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**EVALUATION OF SOFT TISSUE PROFILE CHANGES IN
ORTHOGNATHIC SURGERY PATIENTS**

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BEYAN

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İmza

STATEMENT

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Signature

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III. ABBREVIATIONS AND SYMBOLS

- %: Percent
- (°): Degree
- $\bar{X}$: Mean
- 2D: Two-Dimensional
- 3D: Three-Dimensional
- BSI: British Standards Institute
- BSSO: Bilateral Sagittal Split Osteotomy
- CLP: Cleft Lip and Palate
- CO: Centric Occlusion
- CR: Centric Relation
- HRQoL: Health-Related Quality of Life
- IVRO: Intraoral Vertical Ramus Osteotomy
- LAFH: Lower Anterior Facial Height
- MEAW: Multiloop Edgewise Arch Wire
- NSAID: Non-Steroidal Anti-inflammatory Drugs
- OP(°): Occlusal Plane Inclination Angle
- RIF: Rigid Internal Fixation
- SD: Standard Deviation
- SRIF: Semi-Rigid Internal Fixation
- TFH: Total Facial Height
- VTO: Visualised Treatment Objective

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Ortognatik cerrahi hastalarında yumuşak doku profili değişikliklerinin değerlendirilmesi

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1. ÖZET

Amaç: Sınıf III hastalarda ortognatik cerrahi sonrası yumuşak doku profilindeki değişiklikleri değerlendirilmesi ve maksiller aşağı kırık ve maksiller gömme gruplarının yanıtının karşılaştırılması.

Gereç ve Yöntem: Bu retrospektif çalışma 22 hastanın lateral sefalogramları kullanılarak yapıldı. Tüm hastalar sabit ortodontik tedavi ve bimaxiller cerrahi ile tedavi edildi. Hastalar maksiller dikey harekete göre iki alt gruba ayrıldı, Grup A; 13 maksiller aşağı kırık hasta ve Grup B; 9 maksiller gömme hastası. Sefalogramlar T1 (ameliyat öncesi) ve T2 (ameliyattan 6-24 ay sonra) zaman aralıklarında alındı. Sefalogramlar dijital olarak 12 iskelet, 6 diş ve 16 yumuşak doku parametresi kullanılarak analiz edildi. İstatistiksel analizde Paired t-test, Independent t-test ve Pearson Korelasyon testleri kullanıldı.

Bulgular: SNA, SNB, ANB, witts, N per A, N per B ve iskelet profilinin ortalaması her iki grupta da istatistiksel olarak anlamlı değişti. Her iki grupta da H açısı, yumuşak doku profili, üst dudak-E-çizgisi, alt dudak kalınlığı ve uzunluğu, burun projeksiyonu, alt dudak-TVL ve B'-TVL ortalamalarında istatistiksel olarak anlamlı yumuşak doku değişiklikleri rapor edildi. İki grup arasında maksiller yükseklik ve alt dudak uzunluğu ortalamasındaki değişim açısından farklar anlamlıydı. İskelet ve yumuşak doku profilleri, N per A ve üst dudak-TVL Grup B'de ve her iki grupta da B'-TVL ve alt dudak-TVL arasında istatistiksel olarak anlamlı ilişkiler bulundu.

Sonuç: Ameliyattan sonra iskelet sagital parametreleri, iskelet ve yumuşak doku profilleri, labial pozisyon, kalınlık ve uzunluk anlamlı değişim gösterdi. Gruplar arası önemli fark, maksiller yükseklik ve alt dudak uzunluğu değişiklikleri ile sınırlıydı.

Anahtar Kelimeler: Ortodonti, ortognatik cerrahi, Sınıf III maloklüzyon, yumuşak doku değişiklikleri, sefalometrik analiz.

Evaluation of soft tissue profile changes in orthognathic surgery patients

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2. SUMMARY

Aim: To evaluate the soft tissue profile changes after orthognathic surgery in Class III patients and to compare between two groups of maxillary downfracture and maxillary impaction.

Materials and Methods: This retrospective study was done using lateral cephalograms of 22 patients. All were treated with fixed orthodontic and bimaxillary surgery. The sample was divided into two subgroups according to the maxillary vertical movement, Group A; 13 maxillary downfracture patients, and Group B; 9 maxillary impaction patients. The cephalograms were taken at T1 (before surgery) and T2 (6-24 months after surgery). Cephalograms were traced digitally, 12 skeletal, 6 dental, and 16 soft tissue parameters were used in the analysis. The Paired t-test, Independent t-test, and Pearson Correlation tests were used in the statistical analysis.

Results: The mean of SNA, SNB, ANB, witts, N per A, N per B, and skeletal profile, have changed significantly in both groups. Significant changes were reported in both groups in the mean of H angle, soft tissue profile, upper lip-E-line, lower lip thickness and length, nasal projection, lower lip-TVL, and B'-TVL. Significant inter-group differences were limited to maxillary height and lower lip length changes. Skeletal and soft tissue profiles, N per A and upper lip-TVL in Group B, and B'-TVL and lower lip-TVL in both groups were significantly correlated.

Conclusion: Skeletal sagittal parameters, skeletal and soft tissue profiles, upper and lower lips positions, thickness and length have changed significantly after surgery. Significant inter-group differences were limited to the maxillary height and the lower lip length parameters.

Keywords: Orthodontics, orthognathic surgery, Class III malocclusion, soft tissue changes, cephalometric analysis.

3. INTRODUCTION AND AIM

Skeletal malocclusions result from an abnormal position of the maxilla and/or the mandible to the cranial base. Treatment of such malocclusions varies depending on the severity of the case, patient's age, patient's expectation, and availability of treatment modalities. In non-growing individuals, these malocclusions are commonly treated by what is called a camouflage orthodontic treatment, where orthodontic changes are limited to dental movements aiming to provide a stable, functional, and esthetic occlusion while the underlying skeletal problem is concealed. However, severe skeletal discrepancies that lie outside the scope of conventional orthodontic treatment options demand the need to surgical interventions to align the position of the upper and/or lower jaw along with orthodontic dental correction to achieve the desired outcome of the treatment (Kafle et al., 2017).

As facial attractiveness is one of the main purposes of orthodontic treatment, more light has been shed on the changes in the soft tissue profile following orthodontic treatments –in general- and orthognathic surgery –in particular- in contemporary studies and the focus has been increased on it in the latest years by both patients and orthodontists (Spyropoulos and Halazonetis, 2001). In the 1970s, the first studies were published investigating the change in the soft tissue profile through orthognathic surgery, aiming to achieve a predictable esthetic outcome, since then numerous studies covering the issue have followed (Rupperti et al., 2019). Holdaway in 1983 stated the importance of the soft tissue parameters in the orthodontic treatment and suggested a visualization of the treatment objective (VTO) to have an idea as to how the outcome of the treatment would affect the profile of the patient. Progressively since then, there had been a paradigm shift from hard tissue to the soft tissue envelope and how it is affected by treatment (Parappallil et al., 2018).

Surgery has its effects on the overlying soft tissue envelope, some of which are beneficial while others may be detrimental to facial aesthetics. It is important that these

are anticipated and minimized, but also that they are discussed during the planning and consenting stages of treatment as patients need to understand the implications of the treatment fully (Gill et al., 2017).

Moreover, since the structure of the human face depends on both the structure of the hard tissue (bone) and the overlying soft tissue, it is fair to say that thorough analysis of the soft tissue and its response to the hard tissue changes during diagnosis as well as a proper treatment planning that respects not only the skeletal correction but also the improvement of esthetics is mandatory (Altug-Atac et al., 2008).

Orthognathic surgery is not an event, rather a program that spans the time from the initial evaluation to the postsurgical orthodontics, one that might prove to be very demanding in terms of patient motivation and compliance. The complete understanding of the changes in soft tissues that result from the bony movements and the ability to accurately predict such changes allow the orthodontist to provide a clear explanation of the anticipated improvements in facial esthetics to the patient. Such a crucial enhancement has been found to boost the morale of the patients and hence considered a significant motivating factor for patients to undergo the treatment.

The concept of oral health-related quality of life (HRQoL) has been the focus of many pieces of research recently as they aimed to address the relationship between oral conditions as well as malocclusions and the psychosocial well-being of individuals. It was evident that severe malocclusions impair patients' quality of life more than many other oral conditions (Rusanen et al., 2010). Patients with malocclusion, especially those in need of surgical correction, have lower (HRQoL) and higher anxiety. Moreover, an unesthetic appearance can dramatically decrease the self-esteem of individuals, as dentoskeletal malformations cause not only esthetic problems for patients but also can extend to psychosocial consequences including concerns with body image and a low self-concept (Kohzuki et al., 2008). The results have concluded that orthognathic surgery had a notable impact on patients' quality of life as it has markedly improved their self-confidence and satisfaction about their image (Rezaei et al., 2019).

Visualizing the results of any proposed treatment is of utmost importance. Not only does it guide us in each part of the journey toward the final result, but also aids in assessing if the treatment objectives are met. The term visualized treatment objective (VTO) was first coined by Holdaway but used extensively by Dr. Ricketts. According to (Proffit), a (VTO) is a cephalometric tracing representing the changes that are expected during treatment. For routine orthognathic surgery cases, cephalometry and two-dimensional photogrammetry are common and less expensive tools that may have the potential to analyze and predict the resulting profile (Rustemeyer and Martin, 2013).

The aim of this thesis is twofold; the first is to analyze and assess the changes in the soft tissue profile of patients who underwent orthognathic surgery. The second objective is to compare between two groups of maxillary downfracture and maxillary impaction in terms of differences in their soft tissue response to the surgery.

4. GENERAL INFORMATION

4.1. Definition of Orthodontics

Orthodontics is a specialized branch of dentistry that is concerned with the diagnosis, prevention, and treatment of dental deformities as well as irregularities in the relationship of the lower to the upper jaw. Moreover, it is a study of the variations of the development and growth of the structures of the face, jaws and teeth, and of how they affect the occlusion (bite) of the teeth.

The term orthodontics was first coined by le Felon, and it is derived from the Greek words; orthos meaning straight or proper, and odons meaning teeth.

4.2. Occlusion and Malocclusion

4.2.1. Definition of malocclusion

Malocclusion is defined by the Dental Practice Board as an abnormal occlusion in which teeth are not in a normal position with adjacent teeth in the same jaw and/or the opposing teeth when the jaws are closed (Davies, 2007). The term was coined and popularised by Edward Angle, as a derivative of occlusion, which refers to how opposing teeth meet.

While not a true disease per se, rather, a descriptive term referring to a wide variation including any deviation from the normal relation or alignment of maxillary teeth, mandibular teeth, or to one another.

Malocclusions can have esthetic and functional implications; from an esthetic

standpoint, there are psychological impacts related to social acceptance, self-esteem, and success. On the other hand, from a functional point of view, mastication, speech, and protection of the structures in the entire stomatognathic system can contribute to or be the result of a malocclusion that is present.

4.2.2. Classification of malocclusion

Edward Angle, the father of modern orthodontics, was the first to establish a clear and simple definition of normal occlusion in 1899, which has served as the first classification for malocclusion as well.

Angle's classification was dependent on the position of maxillary first molars, in which the mesiobuccal cusp of the upper first molar should occlude against the buccal groove of the lower first molar. Angle then defined normal occlusion as a state where this condition is met alongside having all the teeth arranged on the line of occlusion. The line of occlusion is a smooth curve passing through the central fossa of each upper molar and across the cingulum of the upper canine and incisor teeth. The same line runs along the buccal cusps and incisal edges of the lower teeth (Figure 1).

Angle then described three classes of malocclusion, based on the occlusal relationships of the first molars (Figure 2):

Class I: Normal relationship of the molars but the teeth do not coincide with the line of occlusion.

Class II: Lower molar distally positioned relative to the upper molar, regardless of the line of occlusion.

Class III: Lower molar mesially positioned relative to the upper molar, regardless of the line of occlusion.

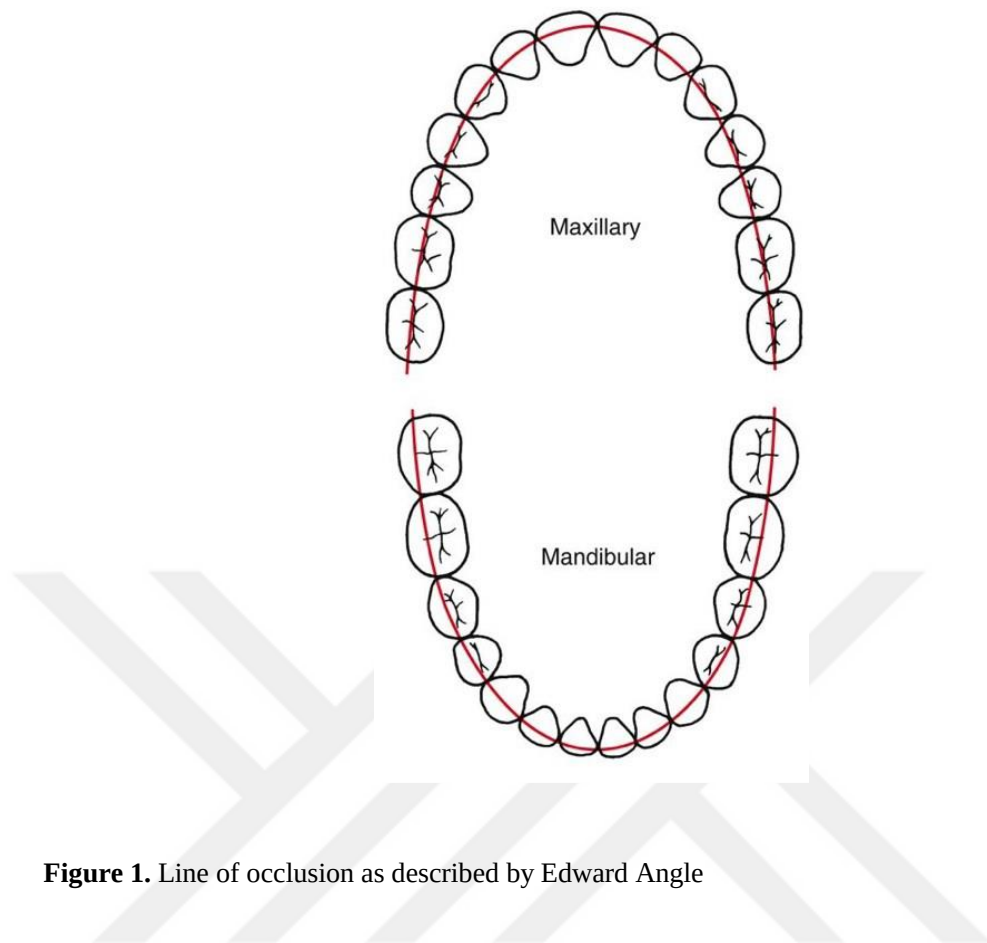


Figure 1. Line of occlusion as described by Edward Angle

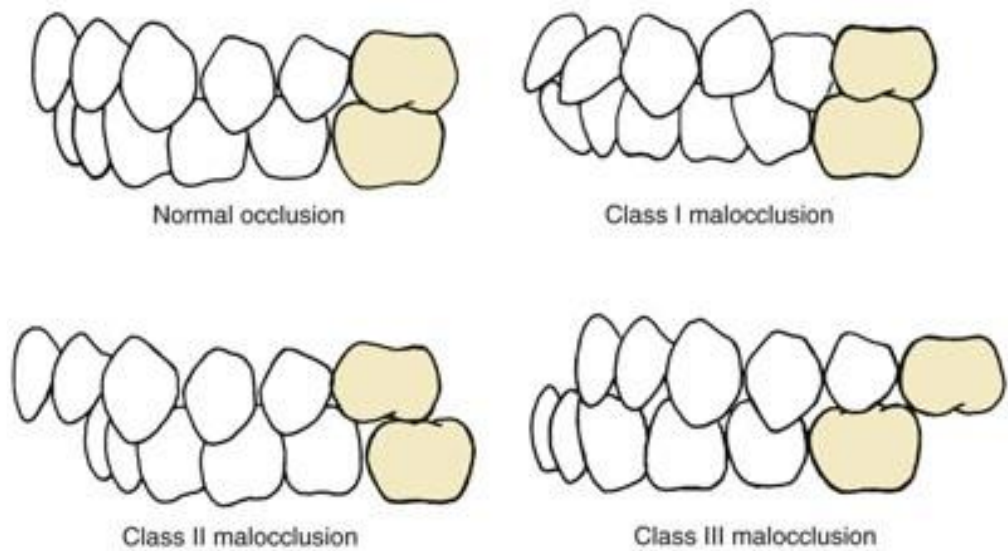


Figure 2. Edward Angle's classification of malocclusion

The invention of the cephalometer by B. Holly Broadbent in 1930 has marked the start of the history of imaging in orthodontics. These cephalograms made it clear that many Class II and Class III malocclusions are actually attributed to an irregular relationship of the jaws rather than just being caused by faulty dental relationships or malposed teeth. It also was possible to see that jaw growth could be altered by orthodontic treatment. In Europe, the method of “functional jaw orthopedics” was developed to enhance growth changes, while in the United States; extraoral force came to be used for this purpose (Proffit et al., 2007). Gradually, Angle’s classification was modified and additional information such as jaw relationship and the pattern of growth was also included.

Besides the Angle classification that had addressed the molar relationship, the British Standards Institute (BSI) in 1983 provided a description of the incisor relationship as part of their classification of malocclusion as follows:

Class I: The lower incisor edges occlude with or lie immediately below the cingulum plateau of the upper central incisors.

Class II: The lower incisor edges lie posterior to the cingulum plateau of the upper incisors, which was further subdivided into:

Class II division I: The upper central incisors are proclined or have the average inclination.

Class II division II: The upper central incisors are retroclined.

Class III: The lower incisor edges lie anterior to the cingulum plateau of the upper incisors.

The canine relationship also provides useful insight into the anteroposterior classification of the malocclusion, and it can be described as the following:

Class I: The upper canine occludes directly in the embrasure between the mandibular canine and the first premolar.

Class II: The upper canine occludes anterior to the embrasure between the mandibular canine and first premolar.

Class III: The upper canine occludes posterior to the embrasure between the mandibular canine and first premolar.

4.3. Class III Malocclusion

4.3.1. Definition of Class III malocclusion

According to Angle classification, a Class III malocclusion is one in which the lower permanent molar is positioned anteriorly relative to the upper permanent molar by at least the width of one bicuspid, with no specifications to the line of occlusion. On the other hand, (BSI) described it in terms of incisor relationship as to when the lower incisors edges occlude anterior the cingulum plateau of upper incisors (Jaradat, 2018).

It is now widely accepted that Class III malocclusion is nearly invariably caused by a skeletal misalignment, rather than merely dental anomalies. In that instance, it is defined as a maxillofacial disorder that is characterized by a concave profile, which may exhibit mandibular protrusion, maxillary retrusion, or a combination of both (Chang et al., 2006).

Further, Charles Henry Tweed classified Class III malocclusions as a pseudo Class III malocclusion with normal mandible and underdevelopment of maxilla (category A) and skeletal Class III malocclusion with prognathic mandible or underdevelopment of maxilla (category B). Occasionally, due to dental compensation, sometimes there is a Class I dental relationship on the Class III skeletal base (Zere et al., 2018).

4.3.2. Prevalence of Class III malocclusion

A wide range of reported prevalence rates of Class III malocclusion has been found among and within different races, ethnic groups, and geographic studied regions, even with conflicting results. These discrepancies might be attributed to the variation among samples, the timing of the investigation, and/or the type of analysis performed.

A prevalence rate ranging from 0% to 26,7% was found in the general population (Hardy et al., 2012). Populations from the Southeast Asian countries, Chinese and Malaysian showed the highest rate of 15,8%, 15,69%, and 16,59% respectively (Lew et al., 1993; Tang, 1994; Woon, 1989; Soh et al., 2005), while the Indian population had the lowest rate of 1,2% (Gaubha et al., 1998; Woon, 1989; Soh et al., 2005). Among Japanese, it was around 14%, for Koreans ranged from 9% to 19%, and about 1,65% for Taiwanese.

Middle Eastern nations had a mean prevalence of 10,18%. The rate was 14% for Syrians, ranging from 15,4% to 20,5% for Saudi Arabian individuals, and Egyptians showed a rate from 4% to 11,38% (El-Mangoury and Mostafa, 1990; Toms, 1989; Mouakeh and Sulaiman, 1996; Behbehani, 2005; Staudt and Kiliaridis, 2009; Gudipani et al., 2018; Fatani et al., 2019).

The European studies had an average prevalence rate of 4,88% and ranging from 2% to 6%. Italians showed a rate of 5%, for Germans it was 2,8%, while British had a rate of 2,9% (Sidlauskas and Lopatiene, 2009; Perillo et al., 2010; Silva and Kang, 2001).

Latins had a 5% prevalence rate and it has been found that it is more prevalent in Hispanic than in African or Caucasian groups, as prevalence rates of about 9,1% and a rate of 8,3% were reported for Americans and Mexican Americans, respectively (Silva and Kang, 2001).

Regarding the Turkish population, many different studies have been published with varying results as the following: (Sayin and Turkkahraman, 2004) 12%, (Gelgor et al., 2007) 18,44%, and (Uslu et al., 2009) 10,3%.

Besides the ethnic group, gender differences in prevalence rate have been reported, with Class III malocclusion being three times more prevalent in males than in females (Baccetti et al., 2005).

4.3.3. Components of Class III malocclusion

The description suggested by Angle was more of a phenotypic description that was based on molars' relationship alone, and although it had become widely used due to its simplicity, it had its flaws that have led to many critics by many authors.

The fact that it does not take into account the underlying skeletal relationship, as well as lack of transverse or vertical considerations, are both obvious shortcomings in terms of defining the components of Class III malocclusion.

Class III malocclusion rather represents a complex three-dimensional facial skeletal imbalance between maxillary and mandibular growth along with varying degrees of dentoalveolar and soft tissue compensations that can be expressed in many morphological ways (Zere et al., 2018). Hence, both skeletal and dentoalveolar components can be present as components of a Class III malocclusion case.

It has been reported that the origin of Class III malocclusions was to be skeletal discrepancies in 75% and dentoalveolar in 25% of the sample (Staudt and Kiliaridis, 2009). This was coinciding with the results of other previous research as the skeletal discrepancy was detected in 87,7% (Sanborn, 1955), 75% (Jacobson et al., 1974), and in 68,6% (Ellis and McNamara, 1984) of their samples respectively. These skeletal discrepancies can exist in many patterns of maxillary retrognathism, mandibular prognathism, or a combination of both.

In regards to the maxillary skeletal position, pure maxillary retrusion was found in one-third of the sample of (Sanborn, 1955), 38% in the study of (Dietrich, 1970), same finding in 26% of (Jacobson et al., 1974) patients, while (Ellis and McNamara, 1984) had reported a significant prevalence of 65% to 67% of the sample having retrusive maxilla. Furthermore, 57% of the patients with either a normal or a prognathic mandible showed a deficiency in the maxilla (Guyer et al., 1986).

