

T.C.

YEDİTEPE UNIVERSITY

INSTITUTE OF HEALTH SCIENCES

DEPARTMENT OF ORTHODONTICS

**3D EVALUATION  
OF NASOMAXILLARY COMPLEX  
AFTER ORTHOGNATHIC SURGERY**

DOCTOR OF PHILOSOPHY THESIS

Dr. PINAR SAYIN, DDS

İstanbul-2024

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SUPERVISOR

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İstanbul-2024

## THESIS APPROVAL FORM

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### APPROVAL

This thesis has been deemed by the jury in accordance with the relevant articles of Yeditepe University Graduate Education and Examinations Regulation and has been approved by Administrative Board of Institute with decision dated ..... and numbered .....

Prof. Dr. Bayram YILMAZ  
Director of Institute of Health Sciences

## **DECLARATION**

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

Pınar SAYIN



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## **LIST OF SYMBOLS AND ABBREVIATIONS**

|      |                                           |
|------|-------------------------------------------|
| mm   | Millimeter                                |
| nm   | Nanometer                                 |
| %    | Percent                                   |
| 2D   | Two-dimensional                           |
| 3D   | Three-dimensional                         |
| CT   | Computer tomography                       |
| CBCT | Cone-beam computed tomography             |
| BSSO | Bilateral sagittal split osteotomy        |
| RIF  | Rigid internal fixation                   |
| CSM  | Correspondence by sensitivity to movement |
| NHP  | Natural head position                     |

## ABSTRACT

**Sayın, P. (2024). 3D Evaluation of Nasomaxillary Complex After Orthognathic Surgery. Yeditepe University, Institute of Health Science, Department of Orthodontics, PhD Thesis, İstanbul.**

This retrospective study aimed to evaluate the nasomaxillary soft tissue changes of skeletal class III patients with LeFort I before and after orthognathic surgery and compare the changes according to various parameters. The study comprised 27 patients, 8 (%29.6) men and 19 (%70.4) women, aged between 20 and 42. The amount of maxillary advancement was between 1-5 mm in 14 (51.9%) patients and 5.5-10 mm in 13 (48.1%) patients. 16 (59.3%) patients had a high-angle growth pattern and 11 (40.7%) patients had a low-angle growth pattern. 3D stereophotogrammetric recordings of the individuals in the study were taken before (T0) and approximately six months after surgery (T1). Measurements were made on 3D facial photographs and statistical analyses were applied. In the 1-5 mm and 5.5-10 mm advancement groups, the increase in alar width, alar base width, and labiale superius projection; the decrease in nostril show was found to be statistically significant at T1 time compared to T0 time ( $p<0.05$ ). In the 5.5-10 mm advancement group, the upper lip-E line decrease was statistically higher than the 1-5 mm advancement group at T1 time compared to T0 time ( $p<0.05$ ). From T0 to T1, the high-angle group had a significantly higher increase in upper lip-E line and lip length measurements than the low-angle group ( $p<0.05$ ). In the 5.5-10 mm advancement group and the high-angle group, the decrease in nasofrontal angle was statistically significant at T1 compared to T0 ( $p<0.05$ ). As a result, significant changes were found in the nasomaxillary region in patients who underwent maxillary advancement. Stereophotogrammetry device allows 3D evaluation of soft tissues.

**Key Words:** Stereophotogrammetry, Orthognathic surgery, nasomaxillary complex, Soft tissue, Skeletal Class III

## ÖZET

**Sayın, P. (2024). Nazomaksiller Kompleksin Ortognatik Cerrahi Sonrası Üç Boyutlu Değerlendirilmesi. Yeditepe Üniversitesi, Sağlık Bilimleri Enstitüsü, Ortodonti ABD., Doktora Tezi, İstanbul.**

Bu retrospektif çalışmanın amacı LeFort I ile ortognatik cerrahi ameliyatı olan iskeletsel sınıf III hastaların ameliyat öncesi ve ameliyat sonrası nasoalveolar bölgedeki yumuşak doku değişikliklerinin değerlendirilmesi ve çeşitli parametrelere göre karşılaştırılmasıdır. Çalışma yaşları 20 ile 42 arasında değişmekte olan, 8'i (%29.6) erkek ve 19'u (%70.4) kadın olmak üzere toplam 27 hasta ile yapılmıştır. Maksillar ilerletme miktarı 14 (%51.9) hastada 1-5 mm arasında iken, 13 (%48.1) hastada 5.5-10 mm arasındadır. 16 (%59.3) hasta high-angle, 11 (%40.7) hasta low-angle büyüme paternine sahiptir. Çalışmadaki bireylerin üç boyutlu stereofotogrametrik kayıtları ameliyat öncesinde (T0) ve ameliyattan yaklaşık altı ay sonra (T1) alınmıştır. Ölçümler üç boyutlu yüz fotoğrafları üzerinde yapılmış ve istatistiksel analizler uygulanmıştır. 1-5 mm ve 5.5-10 mm ilerletme gruplarında, T0 zamanına göre T1 zamanında görülen artış alar genişlik, alar taban genişliği, üst dudak projeksiyonu ortalamaları açısından; T0 zamanına göre T1 zamanında görülen düşüş, nostril alanı ortalamaları açısından istatistiksel olarak anlamlı bulunmuştur ( $p<0.05$ ). 5.5-10 mm ilerletme grubunda; T0 zamanına göre T1 zamanında görülen üst dudak-E çizgisi değerindeki düşüş miktarı, 1-5 mm ilerletme grubununkinden istatistiksel olarak daha yüksektir ( $p<0.05$ ). High-angle grubunda, T0 zamanına göre T1 zamanında üst dudak-E çizgisi ve dudak uzunluğu değerlerindeki artış miktarı, low-angle grubununkilerden göre istatistiksel olarak daha yüksektir ( $p<0.05$ ). 5.5-10 mm ilerletme ve high-angle gruplarında, nasofrontal açıdaki düşüş istatistiksel olarak anlamlıdır ( $p<0.05$ ). Sonuç olarak maksiller ilerletme yapılan hastalarda nazomaksiller bölgede istatistiksel olarak anlamlı değişiklikler bulunmuştur. Stereofotogrametri cihazı yumuşak dokuların 3 boyutlu değerlendirilmesine olanak tanımaktadır.

**Anahtar Kelimeler:** Stereofotogrametri, Ortognatik cerrahi, Nazomaksiller kompleks, Yumuşak doku, İskeletsel sınıf III

## 1. INTRODUCTION AND AIMS

Class III mandibular prognathism is a dentofacial anomaly characterized by the mandible being positioned more frontally than the usual alignment. Due to recent advancements in orthognathic surgical procedures, there has been a rise in the number of surgical cases aimed at correcting the underlying skeletal abnormality in class III patients.

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To surgically treat patients with Class III malocclusion and protrusion of the lower jaw, either the mandible is set back, the maxilla is moved forward, or both procedures are combined. The LeFort I osteotomy can achieve significant maxillary advancement, which can result in notable alterations in the soft tissue of the lips and nose.<sup>2</sup> Therefore, the patient's soft tissue profile and projected esthetic appearance after treatment should be a primary concern for the orthodontist and surgeon throughout the pre-assessment and treatment planning of any surgery case.<sup>3</sup> To create the best profile impression, it is essential to thoroughly check the positions of the nose, lips, and jaws in both frontal and sagittal orientations, as well as the amount, ratios, and curves of soft tissues before surgery.<sup>3,4</sup> Therefore, treatment planning requires predicting the response of facial soft tissues after repositioning the underlying skeletal structure.<sup>5</sup>

Various techniques have been developed to measure and analyze soft tissue. Traditionally, soft tissue was evaluated from two-dimensional (2D) photographs or x-rays, which presented significant flaws since a three-dimensional concept can't be interpreted correctly in two dimensions.<sup>6</sup> Nevertheless, the capabilities of soft tissue change prediction algorithms are restricted to the superimposition of 2D radiologic shadows. Accurate characterization of the nature and extent of nasolabial alteration in Le Fort I requires three-dimensional analysis and objective data. This information is valuable for meticulous strategizing, suitable patient guidance, and optimizing aesthetic results. Practitioners need three-dimensional (3D) standardized data and a non-intrusive, dependable diagnostic procedure to eliminate subjective factors in the patient examination.<sup>3</sup> It is non-invasive and non-contact to utilize stereophotogrammetry, a visual-based imaging system that generates high-quality records in 1.5–2 milliseconds and performs accurate and coherent measurements on these records.<sup>3,7</sup>

Due to advancements in 3D imaging techniques, digital 3D photography, commonly called stereophotogrammetry, has emerged as a superior alternative to conventional orthodontic diagnostic tools like radiography, study models, and two-dimensional photography.<sup>8</sup>

One example of stereo-photogrammetry is the 3dMD System (Atlanta, GA, USA), which combines the structured light technique and stereo-photogrammetry. This device utilizes many planes to capture photographs of an object to build a 3D reconstruction. This enables the measurement of linear lengths and considers surface lengths, surface sectors, and volumes. Furthermore, three-dimensional coordinates can be extended to conduct diverse statistical shape analyses, which can be employed for diagnosing craniofacial dysmorphology or alterations to the craniofacial complex during treatment.<sup>9</sup>

To assess the alterations in soft tissue following orthognathic surgery, it is necessary to conduct a comparison by superimposing 3D digital pictures taken before and after the therapy. Once the reference frame has been established and all landmarks identified on the preoperative 3D image, superimposition should be performed using the postoperative shot.<sup>10</sup>

The soft tissues in the nasomaxillary area experience alterations following maxillary advancement during LeFort I surgery, with these alterations being influenced by several individual and perioperative circumstances. Several reviews have been published on the use of stereophotogrammetry after orthognathic surgery.<sup>2,3,10-17</sup> Variations in the soft tissues of the nose were observed in the 3D analysis after maxillary advancement via LeFort I osteotomy. These changes were consistently associated with the enlargement of the alar base, reduction of nasal tip protrusion, and alteration of nasal angles. To summarize, substantial changes were observed in the nasomaxillary complex's linear, angular, and perimetric measurements upon maxillary advancement.<sup>2</sup>

Our study focuses on looking closely at soft tissue changes in the nasomaxillary complex before and following the orthognathic surgery procedure, individually comparing the alterations in the values in those two time intervals.

