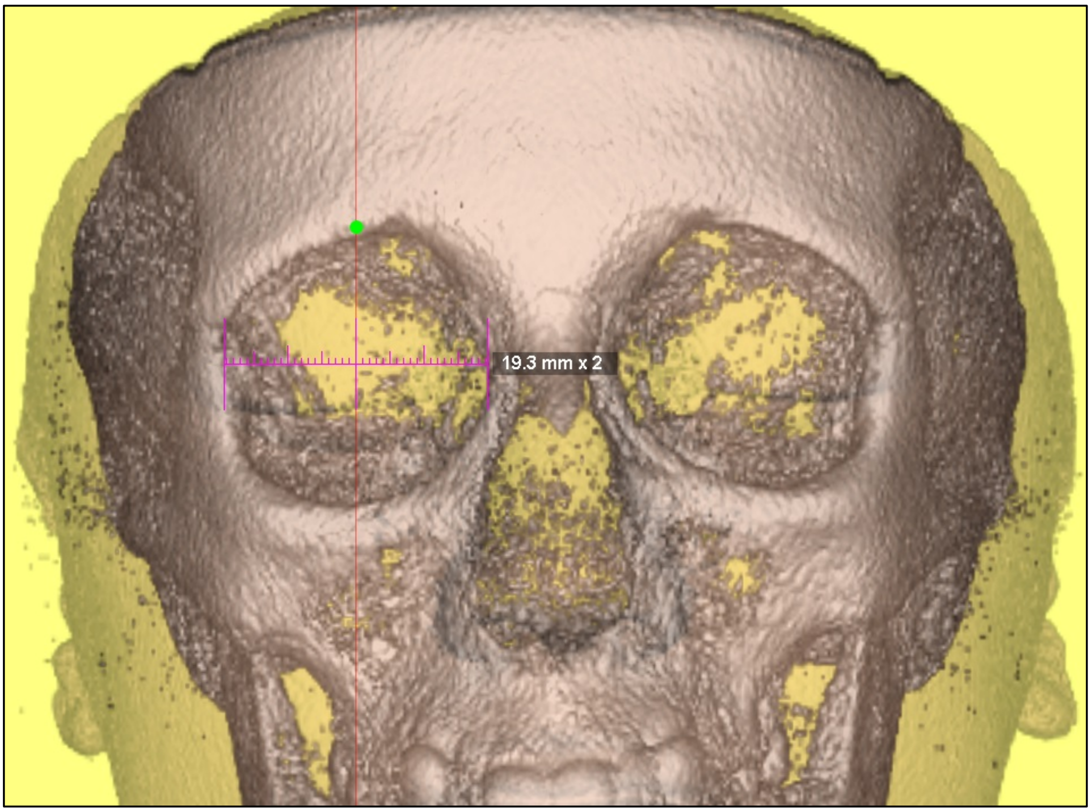

Figure 12. Using a horizontal symmetry caliper to bisect the orbit in order to locate mid-supraorbital (mso) point. Similar method was applied for locating of mid-infraorbital (mio).

5.1 Statistical Analysis

Data was entered in computer using IBM-SPSS for Windows, version 23.0 (SPSS Inc., Chicago, IL, USA). Measure of percentage and measure of tendency and dispersion were performed as descriptive statistics for categorical and continuous data, respectively. Kolmogorov-Smirnov was used to test the normality of continuous variables. Correlation coefficient was used to test the linear correlation between two continuous variables. Linear regression was also used to explain the dependent variables with the independent variables. ANOVA test was used to compare means of continuous data between Classes. Kruskal-Wallis test was used if the data shows abnormal distribution. Internal consistency and agreement were tested by using Bland-Altman methods. A P-value ≤ 0.05 was considered significant in all statistical analyses.

6 RESULTS

The intraclass correlation coefficient (ICC) showed no statistically significant differences between the repeated parameters. ICC values were ≥ 0.9 for all measurements. Descriptive statistics of all facial soft tissue thickness parameters are summarized in Table 3.