Park and Baik classified Class III malocclusions based on the position of the maxilla relative to the craniofacial skeleton into three basic types:

Type A: true mandibular prognathism, individual with normal maxilla and prognathic mandible.

Type B: Individual with excessive growth of maxilla and mandible, but with relatively more growth of the mandible.

Type C: Individual with maxillary hypoplasia (Park et al., 2001).

On the other hand, the mandibular skeletal protrusion is, if not the most prevalent feature, a prominent feature in the majority of Class III malocclusion individuals, as it was found in 71% of the sample (Ellis and McNamara, 1984). Dietrich's investigations had concluded that 31% of his sample exhibited pure mandibular protrusion compared to 49% of the sample studied by Jacobson and coworkers, one that is quite close to the finding by Sanborn of 45%.

A combination of maxillary retrusion and mandibular protrusion was the most common amongst all possible combinations. It has accounted for 30% of the findings in the study of (Ellis and McNamara, 1984). This is in contrast to the results of Sanborn who found this combination in only 9,5% of his sample; Dietrich had only 1,5% of this combination in his sample, and Jacobson and coworkers who found the combination in only 6% of their sample.

In recent studies, findings reported in the study of (Spalj et al., 2008) were as follows: mandibular prognathism in 43% of the sample size, maxillary retrognathism in 19,6%, and the combination of both was the least often observed with only 4,7%.

The study of (Staudt and Kiliaridis, 2009) had introduced the relative size of the maxilla and mandible, which improved the differentiation between the various skeletal types of Class III malocclusion, and this paves the way for specific diagnosis and treatment focusing on the actual site of skeletal discrepancy. The analysis showed that around 47,4% had pure mandibular contribution in position or size, 19,3% had pure maxillary contribution in position or size, and 8,7% had a combination of both.

From the dentoalveolar aspect, several studies showed maxillary incisors protrusion and mandibular incisors retrusion, as the teeth tend to compensate for the sagittal skeletal discrepancy (Ellis and McNamara, 1984; Guyer et al., 1986; Mouakeh, 2001;

Ishii et al., 2002; Spalj et al., 2008). Moreover, Class III molar and canine relationship with a decreased overbite, anterior open bite, and negative overjet are common findings (Gelgor et al., 2005).

From a vertical standpoint, the expression of vertical proportions in these cases is most dramatic in the anterior part of the face, most notably in the lower anterior facial region. An increase in the lower facial height was reported and the lower-facial-height values were greater in most cases. (Jacobson et al., 1974; Ellis and McNamara, 1984; Guyer et al., 1986; Ishii et al., 2002).

The findings of (Staudt and Kiliaridis, 2009) were not much different, as Class III patients had more hyperdivergent vertical dimensions, with increased lower anterior facial heights.

4.3.4. Etiology of Class III malocclusion

Class III malocclusions, like most of the malocclusions and dentofacial abnormalities, are of multifactorial origin, and rather than being caused by a pathological process, it is caused by a distortion of normal development. Expressions of Class III malocclusion are results of interaction between innate factors or genetic hereditary with environmental factors (Kawala and Antoszewska, 2007).

4.3.4.1. Etiology of mandibular prognathism

Mandibular prognathism is one of the best-known facial genetic traits or phenotypes. It is also well recognized that ethnicity is a risk factor; the highest incidence has been observed in Asian populations and the lowest in Caucasian populations (Lew et al., 1993; Tang, 1994; Soh et al., 2005; Spalj et al., 2008).

Familial aggregation studies suggest that familial environmental factors or genetic

components play an important role in its etiology. Several studies have found that relatives of afflicted probands have a much greater occurrence of mandibular prognathism (Stiles and Luke, 1953; Kraus et al., 1959; Schulze and Wiese, 1965).

There have been multiple studies regarding the offsprings of affected parents in Japan, and incidence rates vary from when the father was affected: 31%, the mother was affected: 18%, or when both parents exhibited this trait: 40% (Suzuki, 1961). In siblings of affected probands, a frequency of 13% was found regardless of gender (Litton et al., 1970).

Perhaps one of the most popular examples was of the Habsburgs; one of Europe's most well-known families. The term "Habsburg jaw" has been coined to describe the prognathic mandible seen in 23 successive generations of this family (Wolff et al., 1993; El-Gheriani et al., 2003). However, probably, the prognathism in the Hapsburg family was heavily influenced by inbreeding, an autosomal recessive pattern, and other multifactorial inheritance possibilities. Analyses of less inbred groups usually indicate an autosomal dominant mode of inheritance with incomplete penetrance and variable expressivity in some families and multifactorial influences in others (Otero et al., 2014).

Even though there appears to be a strong familial tendency in the development of mandibular prognathism, the rate in patients with a positive family history 49,3%, is not significantly greater than in those with a negative family history of 50,7% (Susami, 1968).

The pattern of transmission remains a point of contention. According to some authors, it is autosomal recessive, while others believe it is autosomal dominant with complete or incomplete penetrance; yet, some others support the polygenic transmission mode (Sidman et al., 1981; Cruz et al., 2008).

Multiple environmental factors are thought to influence mandibular prognathism, including incorrect mandibular postural habits, that modifies the mandibular condyle location inside the fossa and, as a result, the ultimate mandibular spatial position manifests with a forward movement of the mandible. Other habits such as the history of prolonged sucking habits or resting tongue habits. Obstruction of the airway caused

by enlarged tonsils, nasal airway blockage, acromegaly (enlarged tongue), or mouth breathing which results in functional mandibular anterior shifts to meet those respiratory needs. Endocrine disruptions, hormonal imbalances such as gigantism or pituitary adenomas, and trauma. Congenital anatomic deformities (CLP), since cleft cases with midfacial deficiency usually underdevelop anteroposteriorly and also vertically, leading the accentuation of the relative mandibular protrusion in maxillary retrognathism or mandibular prognathism (El-Gheriani et al., 2003; Chang et al., 2005a; Chang et al., 2005b; Cortés and Granic, 2006; Chang et al., 2006; Sugawara et al., 2016).

Multiple syndromes such as Crouzons and Apert syndrome have been suggested to play a definitive etiological role in mandibular prognathism. Mandibular prognathism has also been linked to some systemic conditions such as acromegaly (Gosau et al., 2009).

4.3.4.2. Etiology of maxillary retrognathism

Genetic etiological factors exhibited in medical syndromes such as Pfeiffer syndrome, Treacher Collins-Franceschetti, Crouzon, and achondroplastic dwarfism have been found to contribute to the condition. Crouzon syndrome is characterized by premature craniosynostosis, mid-facial hypoplasia, and exophthalmos (Bertelsen, 1958). The analysis of a Crouzon skull revealed that the maxilla was rather short and narrow, the mid palatal and the transverse palatal sutures were partly fused, whereas the bilateral vertical squamous sutures between the palatine bones and the two maxillae were completely fused. Nearly all other maxillary sutures revealed initial signs of synostosis (Kreiborg and Bjork, 1982).

Pfeiffer syndrome is a genetic disorder characterized by the premature fusion of certain skull bones (craniosynostosis). This early fusion prevents the skull from growing normally and affects the shape of the head and face.

Cleft lip and palate defects are considered etiological factors as well. It was suggested that much of the anteroposterior deformation in repaired clefts is iatrogenic, caused by

stretching of undersized tissues in bridging the cleft and thus leading to the formation of scar tissue impeding facial growth (Ross, 1987).

4.3.5. Diagnosis of Class III malocclusion

The term diagnosis is defined as the identification of disease by careful investigation of its symptoms and history. While not a true disease per se, malocclusions are the disease processes of orthodontics and the central focus of orthodontic diagnoses.

As it has been discussed, Class III malocclusions are multifactorial in origin, with multiple possible genetic and environmental etiological factors might be contributing. Moreover, it is an anomaly that might consist of several different components; skeletal and dentoalveolar alike and the exhibition of those features can exist in all three dimensions; sagittal, transverse, and vertical.

Hence, an accurate and thorough diagnosis that takes into consideration every factor that potentially contributes to the etiology as well as evaluating each possible component of the malocclusion is essential to determine the proper approach and treatment timing, and thus be able to manage the abnormality appropriately and efficiently (Nanda, 2005).

Initially, clinicians should differentiate between a true Class III and a pseudo-Class III malocclusion. A careful examination of the relationship of the mandible to the maxilla to determine whether a centric relation (CR)-centric occlusion (CO) discrepancy exists is mandatory. A pseudo-Class III malocclusion is one that is caused by the forward sliding of the mandible due to abnormal or premature teeth contact resulting in an anterior positioning of the mandible.

Patients who present with an anterior functional shift upon closure may have a normal facial profile and Class I molar relationship in (CR), but a concave profile due to the prognathic mandible and Class III molar relationship in (CO). Whereas, no shift on closure, Class III dental relationship with prognathic profile suggests that such a

patient most likely has a skeletal true Class III malocclusion (Giancotti et al., 2003; Nanda, 2005).

Such cases are usually associated with proclined maxillary incisors and retroclined and spaced mandibular incisors (Turley, 2007). In most cases of pseudo-Class III malocclusion, the reason is the retroclined maxillary incisors (Hägg et al., 2004). A premature contact between the maxillary and mandibular incisors results in a forward displacement of the mandible so as to disengage the incisors and allow for posterior teeth occlusion (Lee, 1978; Gravely, 1984).

The early detection of pseudo-Class III malocclusions is of utmost importance, and correction of the anterior crossbite must be carried out as soon as possible, to increase the orthopedic effects, thereby increasing the long-term stability of the treatment results (Barnabé Raveli et al., 2004). The risk of a pseudo-Class III malocclusion, going undetected and untreated, developing into a true skeletal Class III malocclusion because of the impediment of the natural growth process of the jaws, additionally complicates the treatment (Major and Glover, 1992; Proffit et al., 2007).

The incidence of pseudo-Class III malocclusion in a sample of 7096 Chinese children was estimated to be 2% to 3%, which is one and a half times that of skeletal Class III malocclusion in the same population, and with such an incidence, it is essential to identify diagnostic criteria for pseudo-Class III malocclusion (Lin, 1985).

Upon profile view evaluation, many characteristics of skeletal Class III malocclusion can be observed. In regards to maxillary retrognathia, the following features can be seen: increased total anterior facial height, flatness of malar infraorbital, cheek and paranasal region, over protruded mentum, and normally shaped labiomental fold (Arnett and Bergman, 1993).

Meanwhile in mandibular prognathism, a concave profile, well-defined and clockwise rotated mandibular border outline, slightly overprotruded mentum, and normally shaped labiomental fold can be noticed.

Assessment of the vertical dimension should not be overlooked. Class III patients can either have a high angle hyperdivergent vertical growth pattern or a low angle

hypodivergent vertical growth pattern. (Nanda, 2005) mentioned the use of occlusal plane inclination (OP°) and the ratio of lower anterior facial height (LAFH) to total facial height (TFH). The average occlusal plane inclination is 7 degrees, and the norm ratio of LAFH/TFH is 0,55. Patients with OP° greater than 7 degrees and a ratio of LAFH/TFH greater than 0,55 are high angle cases, while those having OP° less than 7 degrees and a ratio of LAFH/TFH less than 0,55 are low angle cases. It is crucial to define the vertical growth pattern of the cases as the treatment approach and the device of choice differ greatly amongst those variations.

Growth assessment, although being highly unpredictable is a very important part of the diagnostic process. It is imperative to define the growth stage of the patient and whether the growth spurt has been reached, passed, or not. The amount and rate of remaining growth prove to be very challenging to determine or even speculate, while the pattern of growth is much easier to describe.

The following process of setting treatment objectives and defining a treatment path is very much dependable on the growth stage of Class III patients.

4.3.6. Treatment of Class III malocclusion

After establishing a definitive diagnosis, a list of the problems that have been found is generated. This list acts as a framework upon which a set of treatment objectives aiming to address each one of these problems is put together giving a general blueprint of the pathway to achieving the desired goals of treatment. Eventually, a full treatment plan including the appropriate and specific approach, biomechanics, and appliances to use is designed. It is important to realize that the diagnosis and treatment plan are dynamic processes, continuous monitoring of the treatment objectives is mandatory throughout the treatment to evaluate the need for any adjustments or corrections.

Constructing a treatment plan for Class III malocclusions can be demanding as it depends on multiple factors to be taken into consideration. To start with, the growth

stage of the patient plays a major role as developing and non-developing Class III malocclusions have their own distinctive and different management strategies and timing of treatment.

Many authors, aiming to obtain growth modification, have suggested the concept of early treatment or the two-phase treatment for developing malocclusions through orthopedic techniques. However, the debate about the efficacy of such an approach remains under discussion, as some studies supported it showing greater orthopedic effects when treatment started in younger patients (Sakamoto, 1981; Mermigos and Andreasen, 1990; Baccetti et al., 1998; Kapust et al., 1998; Franchi et al., 2004). On the other hand, other studies reported significant relapse for patients who resumed the original growth pattern (Sugawara et al., 1990; Hagg et al., 2003; Baccetti et al., 2004). According to (Proffit, 2007), treatment is indicated once the Class III malocclusion is diagnosed, while (Rabie et al., 2008) stated that for growth modification the treatment should be initiated pre-growth spurt.

Expansion and partial fixed appliance is one of the treatment modalities aiming to correct anterior crossbite in young patients, especially those with a functional pseudo-Class III malocclusion.

As for skeletal malocclusions, other treatment options are available in an attempt to correct the underlying skeletal cause by the means of growth manipulation. Chin cup therapy aims to provide growth inhibition or to redirect mandibular growth, but since it does not affect the maxilla; protraction facemask therapy is found superior as it takes into consideration the maxillary component as well by applying forward pull on the retrognathic maxilla. Functional removable appliances like the Frankel III regulator were also used for growth modification treatments, also being widely used as retention appliances following facemask treatments.

Needless to say that the vertical growth pattern also affects the treatment of choice. Both chin cups and the protraction face mask devices are contraindicated in patients with high angle growth patterns. Nanda introduced the modified protraction facemask in 1980 for such patients with anterior divergence.

For nongrowing Class III patients, the treatment is mainly based on two concepts: orthodontic camouflage treatment and orthognathic surgical intervention.

Depending on the severity of the case, mild to moderate cases of Class III malocclusions can be camouflaged with fixed orthodontic treatment. A camouflage treatment means that the underlying skeletal discrepancy is accepted and remains unchanged while the objective is providing a stable, aesthetic, and functional occlusion by the mean of dental compensations.

Some of the available methods are, conventional fixed treatment with or without dental extractions, multiloop edgewise archwire (MEAW) with Class III elastics, lower arch retraction using temporary anchorage devices (micro-implants) in the mandible, and maxillary micro-implants or mini-plates with Class III elastics. The vertical component and patient's preference can be decisive factors in choosing the appropriate treatment option.

However, in the severe cases of skeletal Class III malocclusions, where previously mentioned conventional treatment options are inadequate in terms of achieving facioskeletal harmony and stable aesthetic occlusion by just acting on the dentoalveolar apparatus, surgical intervention is the mainstay treatment option for such cases. Different aspects of this subject are explained in detail in the upcoming chapter, as it is the main topic of our thesis.

4.4. Orthognathic Surgery

4.4.1. Definition and history of orthognathic surgery

Orthognathic surgery is derived from the two Greek words “Orthos” meaning straight, and “gnathos” meaning jaw, and also known as corrective jaw surgery or simply jaw surgery. It is a surgical intervention that aims to correct the conditions of the jaw and lower face related to structure, growth, airway issues including sleep apnea, TMJ disorders, malocclusion problems primarily arising from skeletal disharmonies, other orthodontic dental bite problems that cannot be easily treated with braces, as well as

the broad range of facial imbalances, disharmonies, asymmetries and malproportions where correction can be considered to improve facial aesthetics and self-esteem.

Orthognathic surgery can be limited to one jaw hence called a single jaw surgery of the maxilla or the mandible, as well as it can be involving both maxillary and mandibular bone movements in what is called a double jaw surgery or a bimaxillary surgery aiming to correct the maxillofacial deformities.

This surgical intervention is often combined with orthodontic treatment that precedes the operation and continues afterward in order to achieve dental, skeletal, and facial harmony and aesthetics. Nonetheless, a surgery-first approach has also been described in certain cases where preoperative orthodontic treatment is deemed unnecessary, whereas postoperative treatment is needed to provide finishing details for more stable and functional occlusion.

The origin of orthognathic surgery, which was at that time limited to mandibular surgery, was in the United States of America. The first operation for the correction of malocclusion was Hullihen's procedure, which was carried out in 1849 (Figure 3). He, like most surgeons who operated on the jawbones and who performed a remarkable variety of operative procedures, was a general surgeon, but he had also had dental training.

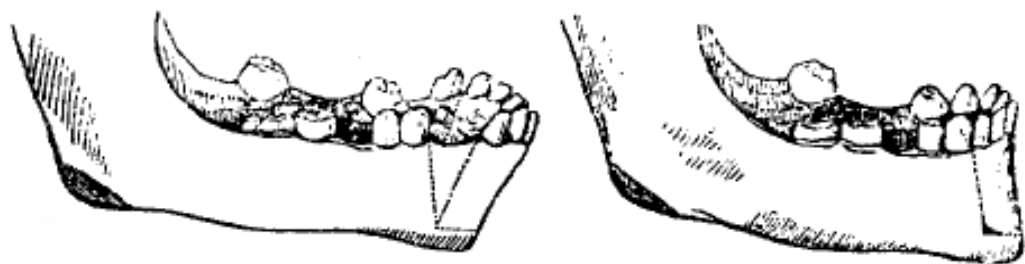


Figure 3. Hullihan's operation in 1849, in a case of distortion of the face with protrusion of the mandibular alveolar segment

Other examples of general surgeons of the 19th century who reported on different maxillofacial operations were Von Langenbeck, Cheever, Billroth, and Dufourmentel.

The cradle of early orthognathic surgery, was in St. Louis where the orthodontist Edward Angle (1898) and the surgeon Vilray Blair (1906) worked together in the first described osteotomy of the horizontal ramus for the correction of a case of mandibular prognathism, in what was later on known as the “St Louis operation” (Figure 4), which was carried out in 1897. This operation was questioned by another American surgeon, Talbot (1907) from Chicago, who even claimed priority for suggesting this type of operation many years earlier, but finally, the St. Louis group of Angle, Blair, and Whipple succeeded in the “Battle of Priority”. The background to this scientific dispute is elaborated upon in the interesting publication by Biederman (1956), who called it “The strange story of the Angle operation”.

There is no question; however, that Blair was the dominant figure in early orthognathic surgery. Before he published his first textbook in 1912, he described several methods for the correction of maxillofacial deformities in an excellent article on “Operations on the Jaw-Bone and Face” in 1907. Blair emphasized how important it is to consider racial differences also in treatment planning to achieve a harmonious face. He was also the first to divide jaw deformities into five classes: mandibular prognathism, mandibular retrognathism, alveolar mandibular and maxillary protrusion, and open bite.

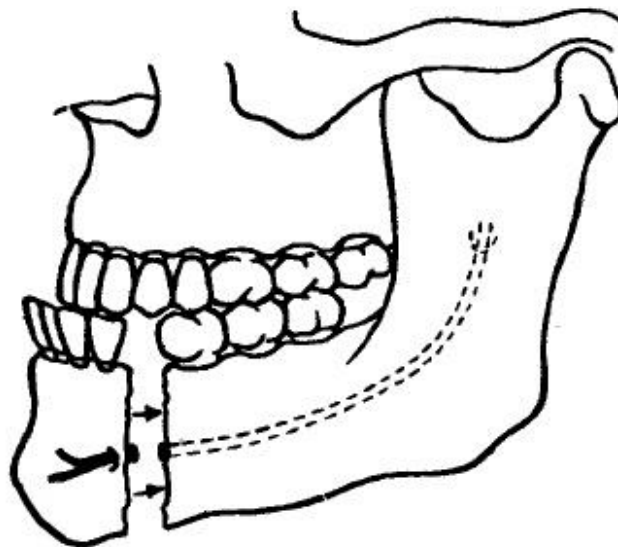


Figure 4. Osteotomy of the mandibular body performed by Blair in 1897 in the St. Louis operation

There is not much to report on orthognathic surgical procedures that were carried out in Europe in the 19th century other than some rare exceptions, such as the report by Berger (1897) from Lyon, France who described a condylar osteotomy for the correction of prognathism. Not long after the First World War, the center of progress in orthognathic surgery had stopped in the USA and moved to Europe, and mainly, Austria and Germany became the predominant countries. Several renowned maxillofacial surgeons invented new methods and new bone cuts for the correction of skeletal mandibular deformities aiming to produce more satisfactory results as the previous procedures of horizontal osteotomy of the ramus and the condylar osteotomy were rather easy but yielded too much relapse and open bite problems. Some of such famous surgeons were Perthes (1922) from Tübingen, Pichler (1928) from Vienna, Wassmund (1935) from Berlin, and Hofer (1936) from Linz. Although the main progress was taking place in Europe, Kazanjian (1932) and Dingman (1944) from the USA must be mentioned as both have described new improved techniques for surgical correction of mandibular deformities.

Again, there was a halt in the development of orthognathic surgery during the Second World War as the few maxillofacial surgeons who were able to perform corrective surgery on the jawbones were totally committed to the treatment of facial injuries and later on overloaded with reconstructive procedures. It was thus until the beginning of the 1950s that orthognathic surgery as a true specialty had its origins, which led to tremendous success all over the world.

The cradle of modern orthognathic surgery was now central Europe, in particular Vienna and Graz, and further north Berlin and Hamburg.

The founder of the “Vienna School” was Pichler, succeeded by his pupil Trauner (1955). Trauner was the inaugurator of several orthognathic surgical procedures, but his main claim to fame was that he trained Heinz Kole and Hugo Obwegeser, who gave the decisive boost to orthognathic surgery. The main innovations that came from Kole were several new methods for changing the position of the alveolar process. To the best of our knowledge, he was the first to describe bimaxillary alveolar surgery for the correction of protrusion, but also a deep bite or short face deformities. He also produced a new technique for open bite closure and for genioplasty, which was proved

to be very successful, because the chin could be advanced and shortened in height at the same time (Kole, 1968). Kole contributed numerous articles to the literature and in 1964 published, together with Reichenbach and Bruckl, the first textbook in the literature on “Surgical Orthodontics”. This book is still a standard work until today (Reichenbach et al., 1964). The other famous pupil of Trauner, Hugo Obwegeser, published the world-renowned method of the intraoral sagittal split of the mandible in 1955. This method, which was improved by the Italian surgeon Dal-Pont in 1958, had opened new dimensions in mandibular surgery; in particular, it was ideal for the advancement of the mandible as no bone grafting was necessary. Obwegeser had also started on maxillary surgery in 1960. He was the first to present a large series of Le Fort I osteotomies (Obwegeser, 1969), at the beginning in non-cleft patients, but a short time later also in cleft patients.