Therefore, this study aims to evaluate the soft tissue changes after orthognathic surgery using angular, linear, and perimetric measurements with a 3dMd stereophotogrammetry device. The null hypothesis is that the soft tissue of the nasomaxillary complex did not change after orthognathic surgery.



## **2. LITERATURE REVIEW**

### **2.1. Class III Malocclusion**

#### **2.1.1. Definition of Class III Malocclusion**

Angle, Moyers, and Tweed categorized Class III malocclusions into three distinct types: pseudo, dentoalveolar, and skeletal. Angle's classification categorizes a Class III jaw relationship, where the mandible is anterior to the maxilla. Tweed categorized Class III malocclusions into two groups: a pseudoclass III malocclusion characterized by a normally shaped lower jaw and a skeletal Class III malocclusion characterized by a more prominent lower jaw or an undeveloped upper jaw. Moyers categorized malocclusions based on their etiology: skeletal, muscular, or dental.<sup>18</sup>

#### **2.1.2. Prevalence of Class III Malocclusion**

Spanning from 0% to 26% of the total population, the prevalence of Class III malocclusions varies considerably between and within populations.<sup>19</sup> Pseudo-Class III malocclusions, predominantly observed in patients with mixed or deciduous dentition, should not be disregarded. Approximately 60 to 70 percent of anterior crossbites in adolescents aged 8 to 12 were determined to be delegated pseudo-Class III malocclusions.

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Comprising 9–19% of cases, the prevalence of Class III malocclusion is highest among Asians.<sup>21,22</sup> The average prevalence rate in the Middle Eastern region was 10.2%. The European region exhibited the lowest prevalence rate at 4.9%, while India demonstrated the lowest prevalence rate at 1.2%.<sup>18</sup>

#### **2.1.3. Components of Class III Malocclusion**

Six distinct categories of class III problems can be distinguished by the anteroposterior position of the mandible and maxilla: mandibular prognathism accompanied by a healthy maxilla, maxillary retrognathism accompanied by a healthy mandible, normal maxilla and mandible, maxillary retrognathism combined with mandibular prognathism, bimaxillary prognathism and bimaxillary retrognathism.<sup>23</sup>

#### **2.1.4. Etiology of Class III Malocclusion**

Population studies have provided information indicating that genetic variables substantially influence the formation of Class III malocclusion. In contrast, many environmental variables have been found to impact the growth of the lower jaw. Class III is considered to have polygenic inheritance, meaning that the interaction of many susceptibility genes and the medium causes this malocclusion. The hereditary examination of families exhibiting the Class III phenotype provides evidence favoring the polygenic inheritance theory. Class III malocclusion arises from the combined influence of several variables during the developmental stage of the lower jaw. It may be feasible to control certain aspects of these factors in early childhood. Hence, Xue et al. proposed that acquiring a more comprehensive comprehension of the genetic factors contributing to Class III's appearance is imperative to formulating novel preventative measures for the illness.<sup>24</sup>

#### **2.1.5. Treatment of Class III Skeletal Malocclusion**

The treatment options for Class III malocclusion can be categorized into three distinct approaches. The choice of option may be related to the skeletal relationship between the mandible and maxilla, the severity of the skeletal discrepancy and the growth stage of the patient.

The three approaches are:

1. Growth manipulation during early growth stages
2. Orthodontic camouflage by dentoalveolar correction of the jaws
3. Orthodontic treatment combined with orthognathic surgery

In the mixed dentition, the correction of an anterior crossbite and minimal skeletal Class III malocclusion can be accomplished by the utilization of several treatment modalities, including detachable appliances, partly fixed appliances, an orthopedic chincup, and a facemask, all of which can be accomplished in a concise amount of time. When it comes to maximizing the orthopedic outcomes and assuring the long-term stability of the therapy, early diagnosis of the anterior crossbite is necessary.<sup>25</sup>

In most circumstances, orthognathic surgery is advised for adult patients with significant differences in the size and alignment of their teeth and jaws. Compensatory procedures such as dentoalveolar compensation or camouflage are suggested for less severe discrepancies. Nevertheless, making a decision, particularly in borderline cases, is challenging. Borderline instances refer to people who have mild to moderate skeletal abnormalities that can be effectively addressed through either orthodontic treatment or surgical intervention. Moreover, it is crucial to acknowledge that the ultimate responsibility for this decision lies entirely with the patients.<sup>26</sup>

## **2.2. Orthognathic Surgery**

Orthognathic surgery is a procedure that improves the jaw skeleton structure in cases where the jaw closures are incompatible. It is carried out by orthodontics and maxillofacial surgery.

The orthognathic correction may be applied to one or both jaws. The modification of the facial skeleton seeks to enhance the accurate anatomical and functional connections in the dentofacial area by modifying the soft tissues and the bone structures.<sup>27</sup>

### **2.2.1. Orthognathic Surgery in the Maxillary Area**

The LeFort I osteotomy is a commonly done surgical operation used to repair abnormalities in the middle part of the maxilla, which is the upper jawbone. The LeFort I osteotomy is named after Rene LeFort, who initially documented the fracture pattern in 1901. This pattern spans from the nasal septum to the tooth apices and across the pterygomaxillary junction.<sup>28</sup>

Class III malocclusion is a prevalent indication that forces the application of LeFort I osteotomy. It is frequently observed in individuals with orofacial clefts, obstructive sleep apnea, and maxillary atrophy and is correlated with hypoplasia of the maxilla. The most common approach to correct malocclusion is the LeFort I osteotomy with horizontal advancement.<sup>28</sup>

To reveal the medial and lateral buttresses of the maxilla, it is essential to create an incision that spans from the first molar to the first molar. It is necessary to perform subperiosteal dissection to expose the anterior aspect of the maxillary canal. During

dissection, it is essential to consider the nasal mucosa and lining near the piriform opening. It is desirable to have the nasal septum and nasal floor exposed at the level of the posterior palate. The dissection attains its maximum extent in proximity to the infraorbital nerves. A lateral dissection is performed when the lateral maxillary buttress is in close proximity. The osteotomy operation is accomplished with an alternating saw positioned on the lateral maxillary buttress to reach the opposite piriform rim. A contralateral osteotomy is performed using a similar technique.<sup>28</sup> An osteotome is utilized to fracture the posterior maxillary wall, the structural connection between the nasal septum and the maxilla. Isolation of the pterygomaxillary junction occurs during the final phase. To validate the accurate placement of the osteotomy, it is possible to palpate its medial extent by inserting a finger into the oral cavity and applying pressure to the hamulus. Distinguishing down fractures should not require an overly excessive application of force. By performing an additional dissection of the nasal floor and nasal mucosa, it is possible to fracture the maxilla. After the down fracture and mobilization are completed, the new position of the maxilla will be determined by aesthetic considerations and preoperative planning. The desired movements are carried out concerning the external reference points assessed before the procedure. After preparing the surgical splint, the patient is positioned in maxillomandibular fixation while the splint remains positioned to support the maxilla. During this procedure, postoperative malocclusion can be avoided by ensuring the mandibular condyles are firmly positioned in their fossa. Once the maxilla is in the proper position, titanium plates and screws should be used to secure it in place.<sup>28</sup>

### **2.2.2. Orthognathic Surgery in the Mandibular Area**

The bilateral sagittal split osteotomy (BSSO) is a crucial component of orthognathic surgery and is commonly used for jaw surgery, either with or without upper jaw surgery. More than 7 to 8 mm of posterior mandibular repositioning with a BSSO can be challenging; therefore, an inverted "L" osteotomy or intraoral vertical ramus osteotomy should be considered.<sup>29</sup> Cases involving asymmetry necessitate careful investigation and intention yet may be readily resolved with a BSSO. Osteogenesis by mandibular distraction is more advantageous in the circumstances needing significant

advancement, individuals with inadequate soft tissue envelopes, and mandibles that have not yet reached their full skeletal development.<sup>30</sup>

The soft tissue incision is performed first during mandibular setback procedures, followed by the periosteum elevation. An osteotomy is performed by making cuts through the cortical bone, beginning above the lingula on the medial side of the ramus, continuing down to the anterior portion of the ramus onto the superior portion of the mandibular body, and then curving inferiorly through the lateral cortical plate, including the inferior border. This is the typical pattern of osteotomy. In the posterior area of the ramus, the osteotomy extends horizontally one-half or two-thirds of the anteroposterior dimension, reaching as far anteriorly as the region of the second molar. After the ramus has been successfully divided, the mandible is relocated to its ideal position per the surgical treatment plan.<sup>31</sup>

### **2.2.3. Facial Soft Tissue and Interventions During Orthognathic Surgery**

During LeFort I osteotomy, some interferences must be avoided. To reduce the extent of soft tissue elongation, it is desirable to increase its size when retracting the upper lip to enhance the visibility of the gingival cuff on the upper jaw. This is because the cuff will inevitably seem shorter once trimmed. Following the mucosa incision and identification of the areolar tissue in the submucosal layer, the dissection should proceed directly toward the bone.<sup>28</sup> Ensuring the structural integrity of this aircraft and refraining from dissecting the facial muscles are crucial. This will induce significant inflammation and hemorrhaging. Precautions should be taken to safeguard against perforations of the nasal membrane. It is critical to exercise caution to prevent harm to the soft tissue and maintain a subperiosteal plane on the sides. To prevent damage to the internal maxillary blood arteries, it is essential to avoid doing a deep corticotomy. The maxillary fracture should be straightforward and not need excessive power. Excessive force might lead to undesirable fractures and problems. This procedure will permit additional dissection of the nasal floor and nasal mucosa.<sup>28</sup> To prevent severe bleeding and maintain the structural integrity of the nasal cavity, it is essential to seal any holes in the nasal lining.<sup>32</sup>

#### **2.2.4. Management of the Nasal Region**

After orthognathic surgery, the most affected area is the nasolabial region. Significant changes such as the elevation of the nasal tip, increased width of the alar base, decreased length of the upper lip, increased upper lip fullness, and increased upper lip length can happen in the soft tissues of this region.<sup>31</sup>

#### **2.2.5. Side Effects of Orthognathic Surgery**

Pain, swelling, nausea and vomiting, trismus, and social/functional impairment are typical findings following orthognathic surgery. All these symptoms typically resolve within the first postoperative week except for facial swelling.<sup>33</sup> For orthognathic surgeons working with patients who need to achieve the final esthetic result, it is essential to precisely quantify the extent and duration of postoperative swelling. Fifty percent of facial swelling resolves within the first three weeks after surgery, twenty percent persists after three months, and there is a significant reduction in swelling through the end of the first postoperative year.