In Class I group, the correlation coefficient between ANB angle and all facial soft tissue thickness parameters (Table 4) showed no statistically significant differences except for Glabella (G), Nasion (N), right mid-supraorbital (mio-R), left mid-supraorbital (mio-L), right posterior anterior ramus (par-R), left posterior anterior ramus (par-L), right Gonion (Go-R) and left Gonion (Go-L), showed positive correlation. The correlation coefficient between the soft tissue profile (G-Sn-Pos) and all facial soft tissue thickness parameters (Table 5) showed no statistically significant differences except for point B and Pogonion (Pog) that showed positive correlation.

In Class II group, the correlation coefficient between ANB angle and all facial soft tissue thickness parameters (Table 4) showed no statistically significant differences. The correlation coefficient between soft tissue profile (G-Sn-Pos) and all facial soft tissue thickness parameters (Table 5) showed no statistically significant differences except for point B, Pogonion (Pog), right zygomaticofrontal medial suture (zfms-R), and left zygomaticofrontal medial suture (zfms-L) that showed negative correlation.

In Class III group no statistically significant differences were found between all facial soft tissue thickness parameters and both ANB angle (Table 4) and soft tissue profile (Table 5).

Table 3. Descriptive statistics of facial soft tissue thickness parameters (mm) in different skeletal Classes.

Parameters	Class I				Class II				Class III			
	Mean	SD	Minimum	Maximum	Mean	SD	Minimum	Maximum	Mean	SD	Minimum	Maximum
G	5.14	0.98	3.6	6.8	5.26	1.11	4	8.5	5.14	0.9	3.6	7.5
N	6.21	1.1	4.3	7.9	6.31	1.27	4.9	9.5	6.46	1.17	4.5	8.8
Rhi	2.59	0.87	0.7	3.8	2.53	0.84	1.7	4.7	2.01	0.74	0.7	3.9
ANS	13.71	1.99	9.6	17.1	14.25	4.55	8.5	24.4	15.617	4.01	9.7	21.7
Pr	11.42	1.88	7	15.9	11.317	1.9	8.3	16.6	12.83	1.93	9.4	18.1
Id	9.92	1.99	6.9	13.1	10.24	1.57	8.4	14.5	9.12	1.29	7.3	12.7
Point B	10.03	1.92	7.2	14.3	11.07	2.77	6.1	17.8	11.04	1.37	8.2	12
Pog	9.35	1.54	7.3	13.2	10.06	2.73	7.3	18.7	8.77	1.72	5.6	12.7
mso -R-	6.78	1.16	5.2	9	7.18	1.58	3.8	11.2	7.28	1.12	4.8	9.2
mso -L-	6.53	1.23	5	9	7.34	1.41	4	11	7.44	1.09	5	9
mio -R-	7.9	2.38	4.8	12.3	7.26	2.33	5	15	6.96	1.39	4.2	9
mio -L-	7.77	2.39	4.2	12.8	7.56	2.28	4.6	15.7	7.4	1.6	3.8	10.3
zfms -R-	8.65	2.28	5.4	12.9	9.42	2.43	6.1	15.9	9.51	1.54	6.6	11.9
zfms -L-	7.72	2.21	4.7	11.6	9.66	2.51	6.2	15.2	9.36	1.45	7.3	12.5
lbna -R-	17.83	4.28	10.7	28.3	21.09	3.92	14.6	28.9	17.85	3.38	11.4	26.2
lbna -L-	18.3	5.48	11.3	31.1	20.87	4.84	13.7	30.2	18.73	5.74	12.3	29.3
Par -R-	22.52	3.25	17.8	29.3	21.82	3.89	17.2	35	21.54	1.91	18.8	26.2
Par -L-	22.64	3.21	18	27.9	22.24	3.82	17.3	35.2	22.22	2.63	19.5	29.8
mx -R-	27.6	4.25	22.5	39.9	26.71	3.2	22.6	33.8	26.52	2.19	23.1	30.7
mx -L-	27.51	3.5	23	35.4	26.07	3.21	21.5	35.2	27.32	3.03	19.9	31.5
Go -R-	12.77	3.58	8.8	21.1	13.96	5.03	8.7	27.8	12.73	3.08	7.4	19
Go -L-	12.5	3.1	8.3	19.2	14.48	4.98	7	26.8	13.18	3.58	7.4	24.4