In Berlin, Martin Wassmund who started the “German School” was an important figure in maxillofacial surgery. It was he who developed the anterior maxillary osteotomy, which is still utilized today, in addition to other corrective procedures on the facial skeleton. His famous pupil was Karl Schuchhardt who developed the posterior maxillary osteotomy (Schuchhardt, 1955), as well as an oblique sagittal osteotomy of the mandibular ramus.

It took quite a while until the American oral-maxillofacial and plastic surgeons discovered the Le Fort I and other maxillary and midfacial osteotomies. In the meantime, their European colleagues were 10 years ahead, it was not until the late 1970s and into the 1980s that the USA caught up, with many excellent textbooks on orthognathic surgery being published at this time.

Another important progress in orthognathic surgery was two-jaw surgery, which represents the simultaneous mobilization of the total maxilla and mandible. Kole had already introduced bimaxillary alveolar surgery in 1959, but it took some time to be universally accepted. Obwegeser published his experience in 1970 as the first to perform total maxillary and mandibular osteotomies.

The latest aspect in the development of orthognathic surgery is the application of rigid or semirigid fixation of the bony segments with plates and screws. Bernd Spiessl must be given credit for being the first maxillofacial surgeon to apply the fixation of a

sagittal split osteotomy of the mandible. In 1974, he published an article in which he described the technique of compression screw application in the mandible.

Another maxillofacial surgeon, who did a great deal of work on the development of rigid osteosynthesis in trauma cases and orthognathic surgery, is Hans Luhr from Germany, who in 1979 introduced his own first miniplate set. There is no doubt that rigid fixation brought tremendous progress in the treatment of trauma, and also in orthognathic surgery. Many operations would not be possible today if this method of fixation and stabilization was not available.

The pendulum of progress and development has now swung back to the US where orthognathic surgery started about 100 years ago. With the growing interest of plastic surgeons in this particular field over the last 20 years, and with the association with maxillofacial surgeons, remarkable contributions have been made to this field. The adjunct of blepharoplasty, rhinoplasty, rhytidectomy, liposuction, and lip corrections, just to name a few of these procedures, has led again to a tremendous boost and progress (Steinhauser, 1996).

Finally, with recent technological breakthroughs, the use of 3D imaging in the diagnosis, treatment planning, and post-treatment evaluation became conceivable, and the reported findings were found to be highly intriguing and encouraging. Cone Beam Computed Tomography (CBCT) is also beneficial for informing the practitioner about the patient's skeleton and soft tissues in 3D.

Moreover, with the use of such advanced software, it is now possible to construct different treatment plans, while at the same time providing a virtual visualization of the results and how would they affect the overlying soft tissues.

With those day-to-day breakthroughs in technology, we can only be assured that such digital inventions will not stop, and will open new horizons for this field.

4.4.2. Anatomy of the maxilla and the mandible

4.4.2.1. Maxilla

The maxilla, also known as the upper jaw, is a pair of bones that makes up the majority of the face. It holds the tooth roots and constitutes the majority of the nasal aperture and floor, the majority of the hard palate, and the orbital floors. Most of the maxillary bone is light and brittle, except for the region that houses the teeth.

The maxillae are made up of five main parts, the body and four main processes called frontal, zygomatic, palatine, and alveolar that communicate with one another as well as with the frontal, nasals, lacrimal, ethmoid, inferior nasal conchae, palatines, vomer, zygomatic, and sphenoid bones (Figure 5).

The body of the maxilla is the biggest and pyramid-shaped part. It contributes to the anterior margin and floor of the orbital bone, the anterior wall of the nasal cavity, and the inferior section of the infratemporal fossa.

It contains the maxillary sinuses extending from the orbital ridge down to the alveolar process that drain to the middle meatus of the nose. The infraorbital foramen is an opening that acts as a conduit for the infraorbital nerve and vessels to the face.

The alveolar process is a horizontally extending, inferiorly located extension of the maxilla that forms the upper dental arch, and houses cavities called alveoli that hold the roots of the upper teeth.

The zygomatic process is the portion that extends laterally to meet with the zygomatic bone and forms the majority of the cheek.

The frontal process extends vertically to articulate with the frontal bone and hence the name, in addition to articulating with nasal, lacrimal, and ethmoid bones. It has a vertical ridge that forms the medial border of the orbit named the anterior lacrimal crest. On the posterior aspect, it forms the lacrimal groove and with the lacrimal bone combined, they form the lacrimal canal containing the nasolacrimal duct.

Lastly, the palatine process extends horizontally, and together with the palatine bone, it forms the anterior two-thirds of the hard palate, serving as the roof of the oral cavity and the floor of the nasal cavity. Anteriorly, it has a thin projection on the middle that lies on the inferior margin of the nasal aperture called the anterior nasal spine, and the incisive foramen, a median perforation just behind the upper incisors allowing passage for the nasopalatine nerve and greater palatine vessels.

As for the borders of the maxilla, superiorly is the frontal bone, inferiorly the nasal concha, medially there are the nasal bone and vomer, while the zygomatic bone forms the lateral border, and on the posterior aspect sphenoid, palatine, lacrimal, and ethmoid bones are located.

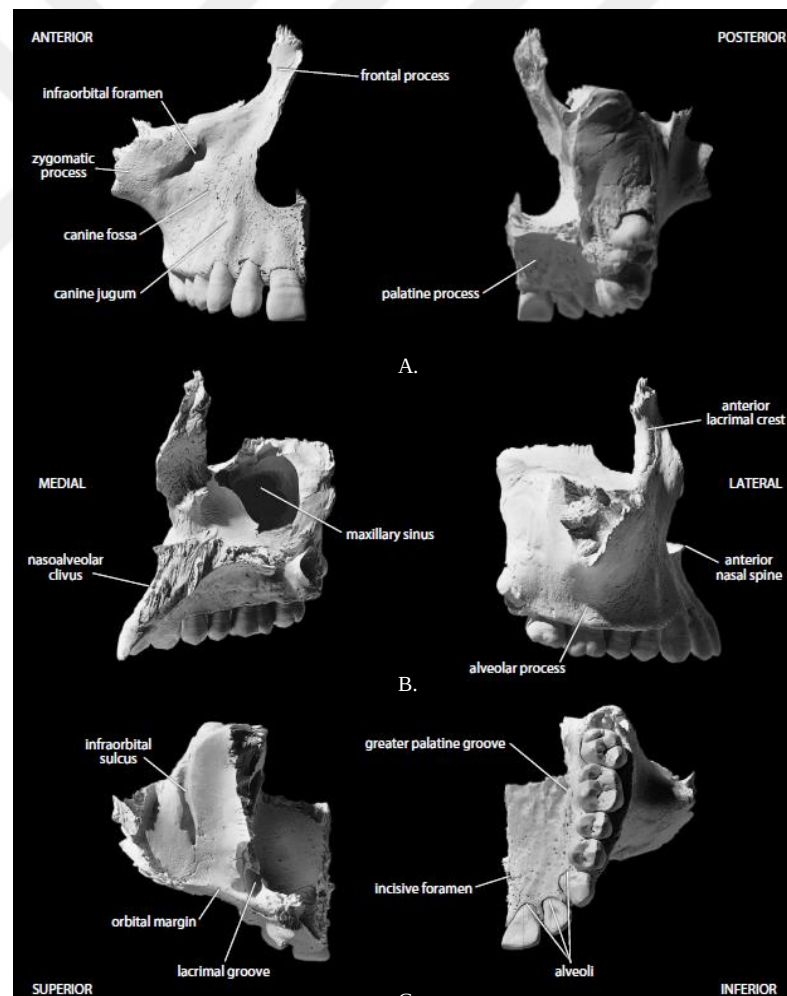


Figure 5. Anatomy of the maxilla (White, 2012). A, Anterior and posterior views. B, Medial and

lateral views. C, Superior and inferior views.

4.4.2.2. Mandible

The mandible also called the lower jaw or jawbone is the largest, strongest, and lowest bone in the human facial skeleton sitting beneath the maxilla. The word "mandible" derives from the Latin word mandibula, "jawbone" (literally meaning "one used for chewing").

It forms the lower jaw, holds the lower teeth in place, and is the only movable bone of the skull (discounting the ossicles of the middle ear) allowing it to contribute to mastication.

The mandible consists mainly of two parts, one is a horizontal part found anteriorly called the body, and posteriorly two vertical processes rising from the body each called the ramus (Figure 6).

The body and the two rami meet on each side at the angle of the mandible or the gonial angle. The rami on the right and the left forms an articulation with the temporal bone through the condylar process located on its superior aspect and thus creating the temporomandibular joint (TMJ).

The body or the corpus forms the anterior portion of the mandible and it is a thick curved horseshoe-like shaped bone with two surfaces and two borders.

The superior border is called the alveolar border and it contains the alveoli which are the cavities housing the lower teeth and thus forming the lower arch, and it is wider in the back compared to the front.

On the other hand, the inferior border is wider and thicker in front than in the back, it is much longer than the superior border, rounded in shape creating the jawline, and has a shallow groove in which the facial artery passes.

On the outer surface, anteriorly and at the median aspect is a slight ridge indicating the mandibular symphysis that fuses at around one year of age connecting the two halves of the mandible. The lower section of it separates downwards enclosing the mental protuberance (the chin), the base of which is sunken in the middle but elevated on both sides to create the mental tubercles. A slight eminence runs backward and upward from each tubercle and meets the anterior border of the ramus called the oblique line. This

line is the attachment site for the masseter muscle, the depressor labii inferioris and depressor anguli oris, and the platysma.

Other anatomical landmarks include a depression known as the incisive fossa situated below the incisive teeth, and the mental foramen located laterally below the second premolar on both sides just midway between the superior and inferior borders of the body allowing passage of mental nerve and vessels.

The internal surface of the mandible, however, has the median ridge at the middle with a pair of laterally located mental spines that give origin to the genioglossus. The mylohyoid line that gives origin to the mylohyoid muscle runs starting from the midline and continues backward and upward to the alveolar border.

The ramus is the other main part of the mandible and it is considerably thinner in comparison to the body. The ascending ramus has outer and inner surfaces, superior and inferior borders, and posterior and anterior borders.

On the lateral aspect, it gives attachment to the masseter muscle; while on the inside is located the mandibular foramen which represents the entrance of the inferior alveolar nerve and vessels that continue to run through the mandibular canal. The lingula is a sharp spine located on the anterosuperior aspect of the mandibular foramen and gives attachment to the sphenomandibular ligament, while at the posteroinferior aspect of the foramen is located the mylohyoid groove encasing the mylohyoid vessels and nerve.

The inferior border of the ramus meets the body of the mandible forming the mandibular angle or the gonial angle.

The superior border extends vertically ending in two processes, the condylar process, and the coronoid process, and they are separated by a deep depression called the sigmoid notch. The coronoid process located anteriorly is thin and triangular, and it is the site of attachment for the temporalis and masseter muscles. The condyle located posteriorly has two parts, the neck and most superiorly the head which constitutes the TMJ throughout the condylar disk.

Posteriorly the ramus is covered by the parotid gland, while anteriorly; it connects with the oblique line of the body of the mandible.

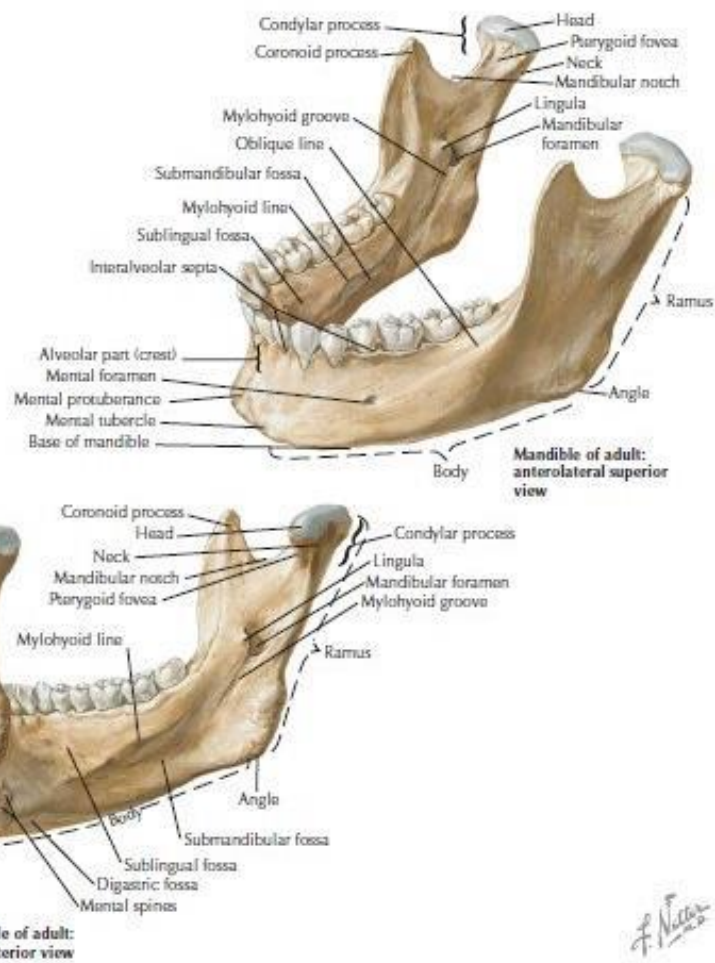


Figure 6. Anatomy of the mandible (Norton, 2006).

4.4.3. Types of orthognathic surgery

Depending on the jaw upon which the surgical procedure is performed, orthognathic surgery can be classified into maxillary orthognathic surgery and mandibular orthognathic surgery, both of which are referred to as single jaw surgery.

On the other hand, when the surgery involves both of the upper and lower jaws, it is then referred to as a double jaw orthognathic surgery or bimaxillary orthognathic surgery, which is the most common type of orthognathic surgery (Haryani et al., 2016).

4.4.3.1. Orthognathic surgery of the maxilla

Maxillary orthognathic surgery depends mainly on a cut of the maxillary bone called LeFort I Osteotomy, called after Rene LeFort's 1901 description of a fracture pattern that extends from the nasal septum, through the tooth apices, and into the pterygomaxillary junction. This cut allows for manipulation of the maxilla in all three planes for proper placement and repositioning achieving facial and skeletal harmony, and it has acquired appeal for a wide range of applications due to its versatility and simplicity.

Class III malocclusion is one of the most common indications for LeFort I Osteotomy, as it enables horizontal advancement of the maxilla to correct such deformity. Furthermore, it is indicated for the treatment of cleft lip and palate patients as they suffer from a significant Class III malocclusion with narrow and collapsed upper dental arch (Scolozzi, 2008). Moreover, other skeletofacial deformities such as vertical maxillary excess call the need for such surgical intervention as it is possible to decrease the vertical position of the maxilla and thus reduce the amount of gingival show. The combination of LeFort I Osteotomy along with mandibular surgery is indicated as well for the treatment of patients diagnosed with severe Class II malocclusions.

This procedure can be one of the most enjoyable and efficient if it was planned and executed properly. Continuous cooperation and intercommunication between all involved parties including mainly the orthodontist and the maxillofacial surgeon are essential for the success of the treatment. Preoperative orthodontic treatment if deemed necessary, especially in cases of naturally compensated dentition. This stage might last anywhere from six months to a year, depending on the severity of the dental malocclusion, and if this phase includes tooth extraction, the length will be extended. This stage includes arch coordination, decompensation, aligning, and leveling. Once the patient is ready to undergo surgery, a facebow transfer is done and after thorough diagnosis and evaluation of the skeletal, facial, dental, and occlusal aspects, a surgical treatment plan is designed to achieve the desired goals. A surgical splint is made to help guide the surgeon while repositioning the maxilla. The patient is then prepared for surgery, nasotracheal intubation is preferred so that occlusion and position of the

maxilla can be checked during surgery without any interference or difficulty. A horizontal incision through the mucosa is then done in the buccal sulcus circumferentially from right to left first molars, using a number 15 blade or with electrocautery on a low setting. Careful and continuous dissection across the submucosal tissue should proceed to the bone. A mucoperiosteal flap is elevated with a number 9 Molt periosteal elevator exposing the surface of the maxilla both anteriorly and posteriorly. After exposure, the osteotomy is marked using a sterile pencil or with a high-speed bur. Care should be given to the root apices of upper teeth not to damage them, by using the canine root as reference being the longest.

The osteotomy cuts are then carried out using a reciprocating saw, starting at the lateral maxillary buttress, directed to the ipsilateral piriform rim, and done bilaterally, followed by separation of the pterygoid plates at the pterygomaxillary junctions using a curved osteotome. Lateral nasal wall osteotomy is initiated next using a safe-sided osteotome, and then a U-shaped osteotome is used to separate the nasal septum from the maxilla. Once all osteotomies are carried out, downfracture can be made with light force digital pressure, and if significant resistance is encountered, the osteotomy cuts are repeated to ensure complete separation. Once the maxilla is free and mobile, it is repositioned according to the prefabricated surgical splint that guides the surgeon to position the maxilla correctly as planned. Upper and lower teeth are ligated together to fix the maxilla in its new position, generally by using 26–28 gauge stainless steel wires tied to the surgical hooks placed on the dental arch wires before surgery.

If impaction is planned then the anterior maxillary bone, vomer, and septum are reduced as much as needed with great care that should be given to establish a stable base and avoid any nasal deviations. On the other hand, if excessive horizontal or downfracture vertical movements are done in a way that creates large gaps, bone grafts should be taken into consideration for having stable results.

After the final position of the maxilla is achieved, maxillary dental midline and transverse occlusal plane cant are correct, occlusion is checked and agreed upon, and all teeth are fitted in occlusion with the surgical guide with no interferences, the maxilla is fixed using titanium plates and screws, and any adjustments such as bending of the plates to better fit the maxillary surface are done prior to fixating them.

Closure of the incisions is done, a V-Y advancement of the mucosa tissue can be done to help prevent a flat upper lip (Hackney et al., 1988), and some surgeons choose an alar-cinch stitch to reconstruct the nasalis muscle's detached insertions and assist in avoiding any nasal-base broadening (Buchanan and Hyman, 2013). For vestibular incisions closure, resorbable sutures such as 3,0 or 4,0 Vicryl sutures in a horizontal mattress-type are made.

The patient is hospitalized for one night for further monitoring and help with postoperative pain and nausea. Maxillary-mandibular or intermaxillary fixation is recommended by instructing the patient to wear the splint with intermaxillary elastics for maintenance of occlusion.

4.4.3.2. Orthognathic surgery of the mandible

Surgical correction of the mandible in Class III malocclusion patients aims to setback the advanced prognathic mandible or reduce the size of a huge mandibular corpus. There have been many approaches suggested and used by many surgeons throughout history to achieve this goal, but two remain the most commonly used these days, Bilateral sagittal split osteotomy (BSSO) and intraoral vertical ramus osteotomy (IVRO) (Kuroda et al., 2009).

While (IVRO) creates less rotational displacement than (BSSO), making it preferable for rotational mandibular asymmetry cases; hence, less condylar displacement and temporomandibular dysfunction may result from the operation (Lee et al., 2015), but it cannot be used for mandibular advancement and primarily is indicated for setback only, making it less commonly used than the (BSSO). The advantages of (BSSO) include but are not limited to (Beukes et al., 2016; Proffit et al., 2007):

- Provides three-dimensional flexibility in repositioning the distal fragments
- Provides a wide range of movements allowing for advancement as well as a setback of the mandible making it applicable in a wide range of cases
- Wide bony overlap between the cut segments which provides a good bony interface for better and faster healing

- Minimal change in the position of muscles of mastication which reduces relapse caused by muscular traction
- Stable results with the use of rigid fixation (RF)

As for the technique of this operation, it has many similarities to those steps of maxillary surgery. After preparing the patient for surgery, it starts with a mucosal incision at the anterior border of the ramus then extends inferiorly and laterally toward the external oblique ridge then continues into the buccal vestibule distal to the first molar. The dissection continues through the submucosa and then the elevation of the periosteum reaching the bone. The working field dictates that the exposed bony surface extends to the inferior mandibular border and the posterior border of the ramus. Once all the tissue has been dissected and retracted adequately, osteotomies can be carried out.

The lingual is identified, then using a reciprocating saw situated medial to the ascending ramus, superior to the lingula, and parallel to the occlusal plane; a cut is made through the cortical bone and into the cancellous bone, and then continues anteriorly down the external oblique ridge to the level of the second molar. Then a vertical cut extends downward reaching the inferior border of the mandible along the buccal cortex. Osteotomes can be used to ensure that all the cuts made were complete, efficient, and through the cortical bone, and once the two segments are free the surgeon can proceed with mandibular repositioning. Pre-made surgical guide splints help the surgeon to determine the position of the mandible, then occlusion is checked, the condyle is checked as well to make sure it is articulating properly in the fossa. Rigid fixation using titanium mini plates and screws, and then all incisions are closed and sutured. Postoperative health care in the hospital for 24 hours, followed by wearing the splint and guiding elastics for the stability of occlusion.

4.4.4. Adjunctive surgical procedures

In some cases where orthognathic surgery alone was not adequate to obtain a certain satisfying and aesthetic facial characteristic or had yielded results that did not meet

with the patients high expectations, or in cases where an undesirable effect on the soft tissues has resulted from the orthognathic surgery, adjunctive cosmetic surgical interventions are proven very beneficial to further enhance the esthetics and skeletofacial harmony.

According to the facial region involved, these adjunctive procedures fall into the following groups:

- Upper face interventions, such as the forehead, temple, or hairline enhancements.
- Midface interventions, such as orbital, piriform, soft tissue, or lip enhancements as well as malar osteotomies and rhinoplasty.
- Lower face interventions, such as chin implantation or reduction, mandibular angle alteration, submental or jowl and neck liposuction, and lower face or neck rhytidectomy

Three of these procedures will be discussed, as they tend to be the most relevant and commonly attached to orthognathic surgery, including genioplasty, rhinoplasty, and malarplasty.

In addition, it is important to note that since facial attractiveness is a result of all parts and facial structures interrelated to each other rather than being separately interpreted, this means that in many cases more than just one procedure is required to attain the desired balanced beauty of the face.

4.4.4.1. Genioplasty

The chin plays a major role in the lower and total facial harmony and is considered an important factor when assessing attractiveness (Naini et al., 2012). Deformities related to the chin that call the need for adjustment by genioplasty include a small or retrognathic chin, big or prognathic chin, too short or too long chin, or in cases of a misaligned or an asymmetrical chin.

Being able to provide a wide range of movements in all three planes of transverse, sagittal, and vertical as well as giving the ability to alter the chin using changing its

shape, size, and/or position, makes it the most commonly used cosmetic surgical intervention. Furthermore, this procedure can be carried out with orthognathic surgery, or solely in cases where the patient demands chin enhancement but is not willing to undergo full orthognathic surgery.

Genioplasty is based on two main approaches, osseous genioplasty, and alloplastic genioplasty.