#### **2.2.6. Stability of the Outcomes of Orthognathic Surgery**

Without stability, achieving good function and pleasing aesthetics is not acceptable. Transverse problems resulting from a narrow maxillary dental arch should be treated, and stability should be carefully considered because transverse occlusal stability ensures vertical occlusal stability. The compatibility of the arch is crucial for guaranteeing rapid stability after surgery and providing the surgeon with precise guidance on mandible positioning in the absence of a splint. An important factor causing the instability and tendency to relapse is the increase in posterior mandibular height due to the downward rotation of the posterior part of the distal segment and the subsequent stretching of the pterygomandibular sling.<sup>31</sup>

Following mandibular BSSO, posterior maxillary expansion by semirigid inner fixation and clockwise rotation with bicortical screw fixation are both considered exceedingly unstable procedures when evaluated at the dental level. According to Haas Junior's research, the maxillary setback with titanium or bioresorbable RIF, maxillary downward movement with bioresorbable internal fixation, and maxillary upward

movement with bioresorbable RIF were considered to be surgical procedures in the maxilla that demonstrated greater instability when compared to the others that were executed.<sup>34</sup> Good function and pleasing aesthetics cannot be accomplished without stability. Due to a narrow maxillary dental arch, transverse problems must be treated, and stability must be carefully considered, as transverse occlusal stability ensures vertical occlusal stability. When a splint is omitted during surgery, the compatibility of the arch becomes crucial for ensuring stability after the operation. It allows the surgeon to determine the optimal position for the mandible accurately. It is believed that the augmentation in posterior mandibular height is due to the downward rotation of the posterior portion of the distal segment, and the subsequent stretching of the pterygomandibular sling significantly contributes to the instability and relapse propensity of the mandible. The mandibular surgical motions were predominantly stable or highly stable. More excellent stability was attained by using bilateral sagittal split osteotomy for mandibular setback and RIF with microplates and bicortical screws for rotations. Throughout the procedures, stability or a high degree of stability of mandibular surgical movements was consistently observed. For mandibular setbacks, BSSO was utilized, while RIF with microplates and bicortical screws was employed for rotations.<sup>34</sup>

## **2.3. Three-Dimensional Surface Acquisition Systems for Facial Soft Tissue Analysis**

### **2.3.1. Radiographic Methods**

Computed Tomography (CT) and Cone Beam Computed Tomography are the most common radiographic methods for imaging 3D soft tissue (CBCT). In a single image, these methods can capture both hard and hard tissues and the overlying soft tissues. The main disadvantage of these methods is the patient's exposure to ionizing radiation.

#### **Computed Tomography**

Computed or computerized axial tomography employs cross-sectional images for a three-dimensional body illustration. This scan yields three-dimensional data about both rigid and delicate tissues. The two types are fan beam tomography and CBCT. Fan beam tomography, or conventional tomography, is characterized by its substantial radiation

emission. As a result, the increased radiation dosage renders routine orthodontic applications unsuitable. However, its informative data on temporomandibular joint, orofacial trauma and fractures, orofacial pathologies, airway volumes, anatomical variations, maxillary sinus, and craniofacial syndromes contribute to its widespread application in dentistry.<sup>35</sup>

### **Cone Beam Computed Tomography**

Cone-beam computed tomography, also known as cone-beam volumetric tomography or cone-beam volumetric imaging, was introduced in Europe in the late 1990s and received Food and Drug Administration approval in 2001 for its application in the United States.<sup>36,37</sup> CBCT employs an extraoral imaging scanner, designed specifically for head and neck imaging, to generate 3D scans of the maxillofacial skeleton.<sup>38</sup> It may be similar in size to a traditional panoramic radiography device. Cone-beam devices employ a 2D planar detector instead of a linear array of sensors used in CT; due to the cone beam's ability to irradiate a significant volume rather than a tight slice, the equipment needs less frequent rotation than a CT scanner.<sup>38</sup> Alternatively, a single rotation suffices, including all the requisite data for reconstructing the desired region. This method allows medical professionals to acquire two-dimensional reconstructed pictures in all orientations and three-dimensional reconstructions with minimum exposure to x-radiation.<sup>39</sup> The primary benefit of CBCT is its capacity to see and evaluate the bony structures of the mouth and face in three dimensions, thereby overcoming the issues of magnification and overlapping that occur with two-dimensional imaging techniques.<sup>37</sup> According to Leonardi's study, despite the positive aspects and benefits associated with CBCT imaging, its routine application to all orthodontic patients is not recommended. A risk-benefit analysis must be conducted to ensure that the information obtained from the investigation outweighs any potential radiation exposure.<sup>37</sup> CBCT imaging offers two distinct benefits to orthodontic practices. First, multiple linear (e.g., lateral and posteroanterior cephalometric images) or curved planar projections (e.g., simulated panoramic images) can be derived from a single CBCT scan for orthodontic diagnosis, cephalometric analysis, and treatment planning. This results in increased clinical efficiency. The second and most significant advantage is that CBCT data can be reconstructed to produce previously unavailable images in orthodontic practice.

Computed tomography (CBCT) data are inherently displayed as inter-relational, undistorted images in three orthogonal planes (axial, sagittal, and coronal). Nevertheless, there are software methods easily accessible for generating three-dimensional visualizations of the maxillofacial skeleton, airway space, and soft tissue boundaries (e.g., facial outline), including maximum intensity projection and surface or volumetric rendering..<sup>40</sup>

### **2.3.2. Non Radiographic Methods**

#### **Stereo-photogrammetry**

Stereophotogrammetry is a subset of photogrammetry that uses the three-dimensional coordinates of points on an object derived from measurements of two or more photographs captured from various angles. Similar characteristics are found in each image. This triangulation determines the point's three-dimensional location.<sup>41</sup> Stereophotogrammetry is founded on stereoscopic principles that enable us to create or enhance the illusion of depth in a photograph using stereopsis for vision. The site is based on presenting two slightly different images to the left and right eyes separately; the brain then combines these images to create the perception of three-dimensional vision. There are various methods for displaying stereoscopic images, including polarization, anaglyph, chroma depth, etc.

#### **Laser Scanning**

The laser scanner is a soft tissue scanner and is highly advantageous due to its simplicity and ability to generate three-dimensional pictures.<sup>42</sup> Laser-scanning methods have significant promise for evaluating alterations in face morphology caused by orthodontic therapy, surgery, and facial growth. The scanning system employed in this study is rapid and user-friendly. Reproducible photos may be captured by having the individuals maintain a normal head position while looking into the mirror. This approach allows precise and dependable evaluation of development or alterations due to face transformation and therapy.<sup>43</sup> According to the mechanism of beam production, the laser devices used for 3D scanning can be categorized into two groups: slit and single-point scanners. Another division of laser scanners is fixed scanners and portable-mobile scanners.

## **Laser Scanners with Fixed Units**

A group led by Moss developed a laser scanning system for surgical purposes that can measure over 20,000 coordinates of points on the whole facial area with an accuracy of 0-9 mm. The automatic device takes only 30 seconds to complete and record the measurements. To measure a patient's face in 3D, the platform they sit on is rotated by a computer with a laser stripe traversing the target area. An optical shaft encoder collects profiles at predetermined intervals while the patient turns. The chair has an adjustable headrest with a soft Velcro strap to keep the head still during data collection.<sup>44</sup>

On the other hand, McCance and colleagues proposed a technique that measured the differences between preoperative and postoperative facial surfaces by taking measurements from the centroid of the head. However, this method may not accurately record lateral movements. For instance, if the nose tip moves laterally, it is recorded as a radial movement of a different part of the nose or cheek.<sup>45,46</sup>

In 1995, Girod et al. developed an innovative approach to assist with craniofacial surgeries. They proposed a method to enable accurate preoperative visualization of the patient's head. To achieve this, preoperative patient data is acquired through CT and a 3D laser scanner. The 3D laser scanner is crucial for creating photorealistic preoperative and simulated postoperative visuals for the patient. This simulation would not be possible if only CT data were used. The surface-based marching cubes 3D segmentation approach is used to delineate the shape of the skull by separating it from the CT data and identifying individual bones as separate entities.<sup>47</sup> Thanks to successful data reduction, the interactive manipulation of the data is possible on modern graphics workstations. Ultimately, the CT and laser scan data are aligned using an affine coordinate transformation.<sup>47</sup>

Xia et al. utilized an alternative approach to convert a generic facial model to a specific patient's soft tissue surface. They used landmarks as a preliminary reference and then applied the radial method to calculate the remaining displacements.<sup>45,48</sup>

In 2001, Guest et al. introduced a new method to compare facial surfaces before and after bimaxillary orthognathic surgery. The study involved two patients who underwent the surgery and the results were compared to three other automatic techniques.