Table 4. Correlation coefficient of ANB and facial soft tissue thickness parameters in different skeletal Classes.

Parameter	Class I		Class II		Class III	
	Correlation Coefficient	P-value	Correlation Coefficient	P-value	Correlation Coefficient	P-value
G	0.604	0.006*	-0.177	0.482	0.286	0.25
N	0.492	0.032*	-0.345	0.16	-0.075	0.768
Rhi	0.275	0.255	-0.368	0.133	0.204	0.416
ANS	0.066	0.789	-0.193	0.444	-0.263	0.346
Pr	-0.093	0.704	-0.383	0.117	-0.272	0.274
Id	-0.31	0.197	0.095	0.706	0.144	0.57
Point B	0.329	0.169	-0.022	0.931	0.156	0.537
Pog	0.127	0.603	-0.09	0.723	0.026	0.918
mso -R-	0.069	0.779	0.053	0.835	0.005	0.984
mso -L-	0.113	0.657	0.021	0.934	-0.211	0.4
mio -R-	0.567	0.011*	-0.093	0.715	-0.147	0.56
mio -L-	0.698	0.001**	-0.177	0.482	-0.244	0.329
zfms -R-	0.147	0.547	-0.183	0.468	-0.202	0.421
zfms -L-	0.204	0.403	-0.208	0.408	-0.259	0.299
lbna -R-	-0.01	0.967	0.053	0.834	0.013	0.958
Ibna -L-	0.354	0.137	0.205	0.414	0.323	0.191
Par -R-	0.69	0.001**	-0.095	0.707	0.12	0.636
Par -L-	0.69	0.001**	-0.061	0.809	0.167	0.507
mx -R-	0.293	0.223	-0.244	0.33	-0.091	0.718
mx -L-	0.327	0.172	-0.427	0.077	0.041	0.871
Go -R-	0.685	0.001**	-0.026	0.92	0.077	0.762
Go -L-	0.686	0.001**	0.009	0.972	0.221	0.378

*P-value ≤0.05; **P-value ≤0.001

Table 5. Correlation Coefficient of soft tissue profile and facial soft tissue thickness parameters in different skeletal Classes.

Parameter	**Class I**		**Class II**		**Class III**	
	Correlation Coefficient	P-value	Correlation Coefficient	P-value	Correlation Coefficient	P-value
G	0.18	0.461	-0.347	0.158	0.231	0.357
N	0.124	0.614	-0.359	0.143	0.088	0.728
Rhi	0.096	0.695	-0.338	0.171	-0.256	0.305
ANS	0.108	0.659	-0.245	0.327	0.204	0.417
Pr	0.436	0.062	-0.215	0.392	0.139	0.584
Id	-0.217	0.371	-0.056	0.826	0.24	0.338
Point B	0.58	0.009*	-0.48	0.044*	0.149	0.556
Pog	0.429	0.032*	-0.525	0.025*	-0.391	0.109
mso -R-	0.17	0.487	-0.377	0.123	0.389	0.111
mso -L-	-0.049	0.847	-0.426	0.078	0.263	0.291
mio -R-	-0.03	0.903	-0.289	0.245	-0.015	0.954
mio -L-	0.057	0.816	-0.353	0.15	0.065	0.797
zfms -R-	-0.233	0.336	-0.502	0.034*	0.175	0.487
zfms -L-	-0.413	0.079	-0.579	0.012*	-0.028	0.913
lbna -R-	0.364	0.125	0.07	0.784	0.102	0.688
Ibna -L-	0.137	0.576	-0.064	0.802	0.381	0.119
Par -R-	0.338	0.157	-0.44	0.068	-0.187	0.458
Par -L-	0.394	0.095	-0.359	0.143	-0.155	0.54
mx -R-	0.254	0.294	-0.16	0.525	0.072	0.777
mx -L-	0.251	0.3	-0.36	0.142	0.364	0.138
Go -R-	0.317	0.186	-0.412	0.089	-0.281	0.258
Go -L-	0.266	0.271	-0.378	0.122	0.03	0.906