Osseous genioplasty is a surgical operation in which an osteotomy is made and the chin is freed from the body of the mandible. This offers manipulation of the sliding segment allowing correction in horizontal, vertical, and transverse planes while in the meantime providing predictable and stable results, making it an efficient and widely adaptable technique to treat a variety of chin deformities (Chang et al., 2001; Jones and Vesely, 2006).

In cases of a small or receding chin, advancement osseous genioplasty aims to protrude the sliding segment forward which gives the chin a more prominent look and position (Deshpande and Munoli, 2011).

On the contrary, reduction genioplasty is indicated in cases of a protruded or large chin, and it is made to reduce the size or retract the bony chin. Inferior border osteotomy and osteoplasty are the two main approaches. The lack of hard tissue support with either operation leads to a decrease of skin elasticity, which might result in an unfavorable soft tissue reaction, and this was found more associated with osteoplasty alongside being unpredictable as the main disadvantages (Profitt et al., 2003).

Finally, yet importantly, anterior chin asymmetry can also be corrected with osseous genioplasty by manipulating the osteotomized segment laterally to the left or the right, vertically by shortening or lengthening it, or sagittally by advancing or retruding it asymmetrically. Nonetheless, a complex procedure that poses difficulty in determining the exact degree of lateral shifting or the exact amount of bone removal to yield a satisfying symmetrical correction.

The second method of genioplasty is the use of alloplastic implants to obtain chin augmentation, where these materials are inserted after making an incision to give the

chin a more pronounced appearance and a larger size.

Mandibular or chin implants, regardless of their type, should have the following characteristics as an ideal implant: immunologically inert, malleable, and readily conformable, and a shape that mimics natural anatomical outline (Louis and Cuzalina, 2000; Yaremchuk et al., 2011). These implants could improve two aspects of the mandibular angle: vertical lengthening and lateral plane widening.

Currently, there are two widely used alloplastic implants, Silastic implants which are the most commonly used, and porous implants, such as Medpor and Gore-Tex.

Although having the pros of being removable, meaning that if the patient was not satisfied with the result, they can be simply taken out, moreover, they allow for an increase of the width laterally. However, the chances that these implants could be complicated with infection, chronic inflammation, extrusion, bone resorption, capsular contraction, displacement, and chin ptosis marks a considerable disadvantage when using them (Hamilton and Chan, 2014).

Dermal fillers, such as body fat, pose a nonsurgical incision-free alternative to enhance the appearance of the chin or enlarge it by a needle injection instead.

Even though dermal fillers leave no scarring and have shorter recovery times than sliding genioplasty and implant surgeries, still the material might dissolve after several months making it obligatory to repeat the procedure.

As for the side effects of genioplasty procedures, temporary findings such as redness or bruising, tenderness or pain, and swelling are common to find.

Possible complications of genioplasty on the other hand might include infection, hematoma, damage to nerves or tooth roots, allergic reaction to the implant material or the filler, or changes in implant position (Khan et al., 2021).

4.4.4.2. Rhinoplasty

Rhinoplasty, commonly known as a nose job, is a plastic surgery procedure for altering and reconstructing the nose. There are two types of plastic surgery used, reconstructive

surgery that restores the form and functions of the nose and cosmetic surgery that changes the appearance of the nose, during which, the nasal cartilage and bones are modified, or tissue is added to improve the shape and look of the nose.

Rhinoplasty can also be used to treat nose fractures and other structural issues with the objective to restore a pre-injury look or establishing a normal appearance.

Although mandibular movements have a minimal direct effect on the nose and surrounding structures since as was mentioned before, all facial structures are interpreted as a whole and in direct correlation with each other, meaning a mandibular surgery resulting in a bit more protruded or retruded chin might create an assumption of a smaller nose or larger nose respectively. On the other hand, maxillary movements directly influence nasal changes, such as an increase in nasolabial angle, alar base width, and tip projection seen in cases of maxillary advancement (Mohamed and Perenack, 2014).

It is still debated whether rhinoplasty should be done concurrently or independently from orthognathic surgery. Supporters of the simultaneous method (Fattahi, 2007; Colbert et al., 2011) claim that correcting maxillomandibular discrepancies and nasoseptal abnormalities in a single operation, decreases postoperative discomfort and gives higher patient satisfaction.

In contrast, the requirement for an endotracheal tube shift from a nasotracheal to an orotracheal tube after orthognathic surgery is a drawback of conducting rhinoplasty during orthognathic surgery. On top of that, the inadequate management of intraoperative swelling and edema around the nose, which can deform nasal architecture and significantly influence the overall result of nasal surgery, is perhaps the most significant disadvantage of combined orthognathic surgery and rhinoplasty (Fattahi, 2007).

4.4.4.3. Malarplasty

The midface or the cheek area is a very important part of facial beauty that often is overlooked. The malar eminence is defined as the most prominent portion of the

zygomaticomaxillary complex, and it dominates the lateral midface and defines cheek projection and contour. A malarplasty or cheek augmentation is a procedure to increase the definition and prominence of the cheekbones.

A common finding in Class III malocclusion patients with a retrognathic maxilla is a deficient midface that a standard LeFort I osteotomy advancement of the maxilla does not correct leaving a facial disharmony.

One of the approaches in malarplasty is the surgical intervention involving a high LeFort I osteotomy, that includes the cheekbones and allows for advancement of the malar region in comparison to the conventional LeFort I osteotomy, thus improving the zygomatic prominence (Nakajima et al., 2016).

The other approach is the use of malar alloplastic implants that may either be prefabricated and trimmed to size perioperatively to conform to the underlying anatomy or custom-made. Commonly used implant materials have included silicone rubber, porous polyethylene, polymethylmethacrylate, polyetheretherketone, and titanium.

According to (Niamtu, 2010), numerous complications related to malar implants have been described including malposition or migration of the implant, underlying bone resorption, and neuropraxia secondary to impingement of the implant on the infraorbital nerve.

4.4.5. Effects of orthognathic surgery on the facial features

In almost all LeFort I osteotomies, widening of the alar base is almost an inevitable result, whether was an advancement or a setback movement of the jaw. It is believed to be due to the muscular detachments from their insertions when the periosteal elevation is carried out which in return leads to retraction of those muscles giving a wider alar base. Meaning it is more related to the technique of the LeFort I osteotomy rather than being actually attributed to the jaw movement itself (Schendel and Carlotti,

1991). Nonetheless, as discussed earlier, a precaution that can be taken to minimize such effect is the alar-cinch suture which could aid in reconstructing the nasalis muscle's detached insertions (Buchanan and Hyman, 2013).

The nasolabial region is impacted directly by the maxillary surgery and is related to the type of jaw repositioning that takes place. Regarding the nasal tip, generally speaking, since all the structures that are associated with tip support are indeed in direct relation with the maxilla, changes in the nasal tip projection and position are only bound to happen with maxillary jaw movements (Altman and Oeltjen, 2007).

The valuable work of (Reyneke, 2007) had given a summary of the changes in the facial aspects related to different types of orthognathic surgeries and jaw movements as follows:

- Maxillary advancement:

Frontal changes include increased elevation of the nasal tip, increase in upper lip fullness and vermilion exposure, and increased paranasal fullness.

Profile changes include increased paranasal area fullness, elevated nasal tip, increased upper lip fullness, and a relatively decreased prominence of chin and nose.

- Maxillary downfracture:

Frontal changes such as increased lower-third face height, increased upper lip length and vermilion exposure, and increased maxillary tooth exposure are seen commonly.

Profile changes related to such jaw movement are increased upper lip prominence, more obtuse nasolabial angle, and less prominent mandible anteroposteriorly (due to autorotation).

- Maxillary impaction:

Changes like reduced maxillary incisor exposure, reduced upper lip vermilion exposure, reduced interlabial distance, reduced upper lip length, reduced lower-third facial height, and reduced gingival show upon smiling are seen in the frontal view.

Whereas from the profile view, notable changes are seen including elevated nasal tip, reduced lower-third facial height, reduced interlabial distance, increased mandibular anteroposterior prominence (due to autorotation), and increased paranasal fullness.

- Mandibular setback:

Changes seen in the profile view related to BSSO are decreased mandibular

prominence, increased upper lip vermilion prominence, and a decreased lower-third facial height.

From the profile view, however, changes such as decreased mandibular anteroposterior prominence, reduced lower lip vermilion exposure, reduced chin-throat length, and increased chin-throat angle are common to find.

4.4.6. Side effects and complications of orthognathic surgery

A side effect is an unwanted result or condition that comes along with the intended outcome of a drug or a specific treatment; it is secondary to the desired result and does not necessarily imply a wrong or faulty approach, rather an adverse common to happen effect of the procedure itself. Patients should always be informed about the expected side effects and how they could be managed.

Whereas a complication is an unanticipated problem that arises following or is a result of a procedure, treatment, or illness, which further complicates the situation and rises the need for immediate intervention. In contrast to side effects, they can be avoided and resolved if happened with a competent surgeon having a proper and full understanding of the causes, types, and treatments of such complications.

Common side effects of orthognathic surgery include pain, inflammation, limited mouth opening, and postoperative swelling (Phillips et al., 2008).

Postoperative pain was found to be the most common reason for patient's stress before surgery, causing high levels of anxiety for almost half of the patients (Gan et al., 2014), and this concern was not fiction as around 80% of the patients having orthognathic surgery have reported experiencing moderate or severe pain postoperatively (Coulthard et al., 2000). Pain hinders physical function, lowers the quality of life and sleep, and lengthens hospitalization (Walker et al., 2016; Joshi and Ogunnaike, 2005). Medications are prescribed for pain relief such as corticosteroids, non-steroidal anti-inflammatory drugs (NSAID), corticosteroids and (NSAID) together, or enzyme preparations like serratiopeptidase (Bamgbose et al., 2005; Benetello et al., 2007; Al-

Khateeb and Nusair, 2008; Shetty and Mohan 2013).

Postoperative swelling is another common side effect of orthognathic surgery, it obstructs the patient, the surgeon, and the orthodontist from correctly and accurately interpreting the effects of the surgery on facial aesthetics. Peak swelling typically occurs approximately 48 hours after surgery, and it may be asymmetrical. As for the resolution of swelling, there has been a vertical gradient found in the reduction of swelling being faster in the maxilla compared with the mandibular region, likely due to the gravity effect on the tissue fluids. Moreover, this reduction might not be symmetrical, with one side often getting better faster than the other (Gill et al., 2017). It was reported that it takes on average three weeks for the swelling to reduce by 50%, three months for it to reduce by 80% (Kau et al., 2007); this matches the findings of the study made by (Van der Vlis et al., 2014).

While (Yamamoto et al., 2016) have monitored the swelling reduction over a more frequent period and had reported that about 30% of the swelling had resolved within the first week after surgery, 66% healing at one month. Around only 12% of the swelling at two months and 5% at three months have persisted.

Various complications of orthognathic surgery have been reported in the literature, and these complications can be divided into two groups depending on the time of their onset, intraoperative complications are ones that happen during the surgery, and postoperative complications that follow the operation.

The work of (Kim and Park, 2007) has been recognized as an important source for understanding multiple possible complications. Damage to the inferior alveolar, superior alveolar, maxillary, retromandibular, facial, and sublingual vessels might result in hemorrhage. Applying pressure, using bone wax or resorbable hemostatic materials, performing thrombin or epinephrine infused gauze packing, or electrocautery can all be used to halt bleeding. To prevent additional delayed bleeding, major vascular damage must be treated with vessel ligation or angiography. Although it is difficult to control the bleeding that occurs in the large vessels in some cases due to the difficulty to access the area, hemorrhage rarely occurs in the intraoperative period.

Dental injuries may happen in cases undergoing mandibular anterior segmental

osteotomy combined with LeFort I osteotomy and genioplasty. Furthermore, unexpected fractures may occur during surgery, which complicates fixation and stabilization. This is most common in (BSSO) of the mandible and in LeFort I osteotomy. Inappropriate bone fragmentation may cause sequestration, a delayed fusion of bones, no fusion of bone fragments, or fibrotic fusion in the region of bone fragmentation.

Soft tissue injuries may occur at different stages of surgery, for example, injuries may occur due to long-term retraction of the mucosa or lip to facilitate access to the operation area.

Numbness in the inferior alveolar nerve has been reported after sagittal split ramus osteotomy, owing to the fact that it is located near the line of osteotomy making it at risk of being damaged during the procedure. Damage to the inferior alveolar nerve has been described as cutting of the nerve during bone dissection, being torn during the separation and movement of the distal and proximal bone segments, and compression damage may occur during the stabilization of the distal fragments.

An open bite may occur in the postoperative period due to failure of fixation screws and/or plates, or postoperative edema that may occur in the joints.

According to (Jędrzejewski et al., 2015), the rate of nerve injury was found to be the highest at 50%, followed by temporomandibular disorder (TMD) at 14%, hemorrhage at 9%, hearing problem 7%, infections 7%, and relapse 4%.

In the study of (Kim et al., 2010), intraoperative complications including inadequate osteotomy, bleeding due to vascular injuries, nerve exposure and damage, dental injuries, and soft tissue injuries among the patients were observed. On the other hand, postoperative complications included paresthesia due to nerve injuries, dyspnea, cervical pain, gastrointestinal diseases, infections, open bite, relapse, TMD, and malunion or nonunion of bone fractures.

Complications such as infections 4,08%, fixation appliance breakage 2,49%, inferior alveolar nerve damage 1,89%, (TMD) 1,02%, and facial nerve problems 0,29% were the findings of the research by (Jung et al., 2006).

Additionally, (Ahn et al., 2010) mentioned multiple postoperative complications such as open bite, infections, TMD, and relapse, and concluded that specifically for an open bite it was more common in cases where resorbable plates were used for fixation instead of rigid titanium plates.

Another issue to be considered is that rigid fixation may cause torque movement in the condyles within the glenoid fossa, and if this progresses to changes in (TMJ) morphology, then it may cause (TMD) (Kersey et al., 2003).

Orthognathic surgery may cause tension or joint sounds (clicks) in the TMJ, and restriction in mandible movements may occur due to scarring and atrophy in the connective tissue (Dujoncquoy et al., 2010).

Postoperative bleeding, nausea and vomiting, nasal and post-nasal discharge are common conditions, especially after maxillary osteotomy (Phillips et al., 2008).

In addition, reductions in pharyngeal airway dimensions have been reported after mandibular setback operations (Muto et al., 2008), and this reduction is believed to be a factor leading to the "Obstructive Sleep Apnea" syndrome (Turnbull and Battagel, 2000).

4.4.7. Retention and stability of orthognathic surgery results

The results of orthognathic surgery, just like all orthodontic treatments in general, are prone to relapse, making the retention of the treatment outcomes a major topic of discussion and a very essential aspect for the overall success of the treatment.

Relapse is defined as the loss of the correction that has been achieved by orthodontic treatment, whether it was dental, skeletal, or both combined. While retention can be defined as maintenance of the newly moved teeth or jaws in their new allocated position long enough to overcome the possibility of relapse and help stabilize the results of the treatment.

Relapse in orthognathic surgery cases can be of two types according to its time of onset, short-term or immediate relapse and long-term relapse. An early recurrence happens as a result of displacement in the osteotomy site during the first 6-8 weeks

after the procedure. Late relapses are shifts that occur in later times.

A poorly planned surgical treatment or poorly conducted surgical procedure such as faulty positioning of the condyle in the TMJ can result in immediate relapse. Whereas common reasons for later relapse include growth spurts, hard tissue remodeling due to muscular activity, an unstable occlusion, or the inability of the muscles of the face to adjust to the new connections between jaws. Additionally, a chronic functional habit of the orofacial muscular system was also mentioned as a potential cause for relapse (De Haan et al., 2013).

Although not explicitly stated, a displacement of more than 2 mm or an angular shift of more than 2 degrees in the initial operational position is considered as skeletal relapse (Proffit et al., 1996); while in general, a change of less than 2 mm following therapy is not clinically noteworthy. A change of two to four millimeters is considered mild relapse; a change of more than four millimeters is considered severe relapse (Proffit et al., 1996).

The required stability following surgical jaw repositioning is determined by the direction of bone movement, the amount of bone movement, the kind of fixation used, and the surgical method.

Although Class III surgery looks to be less stable than Class II surgery in the short term, the effects of Class III surgery tend to be more stable in the long run (Proffit et al., 2007).

The combination of rigid fixation, maxillary advancement, and mandibular setback is acceptable in terms of stability. On the contrary, solitary mandibular setback procedure was shown to be commonly unstable. Similarly, downward repositioning of the maxilla appears to be an unstable procedure since it induces mandibular downward and backward rotation (Proffit et al., 1996; Proffit et al., 2007).

It has also been noted that sagittal adjustments have better long-term stability than vertical jaw movements (Gallego-Romero et al., 2012). A similar conclusion was stated by (Bailey et al., 2004) that when the maxilla is advanced vertically, the sagittal movement was relatively stable while a higher chance of relapse is found for the vertical movement.

According to (Mobarak et al., 2000), mandibular setback with BSSO and rigid fixation is relatively stable, a closely similar finding to (Costa et al., 2001) who concluded that surgical correction of Class III malocclusion with bimaxillary surgery and internal fixation is also relatively stable.

As for the method of retention applied, rigid internal fixation has been found to be superior and more stabilizing in contrast to other methods of retention. (Luyk and Ward-Booth, 1985; Egbert et al., 1995) both concluded that when rigid fixation was used, the results were better in terms of stability compared with wire fixation.

The type of material used for rigid fixation is also another factor of relapse, upon analysis of the rate of complications related to the fixation material used, it was found that complications occurred at a rate of 8,6% when titanium plates were used while it was 18,3% when resorbable plates were utilized. Relapse was more common when resorbable plates were employed, and this was especially true for an open bite (Ahn et al., 2010). Additionally, rigid fixation can be done using bicortical screws or miniplates, especially for the mandible, some studies suggested that miniplates are more preferred however some studies did not report any difference between the two methods (Ochs, 2003; Stoelinga and Borstlap, 2003).

The amount of bone movement is also a considerable factor in terms of relapse, it has been reported that regardless of the kind of fixation used in maxillary and mandibular advancement surgeries, as the amount of advancement increases, so does the relapse rate, for instance, maxillary advancement that is more than 6 mm was associated with a higher likelihood of recurrence (Costa et al., 2001). Moreover, excessive displacements have been demonstrated to cause relapse in other maxillary and mandibular motions.

In the systematic review conducted by (Haas Junior et al., 2019), posterior maxillary expansion with SRIF when evaluated at the dental level and a clockwise rotation movement of the mandible in BSSO with bicortical screw RIF were identified as highly unstable procedures.

Surgical procedures in the maxilla were deemed more unstable than those performed

in the mandible, with the following techniques ranging from stable and unstable: maxillary downward movement with semi-rigid or bioresorbable internal fixation, maxillary setback with titanium or bioresorbable RIF, and maxillary upward movement with bioresorbable RIF.

Mandibular surgical movements were, for the most part, stable or highly stable, with greater stability when achieved through BSSO for mandibular setback and RIF with mini plates and bicortical screws for rotations.



5. MATERIALS AND METHODS

5.1. Ethical Approval

This retrospective study was approved by the Marmara University Clinical Research Ethics Committee, on 21.12.2020 and with the approval number 2020/97 (Enc. 1).

5.2. Patient Selection

This retrospective study was performed on lateral cephalograms taken for Class III skeletal malocclusion patients who were treated by a combined approach of fixed orthodontic treatment in the Department of Orthodontics, Faculty of Dentistry, Marmara University, and bimaxillary orthognathic surgery operated in various hospitals and healthcare facilities including the Surgery Department of Marmara University.

The files and records in the archive system of the Department of Orthodontics, Faculty of Dentistry, Marmara University was searched to select the sample of this study, according to the following inclusion criteria:

- Class III skeletal malocclusion patients
- Patients treated with combined fixed orthodontic treatment and bimaxillary orthognathic surgery consisting of maxillary advancement by LeFort I type osteotomy and mandibular setback by BSSO followed by rigid fixation
- Available records of a presurgical lateral cephalogram and a postsurgical lateral cephalogram taken at least 6 months and no longer than 24 months after surgery
- No craniofacial anomalies or syndromes including cleft lip and palate

- No history of previous orthognathic surgery treatment or history of jaw trauma
- No adjunctive surgical procedures including genioplasty

The exclusion criteria were:

- Class II skeletal malocclusion patients or Class III skeletal malocclusion patients treated with a single jaw orthognathic surgery
- Patients with missing records, or with a postsurgical lateral cephalogram that was taken less than 6 months after surgery
- Patients with craniofacial anomalies or syndromes
- Patients with a history of previous orthognathic surgery or trauma to the jaw
- Patients who underwent adjunctive surgical procedures eg. Genioplasty
- Patients with an open bite more than 3mm
- Patients with no maxillary vertical movement or those with a downfracture or impaction movements that is less than 1 mm

A total sample of 22 patients (8 male, 14 female) who met the criteria was created. The main group was further divided into two subgroups according to the type of maxillary vertical movement achieved by the LeFort I type osteotomy as follows:

- Group A, including 13 patients (7 male, 6 female) whose maxillae underwent at least 1 mm of downfracture.
- Group B, including 9 patients (1 male, 8 female) whose maxillae underwent at least 1 mm of impaction.

All patients or their guardians had signed informed consent forms as part of the routine process at Marmara University's Department of Orthodontics.

5.3. Data Collection and Assessment

After all the patients who met the criteria were identified, their records were taken from the archive system of the Department of Orthodontics, Faculty of Dentistry, Marmara University. The presurgical lateral cephalograms (T1) which were taken within 1 month before surgery once all the leveling and aligning as well as the dental decompensation was completed and the patients were deemed ready to undergo surgery, and the postsurgical lateral cephalograms (T2) which were taken at least 6 months and no longer than 24 months after surgery were collected.

The cephalograms were taken while patients were in centric occlusion and their lips at rest and under the same standardized technique.

The cephalograms were then added to the NemoCeph cephalometric software (Nemotec, Leganés, Madrid, Spain) and traced by a single examiner to avoid bias.

5.3.1. Cephalometric points, reference planes, and reference lines

Landmarks were identified on the cephalograms using the digital tracing software, based on which reference planes connecting two points were formed, and the measurement angles and values were constructed consequently. Moreover, two reference lines were constructed and used in the analysis.

The cephalometric landmarks fall into three categories; skeletal, dental, and soft tissue landmarks.

- Skeletal landmarks (Figure 7):
 - Nasion (N): The most anterior point on the frontonasal suture.
 - Sella (S): The midpoint of the sella turcica (pituitary fossa).
 - Orbitale (Or): The most inferior and anterior point on the orbital margin.