A Cyberware laser scanner 3030HRC (Cyberware Inc. Monterey, CA, USA) was used to scan the patients before and four months after the surgery. The device is highly accurate, with a 0.2-1.0 mm range based on the surface's disposition.<sup>45</sup> To ensure accurate results, the patients were instructed to remain still during the scanning process, and a headrest was used to minimize movement. Additionally, the patients were positioned in the same way for both scans. The patient's head was positioned accurately during scans by utilizing laser guides. The samples were recorded automatically by pairing the Iterative Closest Point (ICP) registration algorithm with the Correspondence by Sensitivity to Movement (CSM) method. The reproducibility of correspondence is evaluated using the CSM method, which involves a systematic displacement of the point from the preoperative scan and subsequent verification that it aligns consistently with the matching point on the postoperative scan. This approach distinguishes points that exhibit strong correspondence with a single point, line, or tiny area from those in a region with uniform curvature. According to Guest et al., the most promising methods for measuring changes between pre and postoperative patient scans are the closest point method and the CSM method. The closest point method measures the distance between two surfaces, while the CSM approach offers insights into shape alterations and specific points' movement.<sup>45</sup>

### **Portable-Mobile Scanners**

In 1997, Konica Minolta (formerly Minolta Co, Ltd, Osaka, Japan) unveiled their VI-digitizers series.<sup>49</sup>

These digitizers employ galvanometers to sweep a laser line over the item without requiring external mechanical rotation or translation stages. However, refocusing is needed for a specific volume as the optical system does not use an auto-synchronized principle. In addition, a collinear color camera is used to map the color texture information on the object's geometry. While only the sensor resolution is quoted, these digitizers were a significant technological advancement at the time.<sup>50</sup>

The Minolta VI-700 3D surface laser scanner began a series of high-quality scanners. By using triangulation to measure the distances between the scanned surface and the laser beam, as well as the object's width, depth, and length, it was able to reconstruct a 3D model accurately. The scanner's reliability was independently evaluated,

ensuring the accuracy of the resulting 3D object. The Minolta VI-700 3D surface laser scanner began a series of high-quality scanners.<sup>51</sup>

The VI-900 scanner was recently released after four years. It boasts a highly accurate camera manufacturing measuring 0.1 mm. According to the US Food and Drug Administration, its class I laser emitting a wavelength of 690nm at 30 mW is safe for the eyes. The scanner can capture data points of around 307,000 and has a fast scan mode that takes only 0.3 seconds to complete. The device's scanning distance is adjustable, ranging from 600 to 2500 mm.

In 2004-2005, Minolta introduced newer VI-910 and 9i models. A recent addition is the Fastscan scanner from Polhemus Inc., based in Colchester, VT, USA. This device is handheld and lightweight, producing a laser beam with a wavelength of 670nm. The user can move it across the scanned object in a spray-painting-like motion. The scanner has a pair of optical cameras symmetrically placed on either side of the laser generator, collecting the laser beam's deformations.<sup>52</sup> Additionally, an electromagnetic tracking device measures the device's location in space.

### **Structured Light Techniques**

A structured light scanning system projects various light patterns onto a scene and then captures how the light interacts with the objects. This information is then used to reconstruct a 3D model of the scene. Due to their ability to quickly collect data, operate without contact, and provide precise measurements, modern 3D structured light scanning technologies have become highly versatile in a variety of industries.<sup>53</sup>

### **Systems with a Single Camera**

A structured light scanning technique involves projecting a range of light patterns onto a scene and analyzing how the light interacts with objects in that scene. This information is utilized to obtain a three-dimensional model of the scene. Thanks to their ability to gather data quickly, operate without physical contact, and provide accurate measurements, modern 3D structured light scanning technologies are widely used across various industries. Additionally, single-camera systems have been developed to attempt a series of 25 different high-density structured light patterns pioneered by Tuncay et al. in 2001.<sup>54,55</sup>

Enciso and his friends<sup>56</sup> developed a new system that comprises a digital camera, a slide projector, and a calibration model. They utilized a digitizer to confirm, mark landmarks, and measure the linear ranges between the image-produced and actual ranges. The system's margin of error was determined to be between 0.48 mm and 1.55 mm.<sup>52</sup>

## **Systems with Two or More Cameras**

### **Moiré Fringe Patterns**

The Moiré system displays contour lines that indicate equal depth from the grating's plane when the light source and observer are on a plane parallel to the grating.

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Moiré techniques have been used to examine 3D objects and surface topography since the 1970s. Moiré topography is a technique that involves observing moiré fringes, formed when two gratings with identical frequencies are overlaid. Shadow and projection moiré occurs when the moiré fringes assume the shape of contour lines on surfaces under certain geometric circumstances. Nevertheless, determining the precise fringe ordering caused by variations in height between adjacent fringes is still tricky, especially when dealing with intricate rough surfaces with distinct or abrupt cuts. Usually, an item is illuminated with a solitary light stripe at a predetermined angle and observed by one or two cameras from varying perspectives. The stripe is designed to physically or optomechanically scan the sample.<sup>58</sup>

### **OGIS Range Finder RFX – IV**

The OGIS Range Finder RFX-IV, a liquid crystal range finder, was created in 1984 by Inokuchi and Sato of the OGIS Research Institute in Osaka, Japan. Its purpose is to identify three-dimensional objects quickly.<sup>59</sup> The device uses a liquid optical shutter to project light patterns, which are then captured by a charge-coupled device video camera. The triangulation principle is used in a space encoding method to calculate the object's three-dimensional coordinates.<sup>60</sup>

### **CAM 3D Systems**

In 2003, Nkenke and his colleagues from the Department of Optics at the University of Erlangen-Nuremberg in Germany introduced a sensor using a modified

phase measuring triangulation method in their study using two charge-coupled device cameras; this sensor projects a series of phase-shifted fringe sequences of structured light onto the region of use and records the data from various angles.<sup>61</sup> By employing a four-shift approach, it is possible to derive three-dimensional data on the morphology of the object's surface.<sup>55</sup> C3D Systems now utilizes this technology.

### **C3D Systems**

The C3D System utilizes two camera stations on either side of the head to capture a stereo picture. A color digital camera captures the skin texture, while a pair of monochrome digital cameras capture the stereo image at each station. A dispersed flare emits a pattern of arbitrary textures to illuminate the face.<sup>61</sup> Ayoub et al. revealed that this unique illumination method provides enough data in the monochrome camera images to match both sides of the face and create an accurate 3D facial model.<sup>37,61</sup>

### **3dMD Face System**

The 3dMD system (Atlanta, GA, USA) combines of structured light technique and stereo-photogrammetry. It has three cameras which have a high quality capturing power, producing photorealistic pictures. The cameras consist of two infrared and one color camera systems that project a light pattern of random texture onto the subject, and various digital cameras in different angles, located in an ideal format, capture the image simultaneously.<sup>62</sup>



**Figure 1.** Stereophotogrammetry device with two camera pods and flashes.

### **Technical Parts**

The system includes both hardware and software (PC workstation, computer monitor, computer keyboard, computer mouse, three external flashes, cables and connectors, tripod and tripod head, power supply and power cord, two modular camera 27 units (MCUs) of machine vision cameras, lightweight calibration plate) (3dMDacquisition Software and optionally the 3dMD Analysis Software, 3dMDImage Viewer and the 3dMDvultus Software). The system integrates optics-based technology with two Modular Camera Units (MCUs) that house six machine vision cameras. These cameras are synced with a powerful LED lighting system.

### **The Image Capturing Procedure**

Per the manufacturer's instructions, it is recommended that the subject be positioned roughly 95 cm from each modular unit. The subject should be visible in all camera views and centered horizontally and vertically in the window. The subject's head

must be contained inside the two camera viewfinder windows. It is recommended that the head be tilted forward slightly, as this helps visualize the area below the chin. Before capture, the patient must remove their spectacles and any ear jewelry that may obstruct the ears.