*P-value ≤0.05

7 DISCUSSION

Facial soft tissue position is influenced by the underlying hard tissues. One of the principal goals of orthodontic treatment is to achieve an optimum soft tissue profile and final facial esthetics. It is a common knowledge in the field of orthodontics that the skeletal and dental relationships of the jaws to the skull can affect the soft tissue topography of an individual. Manipulation of a patient's jaw and dental positions during treatment also causes a shift in the soft tissues, thus enabling these optimum relationships to be achieved.

Several studies compared facial soft tissue thickness in different skeletal Classes by measuring midline landmarks utilizing conventional 2D lateral cephalometric radiographs (Kamak and Celikoglu, 2012; Kurkcuoglu et al., 2011; Pithon et al., 2014; Utsuno et al., 2010; Lopatiene et al., 2016a; Perovic and Blazej, 2018). While other studies utilized 3D CBCT images to either compare facial soft tissue thickness in different skeletal Classes by using limited anatomical landmarks (Celikoglu et al., 2015; Gomez et al., 2017; Jazmati et al., 2016) or to establish facial soft tissue thickness norms (Fourie et al., 2010; Lee et al., 2012; Hwang et al., 2012b). To the best of our knowledge, no previous studies compared the different skeletal Classes and facial soft tissue thickness using unilateral and bilateral landmarks. The aim of this study was to measure facial soft tissue thickness differences in each skeletal Class and soft tissue profile.

Lateral cephalometric radiographs have always been of great benefit for diagnosis, treatment planning and monitoring treatment progress in orthodontics. These conventional radiographs were used to measure soft tissue thickness in most of the studies which can be justified as they are taken as a routine record in orthodontics. For proper diagnosis of patient's facial soft tissues and underlying skeletal structures, clinicians should use advanced methods to analyze both tissues three-dimensionally.

Several studies reported that CBCT is a reliable method of facial soft tissue thickness measurement and can be used for the purpose of facial reconstruction (Lee et al., 2012; Fourie et al., 2010; Hwang et al., 2012a) and for better prediction of soft tissue position after skeletal movement in orthognathic surgery cases (Park et al., 2013). Moreover, slices and volumetric reconstruction allow greater accuracy in localization of the points on both facial soft and hard tissues compared to lateral cephalometric conventional radiographs (Gomez et al., 2017).

In the current study, we have based our facial soft tissue thickness measurements using skeletal references. The selected skeletal landmarks in this study are easier to locate and more stable than soft tissue landmarks, making the collected data more reproducible according to previous studies (Cavalcanti et al., 2004; Hwang et al., 2012a). Measures of facial soft tissue thickness were standardized by projecting a line, which is parallel to Frankfort Horizontal plane (Pithon et al., 2014), from the hard tissue landmarks to the corresponding facial soft tissue surfaces in all twenty-two landmarks.

The CBCT machine used in study was capable of scanning subjects with a scan size of 0.4 mm voxels, which is recommended, as it gives moderately more accurate measurements of FSTT according to a prior study (Fourie et al., 2010). Another study mentioned that very small voxels size (0.2 mm or 0.3 mm) resulted in a remarkably large surface mesh model that is quite difficult to process in order to create an accurate 3D surface model (Hassan et al., 2010). On the other hand, they also mentioned that large voxel size (0.6 mm, 0.9 mm, or 1.2 mm) resulted in diminished visibility of tissues details.