- Basion (Ba): The most posterior and inferior part of the foramen magnum.
- Porion (Po): The upper outermost point on the external auditory meatus.
- Anterior nasal spine (ANS): The most anterior extension of the maxilla.
- Posterior nasal spine (PNS): The most posterior extent of the hard palate.
- Pogonion (Pg): The most anterior point on the bony chin.
- Menton (Me): The most inferior point of the mandibular symphysis in the midline.
- Gonion (Go): The most posterior and inferior point on the angle of the mandible.
- Gnathion (Gn): The most anterior and inferior point on the bony chin, located nearly midway between menton and pogonion.
- Point A (subspinale): The deepest point on the curved profile of the maxilla between the anterior nasal spine and alveolar crest.
- Point B (supramentale): The deepest point on the curved profile of the mandible between the chin and alveolar crest.
- Articulare (Ar): The intersection of the posterior border of the neck of the mandibular condyle and the lower margin of the posterior cranial base.
- Condylion (Co): The most superior and posterior point on the head of the mandibular condyle.
- Pterygomaxillary fissure (Ptm): The most upward and backward point of the pterygomaxillary fissure.
- Centre of the face (CF): A point formed by the intersection of a line from (Ptm) point that is perpendicular to Frankfort Horizontal plane.

- Dental landmarks (Figure 7):
 - U1i: Incisal edge of maxillary central incisor crown.
 - U1a: Apex of maxillary central incisor root.
 - L1i: Incisal edge of mandibular central incisor crown.
 - L1a: Apex of mandibular central incisor root.
 - U6m: Most mesial point on the contour of the maxillary first molar.
 - U6d: Most distal point on the contour of the maxillary first molar.
 - L6m: Most mesial point on the contour of the mandibular first molar.
 - L6d: Most distal point on the contour of the mandibular first molar.

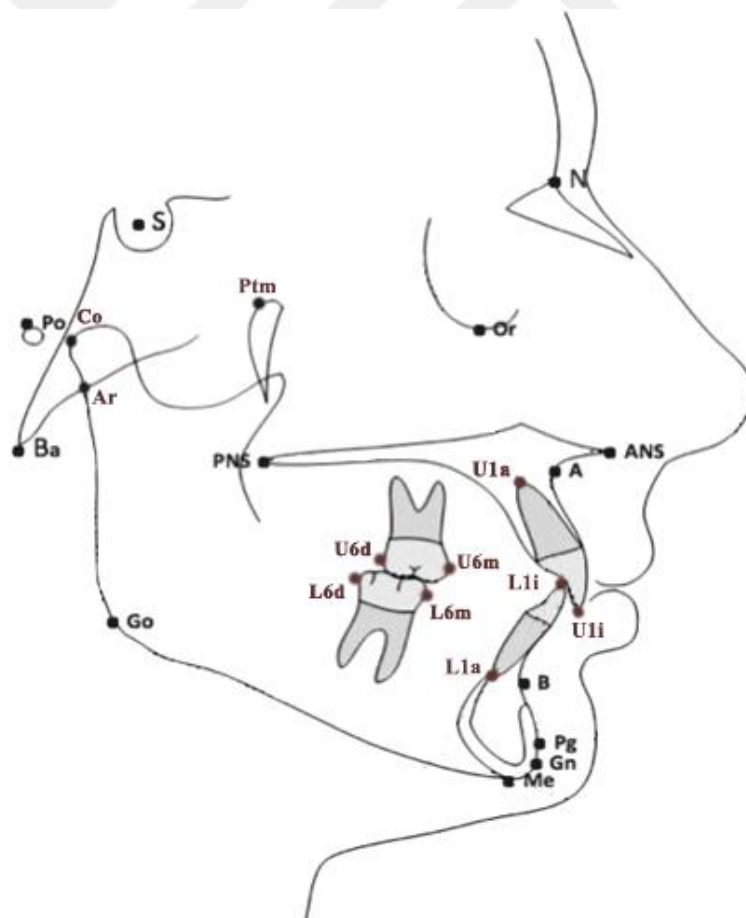


Figure 7. Skeletal and dental cephalometric landmarks.

- Soft tissue landmarks (Figure 8):
 - N': Soft tissue nasion point.
 - Pn: Pronasale point, the most prominent point on the tip of the nose.
 - Cm: Columella point, the most anterior point on the columella of the nose.
 - Sn: Subnasale point, a point at which the nasal septum merges with the upper cutaneous lip in the midsagittal plane.
 - A': Soft tissue A point, represents the superior labial sulcus.
 - ULA: Upper lip anterior point, also referred to as labrale superius point (Ls).
 - Sts: Stomion superius point, the lowest point of upper lip vermilion.
 - ULI: Upper lip inside.
 - LLI: Lower lip inside.
 - Sti: Stomion inferius point, the highest point of lower lip vermilion.
 - LLA: Lower lip anterior also referred to as labrale inferius point (Li).
 - B': Soft tissue B point, represents the inferior labial sulcus.
 - Pog': Soft tissue pogonion point, the most anterior point on the soft tissue chin.
 - Me': Soft tissue menton point, the lowest point on soft tissue over mandible.

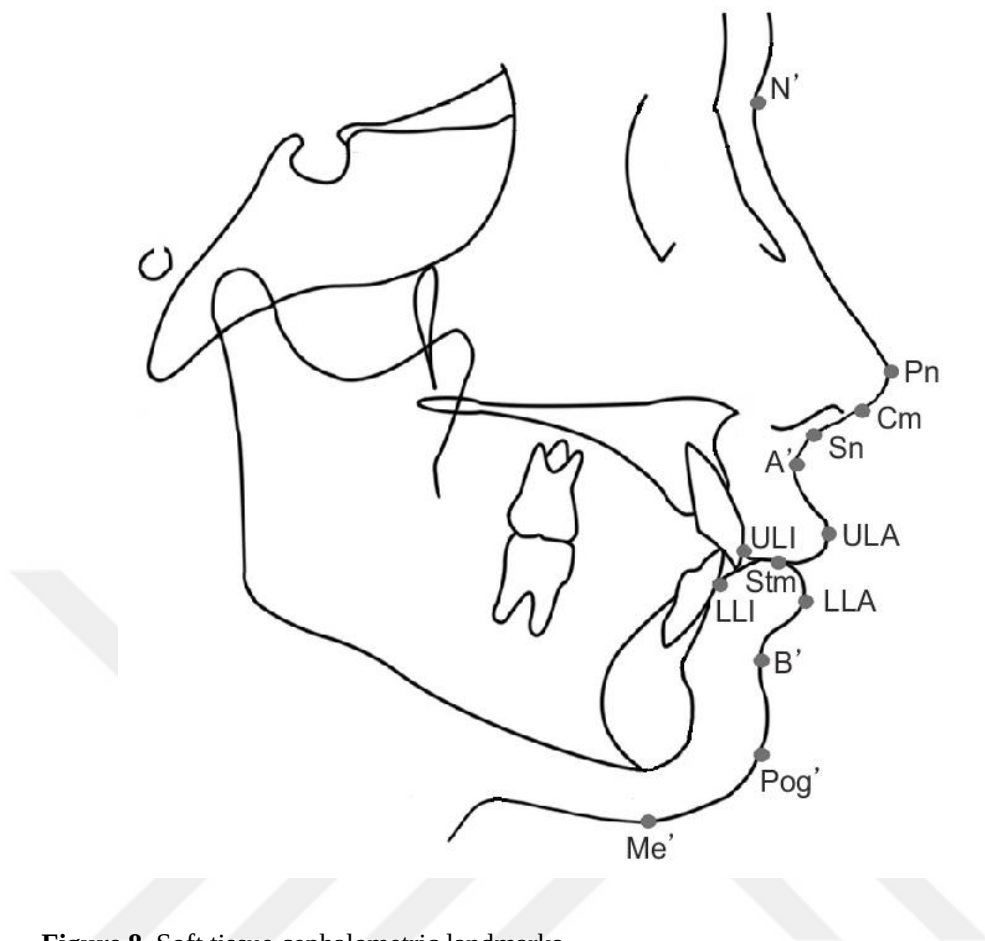


Figure 8. Soft tissue cephalometric landmarks.

- Reference planes (Figure 9):
 - Sella Nasion plane (SN): A plane connecting the points (S) and (N), and it represents the anterior cranial base.
 - Sella Basion Plane (SBa): A plane connecting the points (S) and (Ba), and it represents the posterior cranial base.
 - Frankfort Horizontal Plane (FH): A plane that connects the points (Po) and (Or).
 - Palatal Plane (PP): Also referred to as the maxillary plane, it extends from the (ANS) point to the (PNS) point.
 - Functional Occlusal Plane (FOP): A plane that passes through the occlusion of the premolars or deciduous molars and the first

permanent molars and extends anteriorly.

- Mandibular Plane (MP): A plane that passes through the points (Go) and (Me).

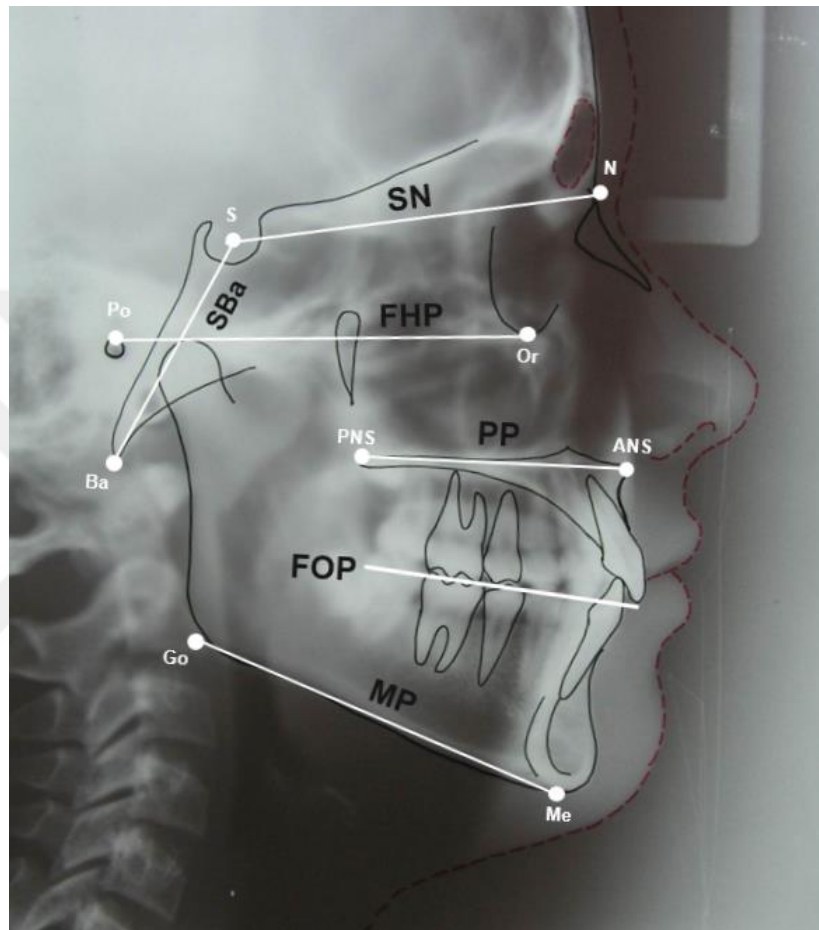


Figure 9. Cephalometric reference planes.

- Reference lines (Figure 10):
 - True vertical line (TVL): A vertical line that passes through the (Sn) point, and is perpendicular to the (FHP).
 - E-line: A line defined by Ricketts that is passing from the tip of the nose (Pn) point to the tip of the chin (Pog') point.

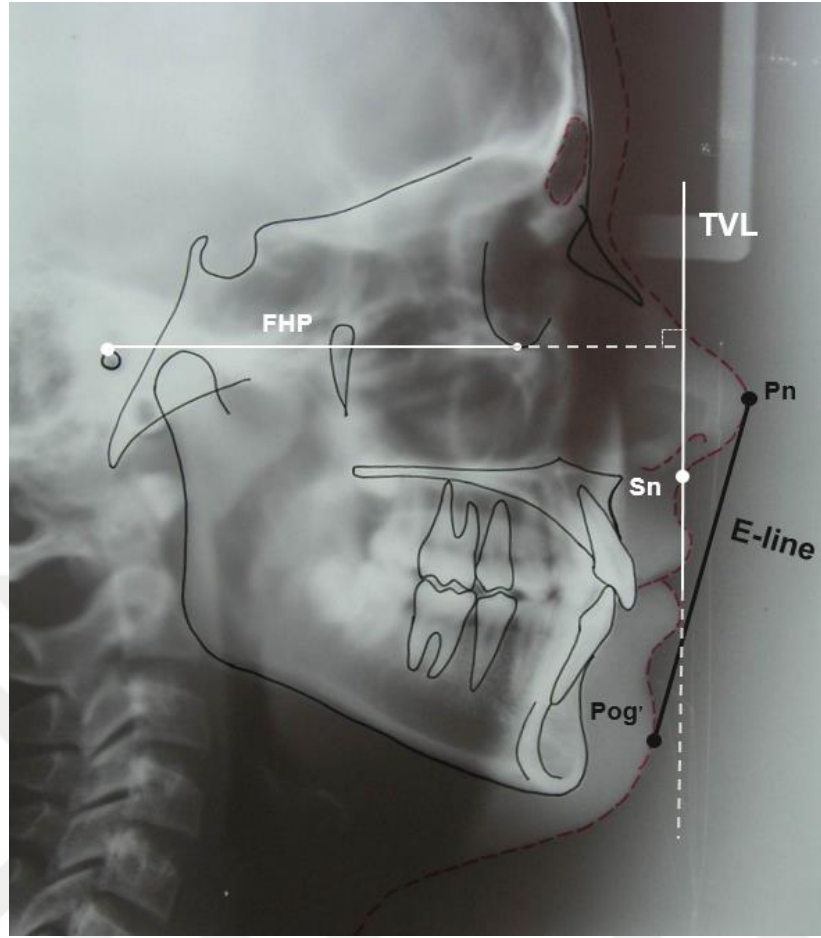


Figure 10. Cephalometric reference lines.

5.3.2. Cephalometric measurements and analysis

The measurements used are comprised of angles that are formed by three points or by two planes, distances between two points or between one point and a reference plane or line, or ratios of one of the distances to another. The measurements were divided into three main categories; skeletal, dental, and soft tissue measurements. The definitions of these measurements are described in (Table 1), (Table 2), and (Table 3) respectively.

The Marmara Analysis was utilized for all cephalometric measurements in this study. This analysis is used for all patients at Marmara University's Department of Orthodontics.

Table 1. Description of the skeletal cephalometric measurements used.

SNA (°)	The angle between points (S), (N), and (A). Indicates maxillary prognathism.
SNB (°)	The angle between points (S), (N), and (B). Indicates mandibular prognathism.
ANB (°)	The angle between points (A), (N), and (B). Indicates the maxillary-mandibular sagittal relationship.
Witts (mm)	The distance between perpendiculars dropped from points (A) and (B) to the (FOP). Indicates the maxillary-mandibular sagittal relationship.
N per A (mm)	The perpendicular distance between point (A) and a vertical line drawn from point (N) that is perpendicular to (FHP). Indicates maxillary prognathism.
N per B (mm)	The perpendicular distance between point (B) and a vertical line drawn from point (N) that is perpendicular to (FHP). Indicates mandibular prognathism.
Inner angles (°)	The collective sum of the saddle angle, articular angle, and the gonial angle. Describes the vertical pattern of the face.
Maxillary height (°)	The angle between points (N), (CF), and (A). Describes the vertical position of the maxilla.
PP - SN (°)	The angle between the (PP) and the (SN) plane.
GoMe - SN (°)	The angle between the (MP) and (SN) plane. Describes the vertical pattern of the face.
ANS-Me/N-Me (%)	The ratio of the skeletal lower anterior facial height (ANS-Me) to the skeletal total anterior facial height (N-Me). Describes the vertical pattern of the face.
Skeletal profile (°)	The angle between points (N), (A), and (Pog). Describes the skeletal profile convexity.

The dental cephalometric measurements that were used included overjet -the horizontal distance between maxillary and mandibular incisors tips, and overbite -the vertical distance between them-. The rest of the dental measurements are in (Table 2).

Table 2. Description of the dental cephalometric measurements used.

UI - SN (°)	The angle between the axis of the maxillary central incisor and the (SN) plane.
IMPA (°)	The angle between the axis of the mandibular central incisor and the (MP).
UI - NA (mm)	The perpendicular distance between the tip of the maxillary central incisor and a plane between (N) and (A) points.
LI - NB (mm)	The perpendicular distance between the tip of the mandibular central incisor and a plane between (N) and (B) points.

Table 3. Description of the soft tissue cephalometric measurements used.

H angle (°)	The angle between a plane passing through points (N') and (Pog'), and the point (ULA).
Nasolabial angle (°)	The angle between points (Cm), (Sn), and (ULA).
Soft tissue profile (°)	The angle between points (N'), (Sn), and (Pog'). Describes the soft tissue profile convexity.
Sn-Me'/N'-Me' (%)	The ratio of the soft tissue lower anterior facial height (Sn-Me') to the soft tissue total anterior facial height (N'-Me').
A' - TVL (mm)	The perpendicular distance between (A') point and the (TVL).
B' - TVL (mm)	The perpendicular distance between (B') point and the (TVL).
Nasal projection (mm)	The perpendicular distance between (Pn) point and the (TVL).
Upper lip thickness (mm)	The distance between points (ULA) and (ULI).
Upper lip length (mm)	The distance between perpendiculars dropped from points (Sn) and (Sts) on the (TVL).
Upper lip – E-line (mm)	The distance from the point (ULA) to the E-line.

Table 3. Description of the soft tissue cephalometric measurements used (continued).

Upper lip - TVL (mm)	The perpendicular distance from the point (ULA) to the (TVL).
Lower lip thickness (mm)	The distance between points (LLA) and (LLI).
Lower lip length (mm)	The distance between perpendiculars dropped from points (Sti) and (Me') on the (TVL).
Lower lip – E-line (mm)	The distance from the point (LLA) to the E-line.
Lower lip - TVL (mm)	The perpendicular distance from the point (LLA) to the (TVL).
Pog - Pog' (mm)	The distance between hard tissue and soft tissue pogonion.

5.4. Statistical Analysis

Statistical methods were used to analyze the data, including the calculation of descriptive statistics such as the frequency and percentage for categorical variables, and the mean ($\bar{X}$), the median, the standard deviation (SD), and the minimum and maximum for the continuous variables.

Intra-observer method error was investigated by remeasuring 40% of our sample (9 subjects), under the same conditions 3 weeks after the initial measuring. For the analysis of reliability regarding parameter measurements, the intraclass correlation coefficient was calculated. The Shapiro-Wilk test of normality was applied to evaluate the normal distribution of the parameters, and since the data was found to support parametric assumptions, paired-samples t-test was performed to compare between the before and after surgery measurements for the same group of patients. Additionally, the independent-samples t-test was performed to compare the measurements between the two subgroups. Pearson correlation test was performed to evaluate the associations between specific corresponding variables.

An alpha level of 0,05 was used for all statistical tests and all were two-tailed. All calculations and analyses were carried out with the IBM SPSS (Statistical Package of Social Sciences) software for Windows, Demo Version 28,0. Armonk, NY: IBM Corp.

6. RESULTS

6.1. Reliability Test

Method error for the studied parameters is shown in (Table 4). Intraclass Correlation Coefficient was found to be close to 1 for all the measurements as seen in (Table 4). All the measurements were found to be reliable. The errors were non-fatal and did not affect the results of our measurements.

Table 4. Single observer's agreements between repeated measurements.

		Intraclass Correlation ^b	95% CI	
			Lower Bound	Upper Bound
Inner angles	Single Measures	0,98 ^a	0,92	0,99
	Average Measures	0,99 ^c	0,96	0,99
ANS-Me/N-Me	Single Measures	0,99 ^a	0,95	0,99
	Average Measures	0,99 ^c	0,98	0,99
Maxillary height	Single Measures	0,98 ^a	0,95	0,99
	Average Measures	0,99 ^c	0,97	0,99
GoMe - SN	Single Measures	0,98 ^a	0,94	0,99
	Average Measures	0,99 ^c	0,97	0,99
PP - SN	Single Measures	0,98 ^a	0,91	0,99
	Average Measures	0,99 ^c	0,96	0,99
SNA	Single Measures	0,98 ^a	0,94	0,99
	Average Measures	0,99 ^c	0,97	0,99
SNB	Single Measures	0,99 ^a	0,96	0,99
	Average Measures	0,99 ^c	0,98	0,99
ANB	Single Measures	0,93 ^a	0,70	0,96
	Average Measures	0,96 ^c	0,82	0,98
Witts	Single Measures	0,99 ^a	0,98	0,99
	Average Measures	0,99 ^c	0,99	0,99

Table 4. Single observer's agreements between repeated measurements (continued).

N per A	Single Measures	0,99 ^a	0,98	0,99
	Average Measures	0,99 ^c	0,99	1,00
N per B	Single Measures	0,99 ^a	0,99	1,00
	Average Measures	1,00 ^c	0,99	1,00
Skeletal profile	Single Measures	0,94 ^a	0,76	0,98
	Average Measures	0,97 ^c	0,86	0,99
Overjet	Single Measures	0,99 ^a	0,98	0,99
	Average Measures	0,99 ^c	0,99	1,00
Overbite	Single Measures	0,99 ^a	0,96	0,99
	Average Measures	0,99 ^c	0,98	0,99
UI - SN	Single Measures	0,96 ^a	0,86	0,99
	Average Measures	0,98 ^c	0,92	0,99
UI - NA	Single Measures	0,99 ^a	0,99	1,00
	Average Measures	0,99 ^c	0,99	1,00
IMPA	Single Measures	0,97 ^a	0,89	0,99
	Average Measures	0,98 ^c	0,94	0,99
LI - NB	Single Measures	0,99 ^a	0,97	0,99
	Average Measures	0,99 ^c	0,98	0,99
H angle	Single Measures	0,99 ^a	0,97	0,99
	Average Measures	0,99 ^c	0,98	0,99
Nasolabial angle	Single Measures	0,93 ^a	0,75	0,98
	Average Measures	0,96 ^c	0,86	0,99
Soft tissue profile	Single Measures	0,93 ^a	0,75	0,98
	Average Measures	0,96 ^c	0,86	0,99
Sn-Me'/N'-Me'	Single Measures	0,94 ^a	0,73	0,98
	Average Measures	0,96 ^c	0,84	0,99
Upper lip thickness	Single Measures	0,99 ^a	0,97	0,99
	Average Measures	0,99 ^c	0,98	0,99
Upper lip length	Single Measures	0,99 ^a	0,98	0,99
	Average Measures	0,99 ^c	0,99	1,00
Upper lip – E-line	Single Measures	0,99 ^a	0,99	1,00
	Average Measures	0,97 ^c	0,90	0,99
Lower lip thickness	Single Measures	0,98 ^a	0,94	0,99
	Average Measures	0,99 ^c	0,96	0,99

Table 4. Single observer's agreements between repeated measurements (continued).