Different 3D photogrammetry systems have specific ambient lighting requirements, although office lighting, such as overhead fluorescents, is often sufficient. Excessive or insufficient ambient light might overpower the camera's sensors at this stage. When using a 360-degree vision system, the height of the chair's back mustn't obstruct the picture capture from the rear cameras.<sup>63</sup> Heike et al. proposed that casters permit multidirectional mobility on most surfaces for systems requiring the subject to be accurately positioned inside a small imaging window.<sup>63</sup>

Generally, providing instructions to participants to relax their facial muscles is usually enough. Operators should pay attention to overt facial tension or emotional reactions and closely monitor the subject's mouth and eyes. Gaping one's mouth will artificially increase the vertical length of the face and change the location of the lower jaw.<sup>63</sup> To avoid this, shutting the subject's mouth and applying gentle pressure during capture is necessary. In most cases, the natural resting position of the jaw with the mouth closed is sufficient; however, as Heike et al. mentioned before, certain studies may necessitate the participant to attain a state of relaxed dental occlusion.<sup>63</sup>

Almost all surgeons and orthodontists who utilize a three-dimensional surface-imaging technology typically advise their patients to eliminate facial hair and hair behind the ears and on the forehead. Their objective is to capture images of the entire face, including the ears, to provide a thorough knowledge and documentation of the soft tissues to diagnose and plan treatment. Due to the variability of a patient's hair between visits, noting the geometry has little usefulness.<sup>64</sup>

### **The Working Principles**

To function, the 3dMD system projects arbitrary light patterns onto the target. The subject is documented using a variety of perspectives captured by multiple digital cameras that are precisely synchronized and positioned at optimal angles. The utilization of various cameras obviates the necessity to "stitch" together multiple images captured from

distinct angles into a unified composite after data acquisition. As a result, a possible source of error in generating a reliable three-dimensional depiction of the subject is eliminated throughout the data acquisition process. In three dimensions, surface texture and geometry are obtained almost simultaneously. Algorithms have been devised by 3dMD to merge multiple shots into a single 3D image. These images may then be analyzed and visualized on a computer using the 3dMD software.<sup>65</sup>

### **The Process of the 3D Model**

For 3D to be utilized to its maximum capacity, the geometry or shape data must precisely represent the patient's anatomy. Depending on the system, two steps are required to generate a 3D surface image. Following the generation of the geometry, the color and texture data are utilized for the geometry. To mathematically represent information about a three-dimensional surface, the dimensional face of the subject needs to be transformed into a set of x, y, and z coordinates. These coordinates correspond to the facial geometry of the individual numerically. To sufficiently cover more considerable extents, including the face (from ear to ear) or the complete head, it is necessary to consider numerous views regardless of the approach used. Comprehending the process of generating a numerical system of coordinates for the whole surface picture is crucial for assessing a system, as it forms the foundation for accuracy.<sup>64</sup> There are, in general, two methods for producing a surface image composed of multiple perspectives. A unique 3D dataset is created from each perspective, such as a range map or a point cloud, each with its coordinate system. These datasets are then merged to build a new 3D coordinate system. A continuous coordinate system is the most effective approach for producing a three-dimensional surface image from various perspectives. This is accomplished by choosing the superior data points for the x, y, and z coordinates from every perspective.<sup>64</sup> Advanced algorithms are frequently used with a capture speed of four milliseconds or less to evaluate and interpret sensor picture data. The color information or texture map is quantitatively included in the shape data based on the imaging equipment used in this procedure.<sup>64</sup> As Lane and Harell mentioned before, due to the ability of the color texture map to hide various imperfections in the underlying geometry, most digital artists want to deactivate the color texture while examining a 3D data sample. This allows them to examine the foundational geometry thoroughly.<sup>64</sup>

## **The Natural Head Position**

According to Broca's first proposition, the natural position of the head is in its best-balanced state while observing an item at eye level.<sup>66,67</sup> Broca's (1862) In 1958, this definition of the natural head position (NHP) was revised to include a standardized and reproducible position with the head in an upright position and the eye focused on a distant point at eye level so that the visual axis is horizontal.<sup>66</sup> Multiple investigations have provided evidence for the sagittal plane stability of each patient's natural head position (NHP).<sup>68</sup> Bjerin (1957) and Moorrees and Kean (1958) recorded variations ranging from 1.3 to 2 degrees. Lundstrom et al. (1995) observed shifts of 1.5 to 2 degrees by the utilization of cephalometric radiography together with photography. Cooke and Wei (1988) reported a deviation of 1.9 degrees using a mirror for orientation. Subsequent cephalograms conducted 15 years later revealed a 2.2-degree variation from the original findings.<sup>69</sup>

Traditional two-dimensional approaches and the requirement for extra radiographs have limited the evaluation of NHP in three planes of space in a few investigations. Unlike cephalometric radiography, stereophotogrammetry may be used to assess the repeatability of the sagittal, coronal and axial space planes. Weber et al. researched the consistency of NHP measurements in both the axial and coronal planes over a while. They used a more straightforward approach that could be easily used during the CBCT (Cone Beam Computed Tomography) scanning procedure. This study established the reproducibility of NHP in the axial, sagittal and coronal planes across time.<sup>68</sup> This conclusion aligns with earlier work that focuses on the sagittal plane. The degree of variation varies among the three planes.

## **Scientific Validation of the 3dMDface System**

In orthognathic, craniofacial, and reconstructive surgery, the 3D depiction of the soft tissue and skull is a promotional instrument. Lübbers et al. assessed the preciseness and accurateness of the 3dMDface System to identify possible errors.<sup>70</sup> The head of a mannequin was selected as the ideal object since it is immobile and doesn't display facial expressions. An ideal scenario simulates a clinical environment by manipulating parameters, including distance, angle, and system re-registration, and assessing data at different magnification levels. The 3dMD-Patient-Software with the capture device was

used to acquire data in NHP on a standard desktop computer. The outcomes were highly dependable, with a mean global error of 0.2 mm for mannequin head measurements, and showed promise for future surgical research. Neither the head position nor the camera position affected these parameters.<sup>71</sup>

In 2015, Nord et al. aimed to assess the inter-examiner accuracy of anthropometric measurements on 3D models of adult faces derived from the 3dMDface system.<sup>72</sup> Each subject was evaluated six times using 27 landmarks. Subjects were assessed eight times. No statistically significant differences were seen in the variability between different examiners and within the same examiner. When evaluating the accuracy and consistency of the various landmarks, they may be categorized into three groupings based on their precision: high, medium, and poor. The virtual 3D models generated by the 3dMDface system offer both exceptional technical precision and reliable consistency in identifying landmarks, both inside and between different observers.<sup>72</sup>

### **Video Imaging**

Caruso et al. were the first to describe a system capable of simultaneously recording the upper lip, lower lip, and jaw movements in three dimensions, capturing multi-structural ways of movement without restricting normal head motion 1989.<sup>44,73</sup> Frey et al. documented facial motion during ten distinct facial animations in normal subjects using a similar technique.<sup>74</sup> Gross et al. aimed to compare the amplitudes of landmark motions obtained using 3D and 2D methods to determine whether a 3D analysis provides a more accurate assessment of facial motions. Based on the study of maximum motion amplitudes, it was resolved that 3D data can achieve a 43 percent improvement over 2D. The results also indicated that the landmarks during animations are moderately to extremely reliable across the entire range of motion.<sup>75</sup> Weeden et al. aimed to quantify facial motions in a sample of healthful adults and investigate the effect of gender and facial shape on these movements.<sup>55,76</sup> Nooreyazdan et al. aimed to find out the differences in facial motions between pre-and post-surgery, whether pre-surgery facial motions were comparable among patients with various dentofacial anomalies, and whether post-surgery dentofacial morphology and soft tissue movement are more similar than pre-surgery.<sup>77</sup> Deng et al. introduced a system for expressive facial animation synthesis that learns speech coarticulation models and expression spaces from facial motion capture data.<sup>78</sup> In

2002, Eian and Poppele introduced an innovative technique for extracting an object's three-dimensional (3D) spatial characteristics from photos captured by a single camera.

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### 3. SUBJECTS AND METHODS

Our study was approved by the Marmara University Faculty of Health Sciences Non-Interventional Clinical Research Ethics Board (Decision no: 145, Date: 29/12/2022). After receiving information about the study, all individuals willing to be involved signed the Informed Consent Form.

#### 3.1. Patient Selection

This study retrospectively investigated 3D stereophotogrammetric pictures of patients with skeletal Class III malocclusion who had received orthognathic surgery for maxillary advancement (maxillary LeFort I type osteotomy) at the Department of Orthodontics, Faculty of Dentistry, Yeditepe University. Skeletal Class III patients who underwent orthognathic surgery were selected from the archive of Yeditepe University, Faculty of Dentistry, Department of Orthodontics. To achieve a significance level of 0.05 and a power of 80%, a minimum of 27 subjects would be required to detect a clinically significant difference.<sup>14</sup>

The inclusion criteria for our study included individuals with skeletal Class III malocclusion who had orthognathic surgery, including maxillary advancement, and whose diagnostic and treatment data was complete. Exclusion criteria included patients with craniofacial syndromes and anomalies, including cleft lip and palate, patients with other than Class III skeletal pattern, and patients with incomplete diagnostic records (missing images and cephalograms) or complete records of unsuitable quality. According to these criteria, the subjects of this study are 27 patients (8 males, 19 females) selected from the archive files of Yeditepe University, Dental School, Department of Orthodontics, Istanbul, Turkey. Patients were operated on between April 2010 and December 2021 by different operators at different healthcare facilities. All patients underwent LeFort I orthognathic surgery. LeFort I maxillary osteotomy was performed to advance the maxilla, followed by RIF. The osteotomy extended from the lateral aspects of the piriform aperture to the maxillary junction with the pterygoid plates.

## **3.2. Methods**

### **3.2.1. Acquisition of Three-Dimensional Images**

The 3D photogrammetric images were taken in the Department of Orthodontics, Faculty of Dentistry, Yeditepe University, using the 3dMDface System (Atlanta, GA, USA), as shown in Figure 1. Three-dimensional facial images were taken from the subjects at two time periods, T0 (at the first follow-up visit to the orthodontic clinic) and T1 (approximately six months after the orthognathic surgery). Dates of image acquisition were concomitant with patients' routine control appointments. 3dMDface system (3dMD LLC, Atlanta, USA) was utilized to capture three-dimensional facial pictures. Before image capturing, the stereophotogrammetry device was calibrated. Calibration requires two images of a specially designed panel, and the software guides the operator through the process. After calibration, the subject was taken to the imaging room alone. During the image capture procedure, the subject was placed at a distance from the modular unit so that the subject's head would fit within the two camera viewpoint windows displayed on the screen. The subject was centered horizontally and vertically in the window. A slight head extension was required for more efficient scanning beneath the chin. The 3D images were captured with the subject relaxed and with their head in a natural stance while seated in a seat that could be adjusted vertically. To ensure consistency in the posture of the head and jaw, the participants were directed to swallow before the scanning procedure and to keep their mouths in a relaxed, closed position while gently biting down during the scanning process.<sup>49</sup> Before being captured, the subjects were instructed to remove their eyewear, any ear jewelry that could have impeded hearing, and any clothing that covered the neck or ears, such as a scarf. The length of facial hair was discouraged. The capture was repeated until the desired image quality was achieved. A 3D image was captured in 1.5 milliseconds, and a single operator (Dt. Pınar Sayın) was able to manipulate the image on the computer screen. The 3D image was retaken if there were distortions or missing areas on the image. All images were automatically saved in Tricorder Surface Binary (TSB) format.