According to previously conducted studies, no facial soft tissue thickness differences were found between skeletal Classes at Gonion (Go) and Nasion (N) points (Utsuno et al., 2010; Utsuno et al., 2014; Kurkcuoglu et al., 2011). However, the result of the current study showed significant differences in facial soft tissue thickness measurements at Gonion (Go) and Nasion (N) points in Class I compared to Class II and III.

Other statistically significant parameters in Class I group, were the bilateral soft tissue thickness measurements at right mid-supraorbital (mio-R) point, left mid-supraorbital (mio-L) point, right posterior anterior ramus (par-R) point, left posterior anterior ramus (par-L) point, right Gonion (Go-R) point and left Gonion (Go-L) point.

In this study, statistically significant differences were found between soft tissue profile and facial soft tissue thickness in point B and Pogonion (Pog) point in Class I group expressing a positive correlation. An explanation of this finding is that with increase of skeletal convexity (ANB angle) facial soft tissue thickness at these two points tend to increase. This is in agreement with a study by Utsuno et al. (2010). However, they reported higher thickness of facial soft tissue at point B and Pogonion (Pog) point in Class II groups.

Facial soft tissue thickness measured at Pogonion (Pog) point, recorded the highest thickness in Class II group and least in Class III group in agreement with previous multiple studies (Utsuno et al., 2010; Kurkcuoglu et al., 2011; Pithon et al., 2014). Also, a study by Dumont (1986) reported that there is a relationship between occlusion pattern and FSTT, but it is weak. She stated that mandibular protrusion and soft tissue thickness at Gnathion point, which is very proximal to Pogonion (Pog) point, are inversely proportional. With reduced mandibular protrusion, soft tissue thickness at Gnathion tends to increase, and vice versa.

In soft tissue profile of Class II group, two bilateral points showed statistical significant differences, right zygomaticofrontal medial suture (zfms-R) point and left zygomaticofrontal medial suture (zfms-L) point.

Upper lip soft tissue thickness measured at Prosthion (Pr) point, had the highest thickness in Class III group. Lower lip soft tissue thickness measured from Infradentale (Id) point, showed the highest thickness in Class II group. These results were in agreement with previous studies (Jazmati et al., 2016; Kamak and Celikoglu, 2012; Utsuno et al., 2010), although both upper and lower lips thickness were not statistically significant in the current study.

All bilateral facial soft tissue thickness measurements were not compared to previous studies as none of them was related to skeletal Classes. Previous studies utilized bilateral landmarks only to be tested for reproducibility and produce a database for facial soft tissue thickness (Hwang et al., 2015; Stephan and Simpson, 2008).

7.1 Limitations

Further studies with larger samples, different age groups of growing and non-growing subjects and different vertical growth patterns will be needed.

Future studies will be needed to establish standardization methods for evaluating and/or comparing the bilateral measurements in a consistent way.

7.2 Recommendations

There is a need for more studies with larger samples to utilize 3D CBCT technology to compare bilateral facial soft tissue thickness to skeletal Classes. In consequence, it will allow clinicians to apprehend the expected displacement of the facial soft tissue in response to orthodontic and orthognathic treatments. Moreover, it will aid in development of a more accurate database of facial soft tissue thickness norms in facial reconstruction.

8 CONCLUSION

Subjects with different skeletal Classes exhibit variations in facial soft tissue thickness among these groups. Most of the statistically significant differences were found in skeletal Class I group, while skeletal Class II group showed less statistically significant differences. Facial soft tissue profile showed significant correlation with soft tissue thickness at the chin area in skeletal Class I and II groups. The highest thickness was recorded in skeletal Class II and the lowest thickness was recorded in skeletal Class III group.

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