Lower lip length	Single Measures	0,99 ^a	0,98	0,99
	Average Measures	0,99 ^c	0,96	0,99
Lower lip – E-line	Single Measures	0,99 ^a	0,97	0,99
	Average Measures	0,96 ^c	0,86	0,99
Pog - Pog'	Single Measures	0,98 ^a	0,92	0,99
	Average Measures	0,97 ^c	0,90	0,99
Nasal projection	Single Measures	0,98 ^a	0,95	0,99
	Average Measures	0,98 ^c	0,93	0,99
Upper lip - TVL	Single Measures	0,99 ^a	0,96	0,99
	Average Measures	0,98 ^c	0,93	0,99
Lower lip - TVL	Single Measures	0,99 ^a	0,96	0,99
	Average Measures	0,99 ^c	0,98	0,99
A' - TVL	Single Measures	0,98 ^a	0,91	0,99
	Average Measures	0,99 ^c	0,95	0,99
B' - TVL	Single Measures	0,99 ^a	0,97	0,99
	Average Measures	0,99 ^c	0,98	0,99

Two-way mixed-effects model where people effects are random and measures effects are fixed.

a. The estimator is the same, whether the interaction effect is present or not.

b. Type C intraclass correlation coefficients using a consistency definition. The between-measure variance is excluded from the denominator variance.

c. This estimate is computed assuming the interaction effect is absent because it is not estimable otherwise.

6.2. Demographic Characteristics of the Enrolled Patients

Descriptive statistics were conducted to describe the characteristics of the total study sample and stratified by the type of surgical maxillary vertical movement. The total

sample recruited was 22 patients. All subjects were Caucasian and from the same geographic area (Turkey). The majority of the sample was female (n=14, 63,3%) and the rest were male patients (n=8, 36,4%). The median of the age of patients at surgery of the total sample was 21 years with a range of (18-24 years), and the mean was ($\bar{X}$ =21,18 years, SD=2,57). The median of the follow-up period for the postsurgical lateral cephalogram (T2) of the total sample was 11 months, the range was (6,5-24), and the mean was ($\bar{X}$ =12,79 months, SD=5,04). The median and range of the vertical maxillary movement in Group A were 2,77 mm (1,23-6,72), and the mean was ($\bar{X}$ =2,78 mm, SD=1,42). The median of the vertical maxillary movement in Group B was 1,54 mm with a range of (1,17-3,54), and the mean was ($\bar{X}$ =1,90 mm, SD=0,78). More details about the demographic characteristics are found in (Table 5).

Table 5. Demographic characteristics of the enrolled patients.

Characteristics	Group A	Group B	Total
Number of subjects (n)	13	9	22
Gender ^A	Male	7 (53,8)	8 (36,4)
	Female	6 (46,2)	14 (63,3)
Age at surgery (years) ^B	21,31 ± 3,14	21,00 ± 1,58	21,18 ± 2,57
Follow up period (T2) (months) ^B	12,62 ± 4,01	13,05 ± 6,53	12,79 ± 5,04
Amount of vertical maxillary movement (mm) ^B	2,78 ± 1,42	1,90 ± 0,78	

A: Qualitative data expressed as frequency and percentage.

B: Continuous data expressed as mean ± standard deviation.

6.3. Intra-Group Comparison of Surgical Changes

Paired-samples t-test was conducted to evaluate the impact of the surgery on the measured variables from before and after surgery for the same group.

6.3.1. Group (A) results

- Skeletal results

The results showed a statistically significant increase in the mean of (SNA) value ($p < 0,001$), a statistically significant decrease in the mean of (SNB) value ($p < 0,001$), as well as a statistically significant increase in the mean of (ANB) value after surgery ($p < 0,001$).

Additionally, statistically significant changes after surgery were also found in the mean of (witts) and (N per A) values, as both have increased significantly ($p < 0,001$).

On the other hand, a statistically significant decrease after surgery was noted in the mean of (N per B) value ($p = 0,002$), and the mean of (skeletal profile) value ($p < 0,001$). The rest of the skeletal parameters showed insignificant change after surgery ($p > 0,05$), as shown in (Table 6).

Table 6. Presurgical and postsurgical values of skeletal measurements for Group A.

	Before (T1)		After (T2)		MD (T1-T2)	P value [#]
	Mean ± SD	Median (Min-Max)	Mean ± SD	Median (Min-Max)		
Inner angles	395,66 ± 6,94	398,4 (387,1- 410,1)	396,33 ± 6,14	395,8 (387,4- 409)	-0,67	0,51
ANS-Me/N-Me	55,79 ± 2,15	55,3 (53,2- 60,2)	54,79 ± 1,84	54,90 (50,9- 57,3)	1	0,10
Maxillary height	64,31 ± 4,57	64 (56-73)	62,54 ± 2,96	63 (59-67)	1,77	0,07
GoMe - SN	38,38 ± 6,26	40 (31-52)	38,15 ± 4,81	37 (32-49)	0,23	0,79
PP - SN	10,85 ± 3,62	12 (3-15)	11,54 ± 3,04	11 (7-16)	-0,69	0,46
SNA	76,69 ± 3,96	76 (72-84)	81,08 ± 4,31	80 (74-88)	-4,39	<0,001*
SNB	81,85 ± 4,20	81 (77-90)	79,38 ± 3,42	78 (75-85)	2,47	<0,001*
ANB	-5,15 ± 1,62	-5 (-8-3)	1,69 ± 1,79	2 (-1-5)	-6,84	<0,001*
Witts	-12,0 ± 3,15	-13,3 (- 16,6- -7,6)	-3,46 ± 3,46	-3,4 (-8,5- 1,7)	-8,54	<0,001*

Table 6. Presurgical and postsurgical values of skeletal measurements for Group A (continued).

N per A	-4,89 ± 5,00	-4,6 (-11,8-3,3)	-0,16 ± 5,15	-1,5 (-9,5-8,4)	-4,73	<0,001*
N per B	1,06 ± 7,56	2,9 (-10,9-13,1)	-3,30 ± 6,18	-5,2 (-12,4-5,8)	4,36	0,002*
Skeletal profile	192,31 ± 4,95	193 (183-199)	179,85 ± 5,22	180 (171-190)	12,46	<0,001*

*. The mean difference is significant at the 0.05 level. #. Paired-samples t-test was applied. SD: standard deviation. MD: mean difference (T1-T2).

- Dental results

The results showed a statistically significant increase in the mean of (overjet) value ($p < 0,001$), after surgery.

On the other hand, a statistically significant decrease after surgery was found in the mean of both (UI-NA) and (LI-NB) values, ($p = 0,04$) ($p = 0,03$), respectively.

The rest of the dental parameters showed insignificant change after surgery ($p > 0,05$), as shown in (Table 7).

Table 7. Presurgical and postsurgical values of dental measurements for Group A.

	Before (T1)		After (T2)		MD (T1-T2)	P value [#]
	Mean ± SD	Median (Min-Max)	Mean ± SD	Median (Min-Max)		
Overjet	-6,12 ± 2,36	-5,8 (-9,8-2,6)	3,33 ± 1,18	3,1 (1,4-5,7)	-9,46	<0,001*
Overbite	1,03 ± 2,28	1,5 (-3,3-4,2)	1,66 ± 0,86	1,6 (0,5-3,5)	-0,63	0,29
UI - SN	107,62 ± 4,33	109 (98-115)	108,69 ± 4,47	108 (103-119)	-1,08	0,54
UI - NA	5,62 ± 2,82	5,7 (0,1-10)	4,48 ± 1,96	4 (1,1-7,2)	1,14	0,04*
IMPA	84,77 ± 8,24	86 (68-96)	84,00 ± 6,67	84 (74-96)	0,77	0,56
LI - NB	4,56 ± 2,49	4,3 (0,5-10,3)	3,81 ± 1,82	4,1 (0,9-7,2)	0,75	0,03*

*. The mean difference is significant at the 0.05 level. #. Paired-samples t-test was applied. SD: standard deviation. MD: mean difference (T1-T2).

- Soft tissue results

The results showed a statistically significant increase in the mean of (H angle) value after surgery ($p<0,001$).

Additionally, both the (upper lip length) and (the upper lip–E-line) values have shown a statistically significant increase in their means after surgery ($p<0,001$).

In contrast, a statistically significant decrease in the mean of (soft tissue profile) and (nasal projection) values was found after surgery ($p<0,001$) ($p=0,01$), respectively.

Moreover, it was noted that the mean after surgery had decreased significantly for the (lower lip thickness) and (lower lip length) values ($p<0,001$), for both of them.

Statistically significant changes after surgery were also found in the mean of (lower lip-TVL) and (B'-TVL) values, as both have decreased significantly ($p<0,001$).

The rest of the soft tissue parameters showed insignificant change after surgery ($p>0,05$), as shown in (Table 8).

Table 8. Presurgical and postsurgical values of soft tissue measurements for Group A.

	Before (T1)		After (T2)		MD (T1-T2)	P value [#]
	Mean ± SD	Median (Min-Max)	Mean ± SD	Median (Min-Max)		
H angle	4,69 ± 3,37	4 (0-10)	11,15 ± 4,46	12 (2-17)	-6,46	<0,001*
Nasolabial angle	96,46 ± 12,73	95 (73-112)	100,38 ± 6,69	99 (90-112)	-3,92	0,18
Soft tissue profile	174,0 ± 6,08	175 (159-182)	166,85 ± 6,40	166 (155-177)	7,15	<0,001*
Sn-Me'/N'-Me'	55,2 ± 2,54	55,1 (50,8-58,9)	55,14 ± 1,58	55,1 (51,9-57,2)	0,06	0,93
Upper lip thickness	12,23 ± 1,56	11,6 (9,7-14,7)	13,10 ± 2,17	12,9 (10,1-16,3)	-0,87	0,15
Upper lip length	18,24 ± 3,51	18,5 (12,0-22,9)	20,63 ± 3,34	21,5 (14,5-25,7)	-2,39	<0,001*
Upper lip – E-line	-9,49 ± 2,10	-8,4 (-13,4-6,3)	-6,02 ± 2,43	-5,3 (-11,1-2,3)	-3,47	<0,001*
Lower lip thickness	15,2 ± 1,36	15 (12,5-18)	13,36 ± 1,84	13,5 (10,6-17,5)	1,84	<0,001*
Lower lip length	52,32 ± 4,84	52,1 (46,1-62,9)	49,10 ± 4,61	49,7 (42,9-55,6)	3,22	<0,001*
Lower lip – E-line	-3,33 ± 2,57	-4 (-8-1,7)	-3,64 ± 2,58	-3,4 (-7,7-2,1)	0,31	0,46

Table 8. Presurgical and postsurgical values of soft tissue measurements for Group A (continued).

Pog - Pog'	12,25 ± 2,33	11,9 (8,2-15,6)	12,45 ± 2,19	12,6 (9,6-17,3)	-0,2	0,67
Nasal projection	18,03 ± 4,14	18 (12,1-25,8)	16,23 ± 3,77	16,5 (8,9-21,9)	1,8	0,01*
Upper lip - TVL	1,54 ± 2,19	1,3 (-2,8-5,4)	2,13 ± 1,90	1,8 (-0,2-5,9)	-0,59	0,36
Lower lip - TVL	5,02 ± 3,04	5,2 (-0,9-9,1)	0,71 ± 2,49	0 (-2,2-6,2)	4,31	<0,001*
A' - TVL	-1,46 ± 1,35	-1,5 (-4,1-8)	-,69 ± 1,31	-1 (-2,7-1,9)	-0,77	0,07
B' - TVL	-1,09 ± 3,13	-1 (-5,3-4,6)	-7,0 ± 3,24	-7,2 (-11,7-0)	5,91	<0,001*

*. The mean difference is significant at the 0.05 level. #. Paired-samples t-test was applied. SD: standard deviation. MD: mean difference (T1-T2).

6.3.2. Group (B) results

- Skeletal results

The results showed a statistically significant increase in the mean of (SNA) value ($p < 0,001$), a statistically significant decrease in the mean of (SNB) value ($p < 0,001$), as well as a statistically significant increase in the mean of (ANB) value after surgery ($p < 0,001$).

Moreover, the change in the mean of (maxillary height) value was found to be significantly decreased after surgery ($p < 0,001$).

Statistically significant changes after surgery were also found in the mean of (witts) and (N per A) values, as both have increased significantly ($p < 0,001$).

On the other hand, a statistically significant decrease after surgery was noted in the mean of both (N per B) and (skeletal profile) values ($p < 0,001$).

The rest of the skeletal parameters showed insignificant change after surgery ($p > 0,05$), as shown in (Table 9).

Table 9. Presurgical and postsurgical values of skeletal measurements for Group B.

	Before (T1)		After (T2)		MD (T1-T2)	P value [#]
	Mean ± SD	Median (Min-Max)	Mean ± SD	Median (Min-Max)		
Inner angles	393,62 ± 6,78	393 (384,9- 405,5)	392,72 ± 4,74	392,2 (384,8- 398,3)	0,9	0,55
ANS-Me/N-Me	56,92 ± 3,36	57,6 (50,3- 62,9)	56,68 ± 2,82	56,8 (51,1- 61,7)	0,24	0,41
Maxillary height	64,22 ± 2,63	64 (60-68)	60,00 ± 1,87	60 (57-63)	4,22	<0,001*
GoMe - SN	37,44 ± 4,87	36 (31-46)	35,89 ± 3,29	36 (31-40)	1,55	0,21
PP - SN	7,00 ± 2,59	7 (2-10)	8,22 ± 2,63	8 (3-12)	-1,22	0,18
SNA	78,33 ± 3,12	78 (75-84)	83,11 ± 3,33	83 (78-89)	-4,78	<0,001*
SNB	82,56 ± 2,83	83 (79-87)	80,67 ± 2,73	81(77-84)	1,89	<0,001*
ANB	-4,22 ± 2,48	-4 (-9- -1)	2,44 ± 2,18	4 (-1-5)	-6,66	<0,001*
Witts	-11,22 ± 2,18	-10,9 (-14,3- -7,8)	-2,76 ± 1,58	-2,6 (-5,4- 0,2)	-8,46	<0,001*
N per A	-4,37 ± 4,11	-3,9 (-8,6- 3,6)	0,55 ± 3,48	0,9 (-4,1- 7,1)	-4,92	<0,001*
N per B	0,01 ± 5,58	-0,3 (-8,2- 8,1)	-2,92 ± 4,99	-2,5 (-9,1- 4,8)	2,93	<0,001*
Skeletal profile	191,11 ± 8,26	191,0 (178- 205)	178,56 ± 5,72	177 (171- 186)	12,55	<0,001*

*. The mean difference is significant at the 0.05 level. #. Paired-samples t-test was applied. SD: standard deviation. MD: mean difference (T1-T2).

- Dental results

The results showed a statistically significant increase in the mean of (overjet) value ($p<0,001$), after surgery.

Additionally, a statistically significant increase after surgery was found in the mean of (UI-SN) value ($p=0,03$).

On the other hand, it was noted that the mean after surgery for the (UI-NA) value was significantly lower than the mean before surgery ($p<0,001$).

The rest of the dental parameters showed insignificant change after surgery ($p>0,05$), as shown in (Table 10).

Table 10. Presurgical and postsurgical values of dental measurements for Group B.

	Before (T1)		After (T2)		MD (T1-T2)	P value [#]
	Mean $\pm$ SD	Median (Min-Max)	Mean $\pm$ SD	Median (Min-Max)		
Overjet	-5,94 $\pm$ 2,23	-5,4 (-10,1-3,4)	2,84 $\pm$ 2,5	2,6 (1,8-4,4)	-8,78	<0,001*
Overbite	1,44 $\pm$ 1,61	1,3 (-0,3-4,4)	2,20 $\pm$ 1,11	2,2 (1-4,5)	-0,76	0,24
UI - SN	105,56 $\pm$ 7,61	107 (89-115)	107,22 $\pm$ 8,22	108 (88-117)	-1,66	0,03*
UI - NA	5,24 $\pm$ 3,08	5,7 (0,5-10,5)	3,61 $\pm$ 3,09	3,5 (-1,3-9,9)	1,63	<0,001*
IMPA	86,22 $\pm$ 5,84	87 (78-96)	86,33 $\pm$ 4,09	85 (80-92)	-0,11	0,95
LI - NB	5,32 $\pm$ 6,7	6,2 (0,9-7,8)	4,12 $\pm$ 2,47	3,8 (1-7,4)	1,2	0,07

*. The mean difference is significant at the 0.05 level. #. Paired-samples t-test was applied. SD: standard deviation. MD: mean difference (T1-T2).

- Soft tissue results

The results showed a statistically significant increase in the mean of (H angle) value after surgery ($p < 0,001$).

Additionally, the (upper lip–E-line) value has shown a statistically significant increase in its mean after surgery ($p < 0,001$).

In contrast, a statistically significant decrease in the mean of (soft tissue profile) and (nasal projection) values was found after surgery ($p < 0,001$), for both of them.

Moreover, it was noted that the mean after surgery has decreased significantly for both the (lower lip thickness) and (lower lip length) values ($p < 0,001$).

Statistically significant changes after surgery were also found in the mean of (lower lip-TVL) and (B'-TVL) values, as both have decreased significantly ($p < 0,001$).

While it was found that the mean of (A'-TVL) value has increased significantly after surgery ($p = 0,01$).

The rest of the soft tissue parameters showed insignificant change after surgery ($p > 0,05$), as shown in (Table 11).

Table 11. Presurgical and postsurgical values of soft tissue measurements for Group B.

	Before (T1)		After (T2)		MD (T1-T2)	P value [#]
	Mean ± SD	Median (Min-Max)	Mean ± SD	Median (Min-Max)		
H angle	4,33 ± 5,72	6 (-4-12)	10,44 ± 5,07	10 (4-19)	-6,11	<0,001*
Nasolabial angle	96,11 ± 8,28	94 (87-113)	98,67 ± 10,78	101 (81- 112)	-2,56	0,42
Soft tissue profile	175,44 ± 9,12	174 (162- 191)	168,44 ± 6,78	168 (160- 182)	7,00	<0,001*
Sn-Me'/N'-Me'	56,06 ± 2,27	55,9 (51,2- 59)	56,04 ± 2,87	56,6 (49- 58,4)	0,02	0,97
Upper lip thickness	13,42 ± 3,85	13,3 (9,8- 21,8)	12,32 ± 2,68	12,1 (8,9- 17,7)	1,1	0,31
Upper lip length	19,78 ± 3,68	20,2 (12,5- 24,2)	20,61 ± 3,53	21,3 (13,3- 24,8)	-0,83	0,18
Upper lip – E-line	-9,41 ± 3,18	-9 (-14,3- 5,3)	-5,62 ± 2,70	-5,6 (-9,7-- 1,3)	-3,79	<0,001*
Lower lip thickness	16,02 ± 1,63	16,4 (12,9- 18)	12,61 ± 2,13	13,2 (9,3- 15)	3,41	<0,001*
Lower lip length	51,65 ± 5,77	50,6 (46,4- 65,1)	46,88 ± 4,8	46,9 (40,4- 55,8)	4,77	<0,001*
Lower lip – E-line	-2,75 ± 3,47	-1,6 (-7,7- 1,4)	-3,16 ± 2,97	-2,90 (-6,5- 2)	0,41	0,53
Pog - Pog'	12,08 ± 1,76	11,60 (9,2- 14,5)	11,45 ± 1,76	11,4 (9,4- 15,2)	0,63	0,36
Nasal projection	19,60 ± 4,05	20,6 (14,6- 26,6)	16,64 ± 4,08	17 (9,3- 22,5)	2,96	0,002*
Upper lip - TVL	1,81 ± 2,48	1,8 (-1,1- 4,8)	2,46 ± 2,07	2,5 (-0,1- 5,7)	-0,65	0,36
Lower lip - TVL	5,57 ± 2,93	4,3 (1,4- 10,7)	1,16 ± 3,15	1,5 (-3,1- 6,8)	4,41	<0,001*
A' - TVL	-1,32 ± 2,28	-0,8 (-4,8- 1,3)	-0,05 ± 1,93	0,1 (-3-2,7)	-1,27	0,01*
B' - TVL	-0,45 ± 4,45	-2,1 (-5,3- 9,3)	-5,51 ± 4,2	-5,8 (-11,7- 3,5)	5,06	<0,001*

*. The mean difference is significant at the 0.05 level. #. Paired-samples t-test was applied. SD: standard deviation. MD: mean difference (T1-T2).

6.4. Inter-Group Comparison of Surgical Changes

Independent-samples t-test was conducted to evaluate the difference in response to the surgery between the two subgroups of our sample. The results are in (Table 12) below.

Table 12. Comparison of surgical changes between the two subgroups.

	Mean Difference (T1-T2) Group A	Mean Difference (T1-T2) Group B	P value [#]
Inner angles	-0,67	0,9	0,36
ANS-Me/N-Me	1	0,24	0,30
Maxillary height	1,77	4,22	0,04*
GoMe - SN	0,23	1,55	0,35
PP - SN	-0,69	-1,22	0,69
SNA	-4,39	-4,78	0,48
SNB	2,47	1,89	0,43
ANB	-6,84	-6,66	0,80
Witts	-8,54	-8,46	0,93
N per A	-4,73	-4,92	0,80
N per B	4,36	2,93	0,31
Skeletal profile	12,46	12,55	0,96
Overjet	-9,46	-8,78	0,57
Overbite	-0,63	-0,76	0,88
UI - SN	-1,08	-1,66	0,78
UI - NA	1,14	1,63	0,50
IMPA	0,77	-0,11	0,69
LI - NB	0,75	1,2	0,45
H angle	-6,46	-6,11	0,79
Nasolabial angle	-3,92	-2,56	0,74
Soft tissue profile	7,15	7,00	0,92
Sn-Me'/N'-Me'	0,06	0,02	0,97
Upper lip thickness	-0,87	1,1	0,08
Upper lip length	-2,39	-0,83	0,12
Upper lip – E-line	-3,47	-3,79	0,73
Lower lip thickness	1,84	3,41	0,38
Lower lip length	3,22	4,77	0,01*
Lower lip – E-line	0,31	0,41	0,17
Pog - Pog'	-0,2	0,63	0,88
Nasal projection	1,8	2,96	0,29
Upper lip - TVL	-0,59	-0,65	0,24
Lower lip - TVL	4,31	4,41	0,94
A' - TVL	-0,77	-1,27	0,93
B' - TVL	5,91	5,06	0,40

*. The mean difference is significant at the 0.05 level. #. Independent-samples t-test was applied.

As the previous table shows, a statistically significant difference was reported between the two subgroups regarding the change in the mean of (maxillary height) value after surgery ($p=0,04$). Moreover, the difference between the subgroups was statistically significant regarding the change of the (lower lip length) value mean ($P=0,01$).

On the other hand, differences were noted in the type of change of some certain values between the two subgroups, yet it was statistically insignificant. For example, the mean of (inner angles) value has increased in Group A, when it has decreased in Group B, the same was found for the mean of both (upper lip thickness) and (pog-pog') values, yet all of them show a statistically insignificant difference ($p>0,05$).