### **3.2.2. Refinement of the Images**

The 3D images of the subjects were imported into the software program 3dMD Vultus (3dMD LLC, Atlanta, USA). The captured images must be refined so that the area to be evaluated can be seen. Using the paintbrush tool in the refinement section, the body of the subject and the other regions were selected and then deleted. Parts that were not connected to the main image were separated after deletion. The remaining segments were then removed from the object window.

Face orientation was the second step in the refining process. The face orientation had to be adjusted to make measurements more convenient and ensure that all recordings were in the same position. By deselecting the lock rotation and lock position options for each dimension of the x, y, and z coordinate system, the position of the image was adjusted independently for each dimension. Using grids, soft tissue nasion (N) was set to (0,0,0). The Frankfurt horizontal plane (from tragus to orbital rim) accommodates the head pitch in the sagittal plane. The head roll was set using the midsagittal plane as a reference point. Adjusting head yaw by using the plane of the forehead from a top-down perspective. Following these procedures, the image was saved for future analysis.

The software 3dMDvultusTM (3dMD Ltd, Atlanta, GA, USA) cuts unneeded areas, locates photographs in standardized three-dimensional plans, and indicates and calculates procedures.<sup>3</sup> The pointing procedure was completed for the posttreatment picture, which involved identifying and marking the reference points (T, G, Na, Zyg, En, Ex, and Tr) that remained unimpacted by the operation.<sup>3</sup>

### **3.2.3. Evaluating the Images**

Image files are imported into 3dMDVultus (Version 2.2; 3dMD Inc.). The application was used to edit three-dimensional picture data and accurately detect distinctive landmarks. Each 3D photograph was imported into the 3dMDVultus application (3dMD Inc.). While determining suitable landmarks, measurements, and proportions for our study, previous research on soft tissue changes succeeding orthognathic surgery was reviewed. The preoperative and postoperative images used in this study were measured independently using the same grid. This facilitated the

implementation of a uniform coordinate system to compare photographs taken before and after a surgical procedure.<sup>10</sup>

## Landmarks

We utilized the definitions and abbreviations of Farkas<sup>80</sup> for anthropometric landmarks. The accuracy of landmark recognition by the three-dimensional facial surface imaging system was documented. In the pre-operative and post-operative photographs, precise landmark identification and reference plane positioning were carried out. To prevent possible errors, the position of all 3D image landmarks was independently verified in each dimension. Twenty landmarks were identified in total. Listed below are all of the landmarks we utilized in our research:

- **Alare (Al):** The most lateral point on each alar contour.<sup>10</sup>
- **Alar curvature (Ac):** The point situated at the facial insertion of the alar base.<sup>10</sup>
- **Subalare (Sbal):** The point at the lower limit of each alar base, where the alar base disappears into the skin of the upper lip.<sup>10</sup>
- **Zygion (Zyg):** The outermost point on the contour of each zygomatic arch.<sup>3</sup>
- **Tragus (Tr):** The point at the midtragus, midposition on the baseline between tragus and face.<sup>10</sup>
- **Trichion (T):** The point situated nearby the hairline at the middle of the forehead.<sup>3</sup>
- **Exocanthion (Ex):** The soft tissue point located at the outer commissure of each eye fissure.<sup>10</sup>
- **Endocanthion (En):** The soft tissue point located at the inner commissure of each eye fissure.<sup>10</sup>
- **Glabella (G):** The anterior midpoint on the fronto-orbital soft tissue contour.<sup>10</sup>
- **Nasion (N):** The midline point where the nasofrontal suture and nasal root converge.<sup>10</sup>
- **Nostril Base Point (Nb):** The apex of the innermost border of the nasal cavity.<sup>16</sup>
- **Nostril Top Point (Nt):** The top of the innermost border encompassing the nostril.<sup>16</sup>
- **Nostril Medial Point (Nm):** The point most medial to the innermost border of the nose.<sup>16</sup>
- **Nostril Lateral Point (Nl):** The point most lateral to the innermost border of the nose.<sup>16</sup>

- **Labiale superius (Ls):** The middle point of the upper lip's vermillion line. <sup>16</sup>
- **Labiale inferius (Li):** The middle point of the lower lip's vermillion line. <sup>10</sup>
- **Pronasale (Prn):** The point in the middle which is most frontal to the nasal tip. <sup>10</sup>
- **Subnasale (Sn):** The intersection between the columella crest and the upper lip on the nasolabial soft tissue contour. <sup>10</sup>
- **Columella (Cm):** The most frontal point of the nasal columella. <sup>16</sup>
- **Cheilion Point (Ch):** The point where the right and left labial commissures meet. <sup>10</sup>

## Measurements

### Linear Measurements

In this study, 16 linear measurements were used.

- **Alar width (Al-Al):** The greatest distance between the left and right alares. <sup>10</sup> (Figure 2.)
- **Alar base width (Ac-Ac):** The length between the right alar curve and the left alare. <sup>10</sup> (Figure 2.)
- **Subalare width (Sbal-Sbal):** The length between the right subalare and the left subalare. <sup>10</sup> (Figure 2.)
- **Nasal height (NH):** On the Y-axis, the length between the nasion and subnasale points. <sup>10</sup> (Figure 3.)
- **Nasal length (NL):** The length between the nasion point to the pronasale point. <sup>10</sup> (Figure 3.)
- **Nasal tip projection (TP):** In the lateral view, the length between the nasal alare to pronasale points (Al-Prn). <sup>10</sup> (Figure 3.)
- **Upper lip-E line:** The length from the E line to Ls in the lateral view. <sup>81</sup> (Figure 4.)
- **Lower lip-E line:** The length from the E line to Li in the lateral view. <sup>81</sup> (Figure 4.)
- **Labiale superius projection:** The distance from tragus to labiale superius. <sup>16</sup> (Figure 4.)
- **Subnasale projection:** The distance from tragus to subnasale. <sup>16</sup> (Figure 4.)
- **Lip length:** The distance between cheilions. (Figure 2.)

- **Nostril heights:** The distance between nostril top point and nostril base point. <sup>10</sup> (Figure 5.)
- **Nostril widths:** The distance between nostril medial point and nostril lateral point. <sup>10</sup> (Figure 5.)
- **Columella width:** The distance between nostril medial points. <sup>16</sup> (Figure 6.)
- **Columella height:** The distance from the subnasale to the columella peak. <sup>16</sup> (Figure 7.)
- **Columella projection:** The distance from tragus to columella peak. <sup>16</sup> (Figure 7.)

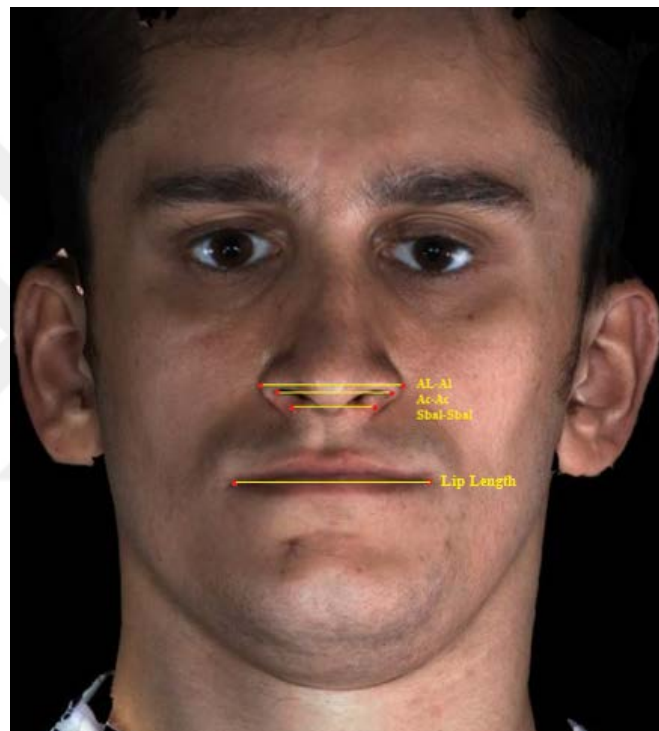


**Figure 2.**

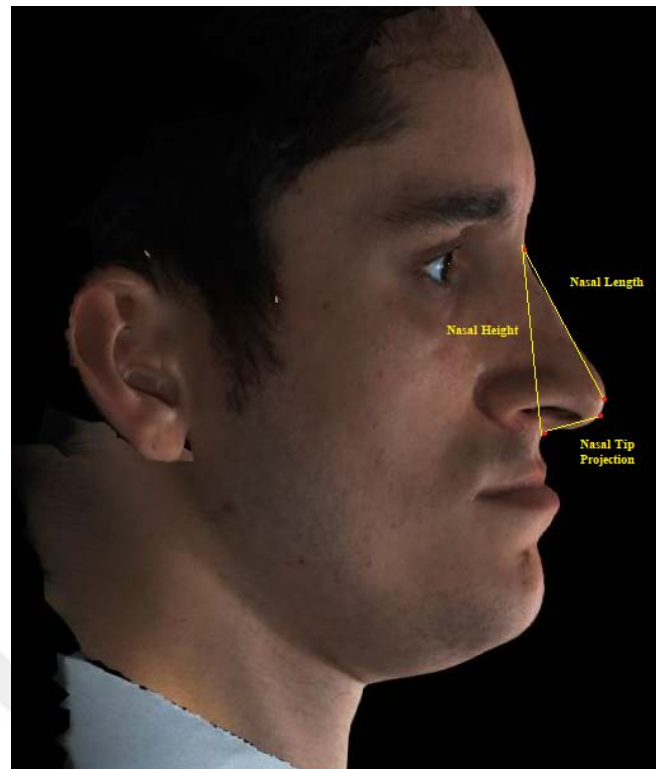


**Figure 3.**

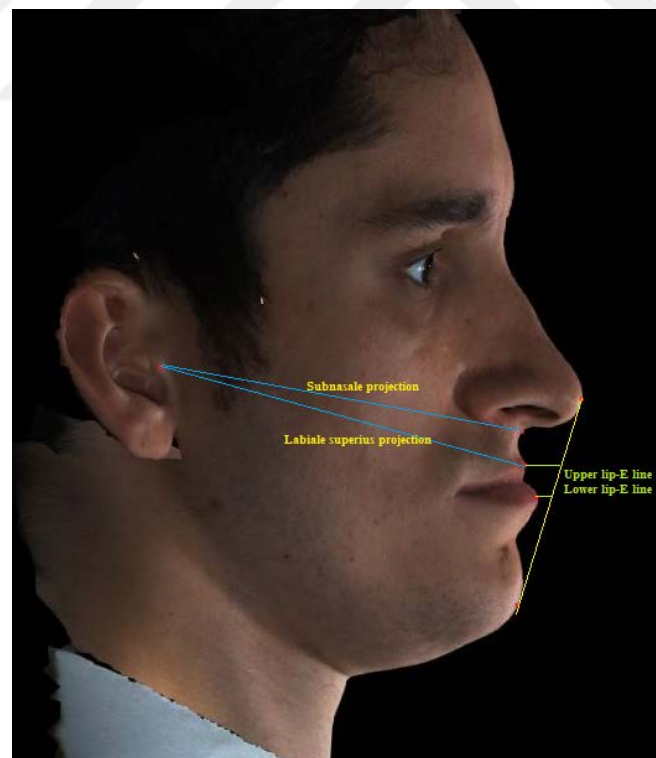


**Figure 4.**

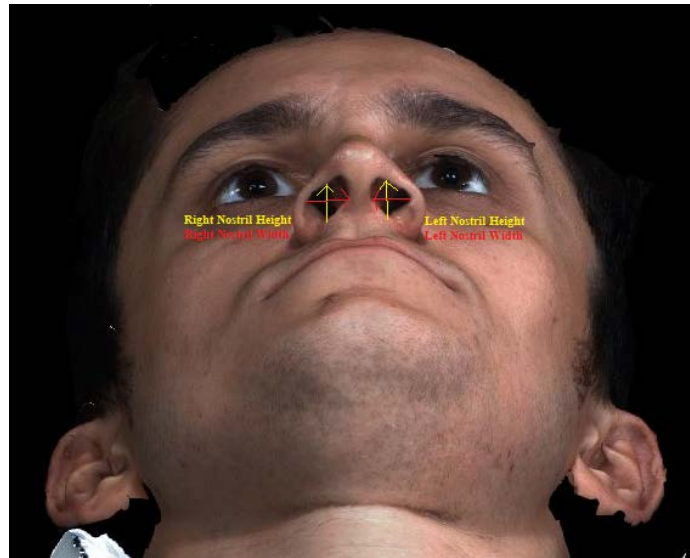


**Figure 5.**

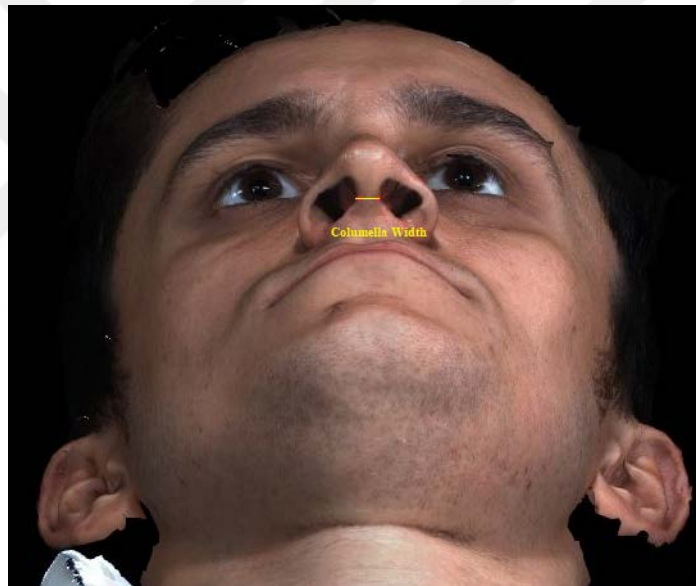


**Figure 6.**

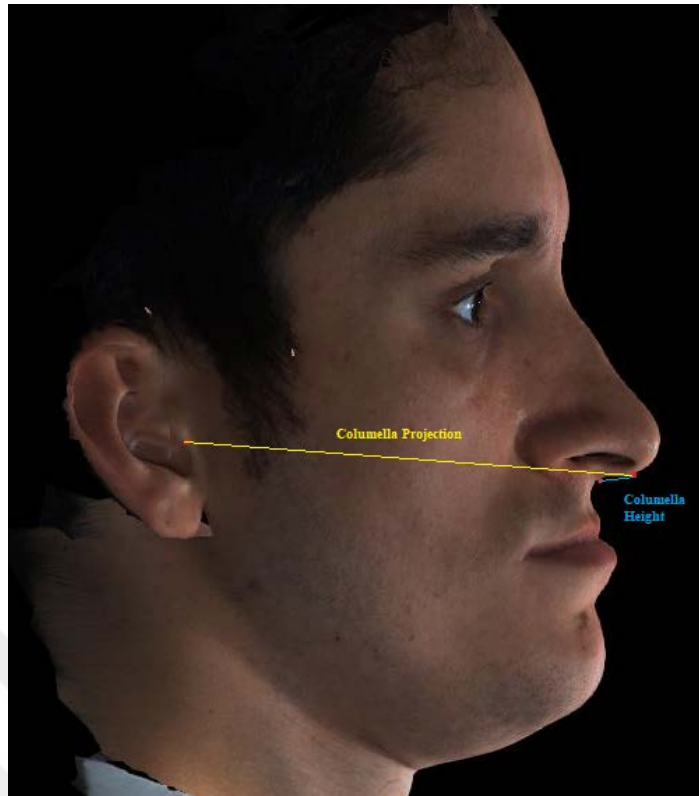


**Figure 7.**

### **Angular Measurements**

In this study, 3 angular measurements were used.

- **Nasofrontal angle:** Angle between glabella, nasion and pronasale. <sup>16</sup> (Figure 8.)
- **Nasolabial angle:** Angle formed by the subnasale, columella apex, and labiale superius. <sup>16</sup> (Figure 8.)
- **Columella inclination:** The angle between subalare, subnasale and pronasale. <sup>16</sup> (Figure 8.)

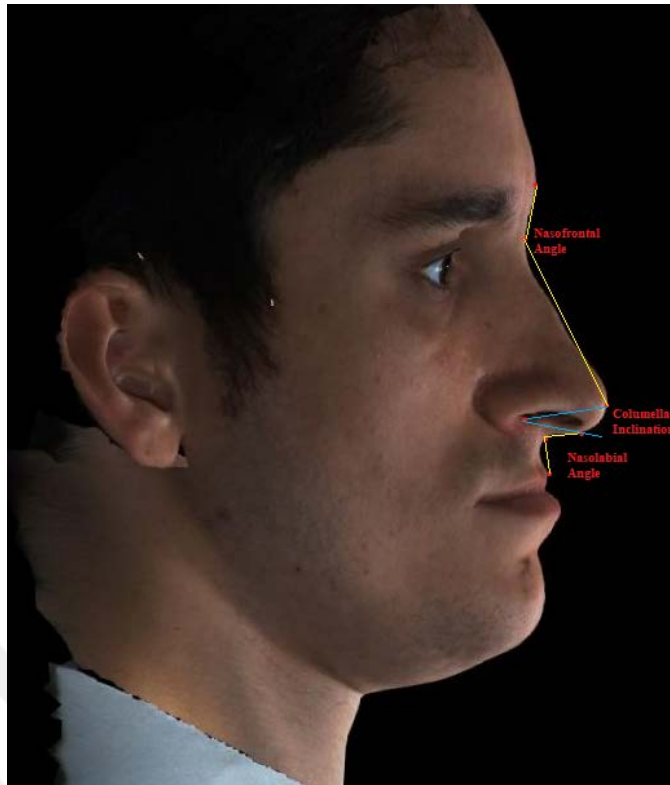


**Figure 8.**

### **Perimetric Measurements**

In this study, one perimetric measurement was used.

- **Nostril show:** Area of the nostril orifice. <sup>10</sup> (Figure 9.)