Another difference was the change in the mean of (IMPA) value, as it has decreased in Group A while it shows to be increased in Group B, although the difference was not statistically significant ($p>0,05$).

For the rest of the values, the difference was statistically insignificant ($p>0,05$).

6.5. Correlation Test

Pearson's correlation test (r) was used to examine the associations between several corresponding variables. This correlation coefficient is a single number that measures both the strength and the direction of the linear relationship between two continuous variables. Values can range from -1 to +1 and are interpreted in the following manner:

- $r = 0,8-1,0$: A very strong positive relationship.
- $r = 0,6-0,8$: A strong positive relationship.
- $r = 0,4-0,6$: A moderate positive relationship.
- $r = 0,2-0,4$: A weak positive relationship.
- $r = 0,0-0,2$: A very weak positive relationship.
- $r = 0,0$: No relationship

The same is applicable for negative (r) values as for the strength of the relationship, except it indicates a negative relationship in terms of direction between the values.

6.5.1. Group (A) results

Table 13. Correlation results between (N per A) and various corresponding parameters in Group (A).

		Nasolabial angle	Nasal projection	A' - TVL	Upper lip thickness	Upper lip - TVL
N per A	Pearson Correlation	0,39	-0,73	0,08	0,10	0,43
	P value	0,18	0,004*	0,79	0,72	0,13

The yielded analysis findings suggested that the (N per A) value is negatively and strongly correlated with the (nasal projection) value ($r = -0,73$), and the correlation was statistically significant ($p=0,004$). The rest of the correlations were found to be statistically insignificant ($p>0,05$).

Table 14. Correlation results between (A'-TVL) and various corresponding parameters in Group (A).

		Nasolabial angle	Nasal projection	Upper lip thickness	Upper lip - TVL
A' - TVL	Pearson Correlation	-0,22	0,39	-0,09	0,64
	P value	0,48	0,19	0,76	0,017*

The yielded analysis findings suggested that the (A'-TVL) value is positively and strongly correlated with the (upper lip-TVL) value ($r = 0,64$), and the correlation was statistically significant ($p=0,017$). The rest of the correlations were found to be statistically insignificant ($p>0,05$).

Table 15. Correlation results between (N per B) and various corresponding parameters in Group (A).

N per B		Lower lip thickness	Lower lip - TVL	B' - TVL
	Pearson Correlation	-0,25	0,45	0,61
	P value	0,41	0,12	0,03*

According to the above table, a positive and strong correlation is found between the (N per B) value and the (B'-TVL) value ($r = 0,61$). The correlations are statistically significant as well ($p=0,03$).

Table 16. Correlation results between (B'-TVL) and various corresponding parameters in Group (A).

B' - TVL		Lower lip thickness	Lower lip - TVL
	Pearson Correlation	-0,77	0,63
	P value	0,002*	0,021*

According to the above table, the (B'-TVL) and the (lower lip thickness) values are negatively and strongly correlated ($r = -0,77$), and the (B'-TVL) and the (lower lip-TV L) values were also found to be correlated positively and strongly ($r = 0,63$). Both correlations are statistically significant ($p=0,002$) ($p=0,021$), respectively.

Table 17. Correlation result between (skeletal profile) and (soft tissue profile) in Group (A).

Skeletal profile		Soft tissue profile
	Pearson Correlation	0,83
	P value	<0,001*

The previous table demonstrates that the (skeletal profile) value is positively and very strongly correlated with the (soft tissue profile) value ($r = 0,83$). The correlation was found to be statistically significant ($p < 0,001$).

Table 18. Correlation result between (amount of downfracture) and (upper lip length) in Group (A).

Amount of downfracture	Upper lip length	
	Pearson Correlation	0,39
	P value	0,19

The above table demonstrated that there is a positive weak correlation between the (amount of downfracture) value and the (upper lip length) value ($r = 0,39$). The correlation is statistically insignificant ($p = 0,19$).

6.5.2. Group (B) results

Table 19. Correlation results between (N per A) and various corresponding parameters in Group (B).

N per A						
		Nasolabial angle	Nasal projection	A' - TVL	Upper lip thickness	Upper lip - TVL
	Pearson Correlation	-0,39	-0,49	0,53	-0,35	0,67
	P value	0,29	0,17	0,14	0,35	0,04*

The yielded analysis findings suggested that the (N per A) value is positively and strongly correlated with the (upper lip-TVL) value ($r = -0,67$), and the correlation was statistically significant ($p = 0,04$). The rest of the correlations were found to be statistically insignificant ($p > 0,05$).

Table 20. Correlation results between (A'-TVL) and various corresponding parameters in Group (B).

		Nasolabial angle	Nasal projection	Upper lip thickness	Upper lip - TVL
A' - TVL	Pearson Correlation	-0,12	0,27	-0,74	0,70
	P value	0,76	0,49	0,023*	0,035*

The yielded analysis findings suggested that the (A'-TVL) value is negatively and strongly correlated with the (upper lip thickness) value ($r = -0,74$), and the correlation was statistically significant ($p=0,023$). Moreover, a positive strong correlation was noted between the (A'-TVL) value and the (upper lip-TVL) value ($r = 0,70$), and it was statistically significant as well ($p=0,035$). The rest of the correlations were found to be statistically insignificant ($p>0,05$).

Table 21. Correlation results between (N per B) and various corresponding parameters in Group (B).

		Lower lip thickness	Lower lip - TVL	B' - TVL
N per B	Pearson Correlation	-0,28	0,90	0,81
	P value	0,46	<0,001*	0,008*

According to the above table, a positive and very strong correlation is found between the (N per B) value and both the (Lower lip-TVL) and (B'-TVL) values with a correlation coefficient of ($r = 0,90$) ($r = 0,81$) respectively. Both correlations are statistically significant as well ($p<0,001$) ($p=0,008$), respectively.

Table 22. Correlation results between (B'-TVL) and various corresponding parameters in Group (B).

		Lower lip thickness	Lower lip - TVL
B' - TVL	Pearson Correlation	-0,46	0,89
	P value	0,213	0,001*

According to the above table, the (B'-TVL) and the (lower lip-TVL) values were found to be correlated positively and very strongly ($r = 0,89$), and the correlation is statistically significant ($p=0,001$).

Table 23. Correlation result between (skeletal profile) and (soft tissue profile) in Group (B).

		Soft tissue profile
Skeletal profile	Pearson Correlation	0,72
	P value	0,02*

The above table demonstrated that the (skeletal profile) value is positively and strongly correlated with the (soft tissue profile) value ($r = 0,72$). The correlation was found to be statistically significant ($p=0,02$).

Table 24. Correlation result between (amount of impaction) and (upper lip length) in Group (B).

		Upper lip length
Amount of impaction	Pearson Correlation	0,50
	P value	0,17

The above table demonstrated that there is a positive moderate correlation between the (amount of downfracture) value and the (upper lip length) value ($r = 0,50$). The correlation is statistically insignificant ($p = 0,17$).

7. DISCUSSION AND CONCLUSION

- Discussion of the aim

This retrospective study aimed to evaluate the changes in the soft tissue profile of Class III skeletal malocclusion patients that were resulted from bimaxillary surgery, which included a combined approach of maxillary advancement by LeFort I osteotomy and mandibular setback by the means of BSSO.

Additionally, an objective of this study was to compare the surgical results between two groups of maxillary downfracture and maxillary impaction patients in hopes to understand the effect of such vertical movement on the resultant soft tissue profile.

Lastly, the study aimed to assess if such changes in the soft tissue were directly associated with specific changes occurring to the hard tissues, and to what extent these corresponding soft and hard tissue changes were correlated if any relation was found.

Because of advancements in orthodontic and surgical treatments over the last two decades, a combined approach has been widely acknowledged as an optimum method of correcting moderate to severe skeletal malocclusions, especially given the fact that orthognathic surgery enables orthodontists to address such issues for which orthodontic therapy alone would be ineffective.

Specifically speaking, the treatment of moderate to severe Class III skeletal deformities in adult patients frequently requires such therapeutic combination to not just achieve dental and occlusal correction, but also improve facial esthetics and to harmonize the facial profile along with the skeletal and functional corrections (Lin and Kerr, 1998; Chew, 2005).

In fact, it was reported to be the most frequent anomaly to be corrected by the combined orthodontic and orthognathic surgery (Aydil et al., 2013).

The ability to recognize the aesthetic factors and predict the final facial profile comes from a proper understanding of the relationship between hard tissue surgery and its

effect on the overlying soft tissues. This simply makes it possible and of utter importance that an accurate and comprehensive prediction of facial changes to be included in the treatment planning.

This can be attributed to many reasons, first of which, correcting the occlusal relationship only is not an adequate prescription for successful treatment, rather achieving a well balanced and harmonious soft tissue facial profile, and this is a very important goal especially in orthognathic surgery (Anic-Milosevic et al., 2010; Abeltins and Jakobsone, 2011; Arad et al., 2011).

Moreover, the resultant facial profile after orthognathic surgery is considered of huge significance for patients (Lin and Kerr, 1998). According to the studies of (Laufer et al., 1976; Kiyak et al., 1981; Jacobson, 1984), aesthetics were discovered to be the primary motivation for the majority of individuals seeking orthognathic therapy.

Facial beauty is achieved through a harmonious balance of all aspects of the face, and for example, the nose and lips play a significant role in this equilibrium. Since the maxillary movement has a direct effect on them, it makes it impossible to attain a pleasing aesthetic facial profile without taking into consideration such a factor (Akan et al., 2021).

In addition to that, facial changes resulting from orthognathic surgery are of a sudden nature and are more profound, to say the least, in contrast to orthodontic treatment which leads to progressive changes in facial characteristics and that of a lesser impact (Lin and Kerr, 1998). Hence, during orthodontic treatment, the patient unconsciously adjusts to the physiognomic alterations and gradually incorporates them into their self-concept, while on the other hand, orthognathic surgery patients might find it more difficult to integrate and cope with such rapid new facial changes. This only creates a high demand and important necessity to produce satisfactory and well-planned aesthetic results.

Last but not least, since there is always a chance that some unpleasing, or detrimental changes to occur by the orthognathic surgery, it is impossible to avoid such unwanted results without a proper understanding of the relationship between skeletal alterations and soft tissue changes and accurate planning for the facial profile.

Although the use of bimaxillary orthognathic surgery is widespread, to the best of our knowledge, relatively few studies are available on the soft tissue changes resulting

from them, and none of which provides a comparison of these changes in relation to the type of vertical maxillary movement carried out in the surgery, which points out the originality of our study.

- Discussion of materials and methods

Our study has a total sample of 22 patients that was created after the exclusion criteria were applied. The patients were assigned into two subgroups depending on the type of surgical vertical maxillary movement, Group A including 13 patients with a mean age at surgery of 21,31 years (7 male, 6 female) and Group B including 9 patients with a mean age at surgery of 21 years (1 male, 8 female). The mean age at surgery for both groups was almost similar, although the gender distribution was not.

Lateral cephalograms were used in this study and were obtained from the archives of the Department of Orthodontics, Faculty of Dentistry at Marmara University.

Despite having the limitation of being a 2D image of a 3D structure, cephalometry is still a very commonly used tool in the diagnostic and treatment planning process of cases in orthodontics. Being feasible, easy to access, inexpensive, reproducible, and causing a minimal dose of radiation makes it a reliable and useful tool to use.

Continuous advancements in computing technology, paired with scientific advances in dental radiography, resulted in the invention of computer softwares intended to perform digital cephalometric tracing and measurements.

Advantages of digital tracing over manual tracing include the elimination of hand errors that might occur while drawing lines and measuring angles. Tracing softwares provide an automatical calculation of linear and angular measurements once the required landmarks have been identified (Tsorovas and Karsten, 2010; Erkan et al., 2012).

Moreover, digital tracing of cephalograms and collecting computer-assessed cephalometrics is less time-consuming compared to hand tracing (Sayinsu et al., 2007; Celik et al., 2009).

In terms of accuracy of the tracing, on the other hand, there was no significant difference found between the two and many have reported that the validity, reliability, and reproducibility of analysis generated manually and digitally is in high mutual correlation (Thurzo et al., 2010; Dinkova and Ivanova, 2015; Kishore et al., 2019).

For the presurgical lateral cephalograms (T1), the ones that were obtained from the database were those taken before the surgery once all presurgical orthodontic treatment has been completed including full leveling and aligning of the dental arches as well as complete dental decompensation.

As for the postsurgical lateral cephalograms (T2), those taken at least 6 months after the surgery were included in the study.

Because of swelling, tissue redistribution, and functional adaptation, a long-term follow-up is advised to assess the soft tissue changes following orthognathic surgery. Most reports suggest that swelling recedes and the soft tissue stabilizes after 6 months (Tomlak et al., 1984; O'Reilly, 1989; Conley and Boyd, 2007), while some others suggest that 12 months is an appropriate period for follow-up (Quast et al., 1983; Rosen, 1988). Additionally, many have concluded that more than 80% of the swelling recedes within 3 months after surgery (Kau et al., 2007; Van der Vlis et al., 2014; Yamamoto et al., 2016), which suggests a period of 6 months to be appropriate in general.

For that reason, only postsurgical lateral cephalograms taken at least 6 months after surgery were included and a period of no longer than 24 months was determined. Furthermore, the mean follow-up period for our sample was 12,79 months (SD:5,04) which coincides with the suggestions.

The NemoCeph software was used to digitally trace the obtained cephalograms, an example of a traced presurgical and a traced postsurgical lateral cephalograms are seen in (Figure 11) and (Figure 12), respectively. The tracing was done by the same examiner. For the linear and angular skeletal, dental, and soft tissue measurements, they were calculated automatically by the software following the tracing, and the Marama Analysis was used.

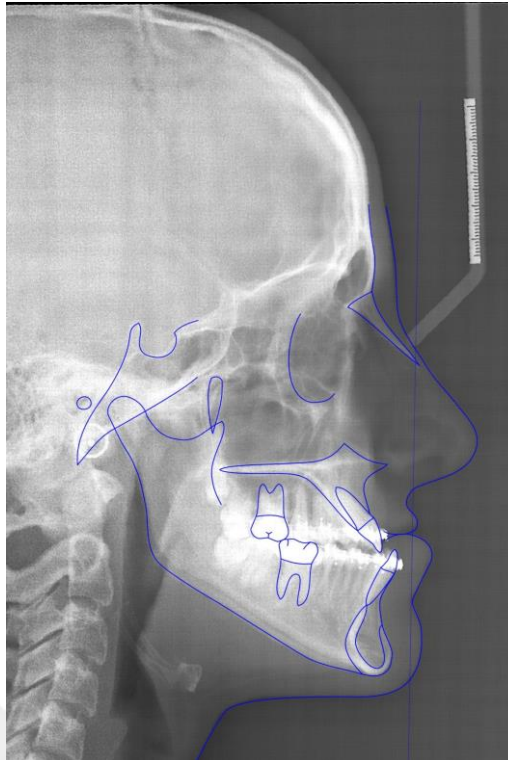


Figure 11. A presurgical lateral cephalogram traced using the NemoCeph software.

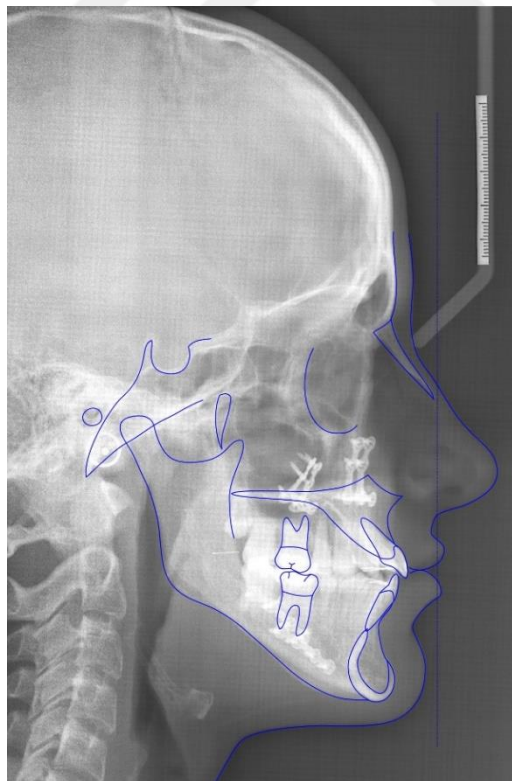


Figure 12. A postsurgical lateral cephalogram traced using the NemoCeph software.

The next step was the superimposition of the two cephalograms, and the anterior cranial base (SN) plane was chosen as a reference plane of anchor. The anterior cranial base is considered a stable craniofacial structure to be used for superimposition, as it completes the majority of its growth before the age of seven.

The calibration was done using the linear length of the (SN) plane in the presurgical cephalogram measured on the software, and then the postsurgical cephalogram was calibrated using the same length for the (SN) plane.

After superimposition, the direction and amount of vertical movement at point subspinale (A point) were measured. Based on this, the two subgroups in our study were created, so those patients whose maxillae underwent at least 1 mm of downfracture movement were referred to as Group A, while those patients whose maxillae were impacted by at least 1 mm were assigned to Group B.

At least one millimeter of vertical movement in any direction was determined as the borderline for inclusion as a margin of error when measuring. Those patients showing no vertical movement at all and those with a vertical movement less than (1 mm) were excluded from the initial sample.

- Discussion of the results

The patients in our sample have been all diagnosed with a severe Class III skeletal malocclusion that required a surgical correction rather than a routine fixed orthodontic camouflage treatment that would be inadequate to establish a stable, functional, and aesthetic occlusion along with providing facial harmony.

The presurgical mean values of skeletal parameters such as (witts) and (ANB) indicated a severe sagittal discrepancy between the maxilla and the mandible, and both were found similar with no significant differences between the two groups before surgery. The components of this Class III skeletal malocclusion were found to be maxillary retrognathism and mandibular prognathism combined, which justified the indispensable need for a bimaxillary surgery including both maxillary advancement with LeFort type I osteotomy along with mandibular setback by BSSO and all had

rigid fixation done for them after surgery. Furthermore, all the patients were Turkish, and this has given our sample uniformity.

Presurgical mean values of the skeletal parameters (SNA), and (N per A) were clear evidence for a retrognathic maxilla, and both were found to be much the same between the two groups, while the mean values of (SNB), and (N per B) before surgery have both demonstrated a prognathic mandible. Again, no significant change was found between the patients of both groups.

The results have shown very clearly how successful the orthognathic surgery was in correcting the severe skeletal anomaly, as significant increases in (witts) and (ANB) mean values have been reported.

Those changes are brought about by the significant increase in the maxillary skeletal parameters of (SNA) and (N per A), accompanied by a significant decrease in the mandibular parameters (SNB) and (N per B). The average maxillary advancement achieved by the surgery measured at point (A) was 4,73mm and 4,36mm for Group A and B respectively, with no significant difference between them. As for the average amount of mandibular setback that resulted from the surgery measured at point (B), it was 4,92mm and 2,93mm for Group A and B respectively. Although it seems different, it was not statistically significant.

Several previous studies have reported similar results to ours in terms of changes in these skeletal parameters, including (Lin and Kerr, 1998; Chew, 2005; Marşan et al., 2009; Al-Gunaid et al., 2012; Jokić et al., 2013; Rustemeyer and Martin, 2013; Parappallil et al., 2018). This further solidifies how crucial and essential is orthognathic surgery in general and bimaxillary surgery in specific, in addressing and correcting severe Class III skeletal discrepancies.

The changes achieved by the surgical movements were very evident as well on the skeletal profile of the patients. A skeletal profile angle that is larger than 180 degrees dictates a concave profile, while on the other hand, an angle lesser than 180 degrees means the patient has an orthognathic to convex skeletal profile. With presurgical mean values of (192,31) and (191,11) degrees for groups A and B respectively, a concave skeletal profile was a dominant finding among the problem list for those patients.

With the significant decrease in this angle that accounted for a mean change value of (12,46) and (12,55) degrees for groups A and B respectively after surgery, a noticeable improvement can be seen in the skeletal profile of the treated patients with changes from concave to more pleasing and aesthetic convex profiles. A similar pattern of a significant increase in the convexity of the skeletal profile has also been noted in the results of previous studies (Rustemeyer and Martin, 2013; Parappallil et al., 2018).

In the vertical dimension, a similarity between the two groups in terms of the mean values of (inner angles) and (ANS-Me/N-Me) parameters before surgery was noted. Moreover, the changes that came about by the surgery were also not of any significance. Additionally, the two groups have shown a similar response to the surgery regarding the changes in the plane angle of both the maxilla (PP-SN) and the mandible (GoMe-SN), as they have been found insignificant.

The maxillary plane angle measured to the cranial base (PP-SN) has increased insignificantly in both groups; such an increase would indicate a clockwise rotation of the maxillary plane. In the maxillary downfracture group, this might be attributed to asymmetrical downfracture where a larger amount of downward vertical movement occurs in the anterior part compared to the posterior part of the maxilla. The same can be speculated for the maxillary impaction group, where more impaction posteriorly than anteriorly would lead to such clockwise rotation of the maxillary plane. Unfortunately, this cannot be concluded with complete confidence, as detailed measurements regarding the rotation of the maxillary plane were not available. A study by (Jamilian et al., 2014) has also reported an insignificant increase in the maxillary plane angle with the cranial base.

The mandibular plane angle to the cranial base, however, showed an insignificant decrease in both groups, and this coincided with the result from the study by (Parappallil et al., 2018). In their study, they have compared the results between a single jaw mandibular setback surgery group and a bimaxillary surgery group. In the mandibular setback surgery group, an increase in the (GoMe-SN) angle was reported and it was believed to be due to the wedging effect in the posterior region. In the bimaxillary surgery group, on the contrary, the wedging effect migrates anteriorly in adaptation to the maxillary advancement alongside the mandibular setback, which

resulted in this decrease in the angle and counterclockwise rotation. On the other side of the coin, the study by (Jamilian et al., 2014) reported a contradicting result of an increase in the mandibular plane angle to the cranial base, but it was insignificant. However, the only significant difference found between the two groups in the changes of the mean values of any skeletal parameter was reported in regards to the change in the (maxillary height) mean value after surgery. Group B has shown a significant decrease in this parameter, this can be explained by the impaction movement that was done alongside the maxillary advancement, which would move the maxilla higher vertically and lead to a decrease in this angle.

On assessing dental parameters, a mean value of -6,12 mm and -5,94mm overjet in Group A and B respectively, is another clear evidence of the severe sagittal discrepancy before surgery. The surgery has brought about a significant increase in the mean value of overjet in both groups, with corrections of 9,46mm in Group A and for group B it was 8,78mm, and a huge improvement from an underbite to a positive and much closer to normal overjet, has been achieved. Our results coincide with those reported by (Chew, 2005; Marşan et al., 2009).

An increase in the mean values of overbite from before to after surgery has been noted as well, yet it was not statistically significant, unlike in the results of the previously mentioned studies. This could be due to the fact that in our study patients with excessive openbite values were excluded, as we have tried to unify our sample and avoid bias since an essential aim was to compare the effect of vertical maxillary movement.

The distance (UI-NA) is significantly decreased after surgery in both groups, while the distance (LI-NB) has decreased in both groups, just only significant in Group A compared to an insignificant change in Group B.

Changes in the inclinations of upper and lower incisors axes to the cranial base and mandibular plane respectively have all been found insignificant except for a significant increase in the mean value of (UI-SN) in Group B.

Moreover, (Al-Gunaid et al., 2012; Parappallil et al., 2018) have both reported insignificant changes in (UI-SN) and (IMPA) values after surgery as well.

The presurgical lateral cephalograms included in our study were all taken before the surgery and when the presurgical fixed orthodontic phase has been completed, in other words, the teeth were leveled, aligned, and fully decompensated and ready for the surgery. The postsurgical cephalograms, on the other hand, have been taken at least 6 months after surgery, during which the postsurgical fixed orthodontic phase has continued with dental movements and thus changes in the dental parameters being a likely probability.

For that reason, it is not possible to explain the changes in the dental parameters accurately based on skeletal changes, or on what has occurred in the surgery alone, as the details of the postsurgical phase of orthodontic treatment are vague to us.

Upon evaluating the inter-group changes regarding the dental parameters, no significant difference was reported whatsoever between the two groups of our sample.

On assessing the soft tissue parameters and how they have reacted to the changes in the skeletal parameters, and starting with the soft tissue profile, a significant decrease in the mean value of this parameter has been noted in both groups and with a similar amount of change between them before and after surgery. As explained earlier regarding the hard tissue profile angle and the interpretation of its value, the same applies to the soft tissue profile angle. The presurgical mean value has indicated a dominant flat to concave profile of the patients, which has been improved with a pattern of increasing convexity after surgery. This result of our study goes along with the results of many other studies such as (Chew, 2005; Marşan et al., 2009; Al-Gunaid et al., 2012; Rustemeyer and Martin, 2013; Parappallil et al., 2018).

Furthermore, a correlation test has been conducted to evaluate how much the soft tissue profile changes relate to those in the hard tissue profile. The results indicated a significant positive correlation between the two measurements, which was very strong in Group A and strong in Group B, a finding that was similarly reported by (Rustemeyer and Martin, 2013; Parappallil et al., 2018).

It has been established that maxillary advancement would have a direct influence on the soft tissues of the nasal and upper labial region. Starting with the nasal region, we had two parameters for evaluating the changes that occurred, firstly, a significant

decrease has been reported in both groups in the distance between the tip of the nose (Pn) point and the (TVL) which was referred to as the nasal projection. As identified before, the true vertical line passes through the point (Sn) and is perpendicular to the (FHP), making its position anteroposteriorly related to the position of (Sn) point.

With the significant maxillary advancement, it is anticipated to witness advancement in the (Sn) as well (Betts and Dowd, 2000), and thus the (TVL), which would explain the significant decrease in the distance between the (Pn) point and (TVL). Moreover, the general trend is that all LeFort I osteotomies tend to cause flattening of the alar base which might further contribute to decreasing the nasal tip projection (Betts and Dowd, 2000; Gill et al., 2017).

Contradicting results were found in the studies of (Rustemeyer and Martin, 2013; Aydil et al., 2013; Akan et al., 2021), where an insignificant increase has been reported. However, they were different from our study in terms of methodology, as the vertical reference line used was a constructed and fixed-line passing through (N) point, whereas in our study the (TVL) passes and moves along with the (Sn) point as explained before.

Secondly, the nasolabial angle whose change in our study was found to be a statistically insignificant increase in both groups. For this angle, and since it is formed by the three points (Cm), (Sn), and (ULA), multiple factors are involved in the change of its value after surgery. The movement of (Sn) point and the tip of the nose affects the inclination with the columella, the movement of the upper lip both sagittally and vertically affects the inclination of the upper lip to the (Sn) point, and because of that, there was no concurrence regarding the change of its mean value after surgery among the literature.

According to (Rustemeyer and Martin, 2013), the mean value has increased insignificantly in their results which is similar to our study, while (Chew, 2005; Marşan et al., 2009; Al-Gunaid et al., 2012) have all reported a significant increase in this angle, although the sample in Al-Gunaid et al. study had undergone maxillary downfracture, while Marşan et al. studied changes in maxillary impaction patients.

On the contrary, a significant decrease was reported by Jamilian et al., and an insignificant decrease was found among the results of (Aydil et al., 2013; Parappallil et al., 2018; Akan et al., 2021).

The bony movement of (A) point with maxillary advancement has been expressed as well on the (A') point, which has moved anteriorly as well in both groups, and although the change was statistically significant in Group B only, still no significant difference was found between the two groups as the change was also big in Group A.

An explanation of the lack of a statistical significance level in our finding regarding Group A could be that the movement of the (A') point is measured in relation to the (TVL), which we have already established the fact that it moves anteriorly as well with the maxillary advancement. Since both are moving anteriorly, it is not possible to accurately measure how much the (A') point has actually advanced compared to its original position, and in a matter of fact, the amount of anterior movement when measured to (TVL) could be underestimated. Although the change was different between the groups, it should be noted that it was not of any significance.

It is worth mentioning that a significant advancement in this point has also been reported in the findings of (Parappallil et al., 2018).

Among the correlation tests that have been done in our study was one to evaluate the correlation between the anterior movement of the (A) point and the (A') point.

In Group A, a positive but very weak and insignificant correlation was found, and it could be due to the fact that the anterior movement of the (A') point was insignificant in the first place. When compared to Group B, a moderate positive correlation was noted yet it was also insignificant, but since the advancement that occurred in this group was significant, the correlation was stronger.

Another point that should be taken into consideration, is that the movement of each of the two points is measured relative to two different vertical reference lines when (A) movement is being measured in relation to the vertical line passing through (N) point and being perpendicular to the (FHP), the (A') anterior movement, on the other hand, is being measured relative to the (TVL). With one being fixed to the point (N) and the other moving with the point (Sn), this could explain the very weak to moderate correlation between the movements of these two points.

For the upper labial region, many related parameters have been included to evaluate the protrusion, thickness, and length changes of the upper lip.

To start with evaluating the anterior movement of the upper lip, a significant increase in the mean value of (H angle) was reported in both groups. As elaborated before, this measurement represents the angle between a plane passing through points (N') and (Pog'), and the point (ULA). It reflects the protrusion of the upper lip, so when the upper lip is retrusive the value of (H angle) will be decreased and if the point (ULA) lies behind the plane (N'-Pog'), the value will be negative. Moreover, the mandibular prognathism affects this value, as a protruded (Pog') point would further decrease the value of this angle. The protruded mandible in addition to the retrusive upper lips in our sample, which have been also concluded based on other measurements, have both contributed to the decreased mean values of this angle before surgery in both groups A and B (4,69 and 4,33 respectively). Additionally, a minimum value of 0 degrees and of -4 degrees has been reported amongst the presurgical readings for groups A and B respectively.

The statistically significant increase in the mean value of this angle after surgery is a result of both an anterior movement of the upper lip, as well as a retrusion of the chin point that accompanied the mandibular setback.

The anterior movement of the upper lip has also been evident when checking the changes in the mean value of the parameters (Upper lip-E-line) and (Upper lip-TVL) after surgery. The presurgical mean values consolidate those of the previous parameter in indicating a retrusive upper lip before surgery, with an average value of -9,49mm and -9,41mm in the distance (Upper lip-E-line) for groups A and B respectively, it is clear that also both groups had similar mean values before the surgery.

The increase was statistically significant for the (Upper lip-E-line) and insignificant for the (Upper lip-TVL). Again, this could be explained by the nature of the movement of the two reference lines used, where the E-line described by Ricketts connects the (Pn) and (Pog') points, it means that changes in these two points would cause a change in the position of this line itself. As described before, with the mandibular setback and alongside it, the retrusion in the soft chin point (Pog'), combined with the anterior movement in the upper lip, the change in this measurement would be greater. On the other hand, when the anterior movement of the upper lip is measured to the (TVL),

which already moves anteriorly with the (Sn) point, meaning in the same direction with the upper lip movement, it is only logical that the change in the mean value of this measurement tends to be understated. Nonetheless, both are obvious indications of the effect of maxillary advancement on the anterior movement of the upper lip.

Corresponding findings to ours regarding the (Upper lip–E-line) has been reported in the studies (Al-Gunaid et al., 2012; Jamilian et al., 2014). Likewise, the same was reported by Akan et al., although their study was conducted on single jaw orthognathic surgery patients who underwent only maxillary advancement.

When compared to the results of (Chew, 2005; Marşan et al., 2009), the same findings were reported as in our study as a significant increase in the upper lip protrusion, although the methodology used in their studies is different in terms of the vertical reference line which was fixed and constructed passing through the point (N).

Another different methodology was noted in the study of (Al-Gunaid et al., 2012), where they used the (Sn-Pog') line proposed by Burstone to control the nasal variability, as a reference to measuring the anterior movement of the upper lip, yet the results were same as in our study. We believe that in this method more variability might be seen due to the changes in (Sn) point with maxillary advancement, which might outweigh the changes in the (Pn) point in the E-line used in our study.

When evaluating the upper lip thickness change after surgery, in Group A an insignificant increase in the mean value was recorded, and when compared to Group B, an insignificant decrease was noted.

Although the difference between the two groups was statistically insignificant, also the change itself within each group is very minimal and insignificant, but an obvious difference in the response is seen. (Gill et al., 2017) had stated that with maxillary advancement in general a flattening and thinning of the upper lip is expected, and further detailed that with impaction the thickness would decrease which already coincides with our results for the impaction group. While with downfracture, they concluded that the upper lip might flatten, which makes our result for the downfracture group not so odd. On looking at results of previous studies, an insignificant decrease was reported by (Parappallil et al., 2018) and a significant decrease was found among

the results of (Jokić et al., 2013) study, both of which did not include any comparison or details regarding the maxillary vertical movement.

When discussing the thickness of the lips, many factors play a role in the change of this parameter, for example, the original thickness and tonicity have a direct effect on the amount and nature of the response. A negative strong correlation was found between the presurgical thickness and amount of change observed after surgery in the study of (Jokić et al., 2013), meaning the thicker the tissue was before surgery the lesser it responded and changed after surgery. Moreover, Betts and Dowd, had concluded that changes in thin lips are more predictable compared to changes in thick lips.

According to (Parappallil et al., 2018), the insignificant change in their study was explained by the fact that the presurgical thickness in their sample was increased and hence minimal changes were noted after surgery, a similar conclusion was revealed by (Stella et al., 1989; McCollum et al., 2009) where patients with thin lips experienced three times more change than those with thick lips for the same amount of skeletal movement.

Another factor is the technique of suturing used, for example, the use of the V-Y closure technique and its effect shows a big contrast. (Radney and Jacobs, 1981; Mansour et al., 1983) both stated that the use of this suturing technique would indeed reduce the flattening and shortening of the upper lip, whereas (Phillips et al., 1986; Talebzadeh and Pogrel, 2000) both have concluded that there was no significant difference between when it was used and when it was not used.

As for the length of the upper lip, our results have shown a significant increase in the upper lip length in Group A with the downfracture, a result that goes along with the one reported by (Al-Gunaid et al., 2012) who studied changes in downfracture patients as well.

A similar response was noted in Group B even though the increase was insignificant with impaction. This result is slightly different from what was found by (Marşan et al., 2009) where they have revealed a significant increase in the upper lip length among their sample of maxillary impaction, but similar to what (Rustemeyer and Martin, 2013) have concluded which was an insignificant increase in this parameter.

The results of multiple previous studies were in agreement with ours as well, Chew and Jamilian et al. both have studied changes in bimaxillary surgery patients and reported a significant increase in the upper lip length. Contrastingly, Gill et al. have claimed that with maxillary advancement, a shortening of the upper lip is expected and further specified that it is even more common with impaction. Nonetheless, they have mentioned this speculation in the context of single jaw surgery composed of maxillary advancement only, and although mandibular movement might not have a direct influence on the upper lip, the relationship between the upper and lower lips cannot be overlooked.

Moreover, (Betts and Dowd, 2000) had also mentioned that the maxillary advancement would tend to decrease the upper lip length, but when discussing bimaxillary movements they stated that the mandibular setback might have a lengthening effect on the upper lip.

One explanation could be related to the fact that with the mandibular prognathism and the severe underbite that was noted in our patients presurgically, in addition to the overbite of 1,03mm and 1,44mm for groups A and B, respectively, the lower lip may overlap and compress the upper lip. The upper lip length is measured in NemoCeph tracing software that we used from the (Sn) point to (Sts) point, and with the mandibular setback and backward movement of the lower lip alongside the correction of the negative overjet, the upper lip might have been relieved which is possible to have increased the vertical distance that measures the (Upper lip length).

A correlation test was incorporated to evaluate the association between the amounts of vertical movement in each group with changes in the upper lip length, although both were not significant, they were positive in direction and the correlation was moderate in Group A and weak in Group B.

When evaluating the changes in the lower labial region resulting from the mandibular setback movement, the same set of parameters were used and studied including the lower lip movement, thickness, and length.

The presurgical mean values of the parameters (Lower lip–E-line) and (Lower lip–TVL) have indicated that the patients of our sample had a protrusive lower lip before surgery.

Our results have shown that the mean value of the (Lower lip–E-line) after surgery has insignificantly decreased in both groups and without a significant difference between the two, meaning that the lower lip has moved backward in relation to the E-line. The insignificance can be explained that both the lower lip and the (Pog') point are moving backward in the sagittal plane alongside the mandibular setback, and with that, the change in the position of the lower lip is also accompanied by a change in the E-line position resulting in an understated difference.

When assessing the change in the mean value of (Lower lip–TVL) parameter, however, a significant decrease was found in both groups, which indicates an improvement from a protrusive and prominent lower lip before surgery to a more harmonized position with the upper lip in particular and with regards to facial beauty in general.

The results of our study have been found in agreement with those of other studies including (Al-Gunaid et al., 2012; Jamilian et al., 2014) regarding the change in the (Lower lip–E-line) value.

Indistinguishable results were also obtained in the studies of (Chew, 2005; Marşan et al., 2009), taking into consideration that they measured the movement relative to a fixed vertical reference line as clarified before. In addition, alike results were reported by Al-Gunaid et al. and Parappallil et al. despite using the Burstone (Sn-Pog') line as a reference.

The changes in the lower lip following the mandibular setback were not limited to change in its position, the results have shown a significant decrease in the mean value of (Lower lip thickness) after surgery in both groups, and the difference between the two groups regarding the mean change was not significant.

There were not many results reported in the literature regarding the change in the lower lip thickness after surgery, except for two studies in which the parameter was found to increase but insignificantly (Jokić et al., 2013; Parappallil et al., 2018).

Upon assessing the changes in the (Lower lip length) parameter after surgery, a significant decrease was found in both groups. Furthermore, the inter-group results have shown a significant decrease between the two groups.

Our result was found to be common when other studies were checked, Rustemeyer and Martin had also reported a significant decrease in the measurement in their bimaxillary surgery sample. Moreover, (Al-Gunaid et al., 2012) who studied changes in patients who underwent downfracture in their maxillae, had also reported a significant decrease, a result matching the one found by (Marşan et al., 2009), though the latter had studied the changes in a maxillary impaction sample.

On the other hand, one mismatched result that we came across was in the study of Jamilian et al. where they have reported an insignificant increase in the lower lip length among their studied sample, yet it is worth mentioning that their follow-up period was markedly different from ours as they have studied the changes 2 months after surgery. Betts and Dowd have mentioned that a decrease in the lower lip length is expected with mandibular superior movement or counterclockwise rotation; this would explain the decrease in this measurement in our sample as the mandible had actually rotated in a counterclockwise pattern with the decrease in mandibular plane angle as described before. The NemoCeph tracing software measures the lower lip length from (Sti) point to (Me') point as a vertical distance parallel to the (TVL), and with such a rotation in the mandible, it is very likely that the (Me') point moves upward and hence decreasing the distance and this parameter.

When looking at the change in the mean value of (GoMe-SN), we can notice that the angle of the mandibular plane to the cranial base has decreased more in Group B compared to a lesser change in Group A, which would clarify the significant difference regarding the change in this measurement between the two groups where it has decreased more in Group B.

When comparing the position of the (B') point before and after surgery in relation to the (TVL), a significant decrease in both groups was seen in the mean value of (B'-TVL) parameter indicating a backward movement of the (B') with the mandibular setback. Both groups have reacted similarly with an amount of backward movement of 5,91 and 5,06 in Group A and B respectively, showing no significant difference.

The results are also corresponding to those brought about by the studies of (Lin and Kerr, 1998; Aydil et al., 2013; Parappallil et al., 2018).

The correlation test that was made between the parameters (N per B) and (B'-TVL) have shown a significant correlation in both groups. For Group A, the correlation was

strong and positive, while in Group B it was very strong and positive as well. One possible explanation of why it was stronger in Group B is that although the amount of backward movement of (B') point was very close to that in Group A, the amount of setback and backward movement of skeletal (B) point was lesser than that achieved in Group A (4,36) compared to (2,93) in Group B.

The last parameter involving the soft tissue was related to the thickness of the soft chin, which was measured by the distance between (Pog-Pog'). The results have shown that the changes in the mean value of this measurement were not significant after surgery and in both groups. In Group A, a minimal change represented by an insignificant increase was noted, while in Group B the measurement has decreased but also very minimally and insignificantly. It can be deduced that since no significant change has occurred in the distance between hard tissue and soft tissue chin points and with the thickness of this area changing very slightly, the soft tissue chin point has actually moved along and followed the movement of the bony chin.

Although a different response was seen between our two groups expressed as an increase in Group A and a decrease in Group B on the other side, still both were insignificant as mentioned before in addition to no significant difference when comparing the groups to each other.

The results reported in the literature show a level of variety, for instance, the study by Parappallil et al. yielded an insignificant increase, similar to the change in our downfracture group yet in their study they did not specify the vertical movement of the maxilla.

Another result of insignificant decrease was declared by (Jokić et al., 2013), one that is matching the result in our impaction group, again despite not specifying their sample as we have done in ours.

One contrasting result that is odd to ours was reported in the study of (Marşan et al., 2009), in which they have studied changes in maxillary impaction patients, and found a significant increase in the mean value of (Pog-Pog') after surgery, making it a contradicting result to what we found. Yet it is believed that this result cannot be compared to ours as their methodology differs in the aspect of postsurgical follow-up

period which was an average of 2,6 years, a period much longer than the one we have applied for including the postsurgical lateral cephalograms.

Other than what was mentioned before, no significant difference was noted in the change of the parameters between the two groups.

Regarding the correlation tests that were carried out, it is noteworthy to state that they do not provide information about cause and effect; rather they just describe a relationship in terms of direction and strength between two sets of continuous variables.

Besides the ones that were already discussed, a correlation test was carried out between (N per A) and the (Nasolabial angle) measurements, and it was weak and without any significance in both groups. A similar result was reported by Marşan et al. where it was a weak and insignificant correlation.

Another pair was the (N per A) and the (Upper lip-TVL), which they were correlated positively and moderately in strength without significance level in Group A. in contrast, the correlation was a significant and strong positive one in Group B, which was closely comparable to the significant positive yet moderate correlation found by (Marşan et al., 2009). From such correlation, it can be concluded that the maxillary sagittal advancement has affected the position of the upper lip synchronously.

Additionally, it was found that (N per A) was negatively correlated with nasal projection in our study in both groups, with the difference being that this correlation was strong and significant in Group A compared to being moderate and insignificant in Group B. The moderate to strong negative correlation indicates a counterchange in the nasal projection with advancement measured at point (A), which was reported indeed among the previously explained results.

The (A'-TVL) was found to be correlated significantly with (Upper lip-TVL) in both groups, and it was positive and strong, showing that the anterior movement in (A') point was coinciding with an anterior movement of the upper lip as well.

In addition, a significant correlation between the (A'-TVL) and (Upper lip thickness) was only reported in Group B, where it was negative and strong as well. The negative correlation was noted when discussing the change in the mean value of (Upper lip

thickness) before and after surgery, where it had decreased where the (A') point had moved anteriorly.

When assessing correlations between the (N per B) parameter with the lower lip protrusion, a positive correlation in both groups indicates that the lower lip did actually follow the backward movement at point (B), yet the correlation was significant and very strong in Group B, when it was moderate and insignificant in Group A.

The same correlation in terms of positive direction was noted in the study of (Marşan et al., 2009), additionally, it was moderate yet significant, which does not stray away from our results.

The lower lip protrusion was correlated with the (B'-TVL) measurement as well, and the backward movement in the soft tissue (B) point was found to have a similar relationship with the position of the lower lip as that the hard tissue (B) point had. Similarly, a positive significant and strong to very strong correlation was noted. This further solidifies the fact that the lower lip moved backward alongside the backward movement of (B').

Lastly, the negative correlation between (B'-TVL) and (Lower lip thickness) was found in both groups, yet it was strong and significant in Group A only. This consolidates to the other results that have shown a decrease in the lower lip thickness with the mandibular setback.

In light of the foregoing, the limitations of our study were firstly the relatively small sample size, which had resulted from applying strict inclusion criteria, so to speak, to overcome the disadvantages of the retrospective study design, avoid bias, and provide homogeneity in our sample. Moreover, the average amount of vertical movement in both groups may have been little and hence not enough to fully express the different effect of the vertical movement on the response of the soft tissue between the two groups. Lastly, using 2D cephalograms to study changes in a 3D structure would not provide sufficient information as it addresses changes in sagittal and vertical dimensions only.

- Conclusion

Taking into account the limitations of our study, the following can be concluded:

- The bimaxillary orthognathic surgery has significantly corrected the skeletal discrepancy of maxillary retrognathism and mandibular prognathism, alongside a significant improvement in the skeletal profile with a pattern of increasing convexity, one that was strongly correlated with a corresponding significant improvement in soft tissue profile as well.
- The effect of the surgery was very evident in the change of labial tissues position, with significant correction of the retrusive upper lip and protrusive lower lip, towards a more aesthetic and harmonious position.
- Significant decrease was evident in the lower lip thickness and length in both groups, with the latter being more significant in the impaction group.
- Significant strong and positive correlations were seen between the movement of the (A') point and the upper lip protrusion, and the movement of the (B') point and the lower lip protrusion, with no inter-group significant difference reported.
- A significant positive correlation between the hard tissue and the soft tissue (B) points, in addition to an insignificant change in the soft chin thickness (Pog-Pog'), both indicating a matching response in these regions to the mandibular setback movement.
- A weighty effect was noted in the response of the soft tissues with significant changes in many regions and aspects, yet it was more evident and predictable in the horizontal rather than the vertical dimension.
- A larger sample size with more expressive vertical movements in the maxilla and the use of 3D analysis are our recommendations for future similar studies.

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