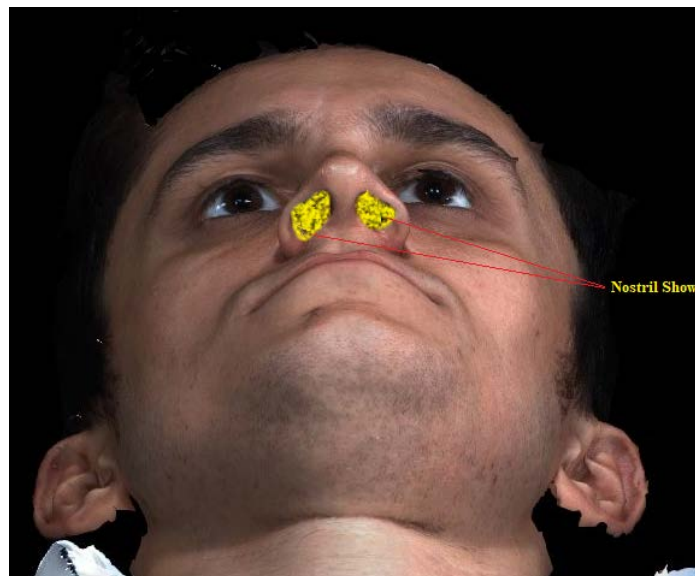


**Figure 9.**

### **3.2.4. Method Error and Reproducibility**

The superimposition method was reversible and reproducible until the root mean square errors reached a threshold of 0.5 mm.<sup>10</sup> Following a successful registration, the postoperative 3D image was utilized for the exact landmark identification and measurement tasks as the preoperative 3D image.<sup>10</sup> While comparing and analyzing pre- and post-operative nasal image data, 54 three-dimensional images were subjected to 16 linear, 3 angular, and 1 perimetric measurements during our research. One month after the initial measurements, the same researcher repeated the measurement procedures and landmark positioning on T0 and T1 3D images of 10 randomly selected patients and controls to evaluate measurement error and intra-operator reliability.<sup>82</sup> According to the intraclass correlation (ICC) data, which were analyzed to determine the consistency and reproducibility of the measurements, a correlation of 90 percent was found between two measurements taken four weeks apart. The Intraclass Correlation analysis relating to the methodological errors revealed that the measurements did not affect the results and were repeated with non-significant errors.<sup>83</sup> For most measurements, the intraclass correlation coefficient was greater than 0.95, and for some measurements, it was greater than 0.90. Therefore, the measurements were determined to be accurate.

### **3.2.5. Statistical Methods**

In this research, statistical analyses were conducted utilizing the NCSS (Number Cruncher Statistical System) 2007 Statistical Software (Utah, United States) package. In addition to descriptive statistical methods (mean, standard deviation, median, interquartile range) for data analysis (median, mean, standard deviation, interquartile range), the Shapiro–Wilk normality test was employed to examine the distribution of variables. The paired t-test was used to compare variables following a normal distribution in the T0 and T1 assessments. In contrast, the Wilcoxon test examined variants that didn't mind a normal distribution in the T0 and T1 evaluations. The Chi-square test was utilized in qualitative assessment.  $p < 0.05$  was determined to be the significance level. Experimental statistical power analyses using the G \*Power 3.1 program were conducted using the observed effect sizes to assess the study's power (Heinrich Heine Universitat, Dusseldorf, Germany). The expected standard deviation of this difference was derived from Worasakwutiphong et al..<sup>10</sup> The sample size was calculated using the effect size

0.50 for the nostril show. According to the calculation, for a study with a power of 0.80 and an alpha of 0.05, we needed 27 participants (T0 and T1 for each subject). The intraclass correlation coefficient and 95% confidence interval were used to determine the reliability of the measurements.<sup>10</sup>



## 4. RESULTS

### 4.1. Demographics of the Study Group

The sample consisted of 27 patients operated on between April 2010 and December 2021. Of these, 19 were female, and 8 were male. The mean age of the subjects at the time of the surgery was 31 years (range 20 to 42).

**Table 1: Comparison of the Age Distribution Between Genders**

|                | Age        |       |
|----------------|------------|-------|
|                | Mean±SD    | p     |
| Male           | 28,50±8,32 | 0,467 |
| Female         | 30,58±5,91 |       |
| Student t-test |            |       |

There was no statistically significant difference in mean age distribution between genders ( $p>0.05$ ).

### 4.2. Evaluation of Linear, Angular and Perimetric Measurements According to the Amount of the Maxillary Advancement

The sample is divided into two groups by the amount of maxillary advancement. One of the groups consisted of 14 patients with 1 to 5 mm of maxillary advancement, and the other group had 5.5 to 10 mm of maxillary advancement. Surgical forward movement of the upper jaw was determined by evaluating the change between the T0 and T1 cephalograms at the mesio-incisal edge of the maxillary right central incisor.<sup>84</sup>

**Table 2: Evaluation of Angular Measurements According to the Amount of Maxillary Advancement**

| Angular Measurements        |                | Maxillary Advancement              |              | <sup>1</sup> p |
|-----------------------------|----------------|------------------------------------|--------------|----------------|
|                             |                | 1-5 mm                             | 5.5-10 mm    |                |
|                             |                | Mean±SD                            | Mean±SD      |                |
| Nasofrontal Angle           | T0             | 158,53±5,04                        | 158,83±3,71  | 0,861          |
|                             | T1             | 157,19±4,73                        | 156,81±4,23  | 0,828          |
|                             | <sup>2</sup> p | 0,097                              | 0,002*       |                |
| Nasolabial Angle            | T0             | 115,83±10,84                       | 115,33±10,61 | 0,905          |
|                             | T1             | 116,65±11,24                       | 114,14±9,91  | 0,546          |
|                             | <sup>2</sup> p | 0,707                              | 0,653        |                |
| Columella Inclination       | T0             | 104,44±11,9                        | 102,98±11,46 | 0,748          |
|                             | T1             | 105,06±10,99                       | 104,45±10,87 | 0,885          |
|                             | <sup>2</sup> p | 0,726                              | 0,610        |                |
| <sup>1</sup> Student t test |                | <sup>2</sup> Paired samples t test |              | *p<0.05        |

There was no statistically significant difference in nasofrontal angle, nasolabial angle and columella inclination means between groups from T0 to T1 ( $p>0.05$ ).

*In the 1-5 mm advancement group, there was no significant difference in nasofrontal angle, nasolabial angle, and columella inclination from T0 to T1 ( $p>0.05$ ).*

*The 5.5-10 mm advancement group showed a statistically significant decrease in nasofrontal angle from T0 to T1 ( $p:0.002$ ;  $p<0.05$ ). However, there was no statistically significant difference in nasolabial angle and columella inclination from T0 to T1 ( $p>0.05$ ).*

**Table 3: Evaluation of Linear Measurements According to the Amount of Maxillary Advancement**

| Linear Measurements         |                | Maxillary Advancement |             | P     |
|-----------------------------|----------------|-----------------------|-------------|-------|
|                             |                | 1-5 mm                | 5.5-10 mm   |       |
|                             |                | Mean±SD               | Mean±SD     |       |
| Alar Width                  | T0             | 32,86±5,55            | 32,18±3,07  | 0,699 |
|                             | T1             | 36,63±3,43            | 35,19±3,13  | 0,268 |
|                             | <sup>2</sup> p | 0,020*                | 0,001*      |       |
| Alar Base Width             | T0             | 29,51±2,69            | 28,84±4,28  | 0,629 |
|                             | T1             | 32,27±3,21            | 31,49±4,1   | 0,586 |
|                             | <sup>2</sup> p | 0,001*                | 0,001*      |       |
| Subalare Width              | T0             | 18,15±5,22            | 16,42±2,41  | 0,285 |
|                             | T1             | 19,05±2,59            | 17,37±2,3   | 0,088 |
|                             | <sup>2</sup> p | 0,607                 | 0,149       |       |
| Nasal Height                | T0             | 60,36±3,59            | 61±3,41     | 0,639 |
|                             | T1             | 61,16±4,51            | 60,23±3,22  | 0,547 |
|                             | <sup>2</sup> p | 0,228                 | 0,307       |       |
| Nasal Length                | T0             | 53,72±5,66            | 55,45±2,75  | 0,321 |
|                             | T1             | 55,13±4,57            | 54,24±2,74  | 0,545 |
|                             | <sup>2</sup> p | 0,259                 | 0,145       |       |
| Nasal Tip Projection        | T0             | 24,73±3,00            | 24,59±1,8   | 0,886 |
|                             | T1             | 25,33±2,65            | 25,15±2     | 0,847 |
|                             | <sup>2</sup> p | 0,074                 | 0,105       |       |
| Upper lip-E line            | T0             | 0,48±0,21             | 0,61±0,11   | 0,060 |
|                             | T1             | 0,40±0,13             | 0,37±0,19   | 0,565 |
|                             | <sup>2</sup> p | 0,181                 | 0,001*      |       |
| Lower lip-E line            | T0             | 0,14±0,31             | 0,11±0,24   | 0,760 |
|                             | T1             | 0,15±0,20             | 0,14±0,24   | 0,928 |
|                             | <sup>2</sup> p | 0,930                 | 0,679       |       |
| Lip Length                  | T0             | 49,82±3,35            | 49,98±2,95  | 0,896 |
|                             | T1             | 50,01±2,58            | 51,71±3,04  | 0,129 |
|                             | <sup>2</sup> p | 0,697                 | 0,034*      |       |
| Labiale Superius Projection | T0             | 122,82±4,61           | 121,81±6,04 | 0,627 |
|                             | T1             | 124,44±4,61           | 125,09±6,75 | 0,772 |
|                             | <sup>2</sup> p | 0,046*                | 0,001*      |       |
| Subnasale Projection        | T0             | 119,49±5,04           | 117,78±5,34 | 0,398 |
|                             | T1             | 120,42±4,53           | 119,92±6,7  | 0,819 |
|                             | <sup>2</sup> p | 0,292                 | 0,007*      |       |
| Nostril Heights right       | T0             | 14,10±3,47            | 14,93±2,09  | 0,458 |
|                             | T1             | 14,91±2,89            | 15,53±2,36  | 0,553 |
|                             | <sup>2</sup> p | 0,203                 | 0,259       |       |
| Nostril Heights left        | T0             | 15,80±3,18            | 14,88±1,89  | 0,374 |
|                             | T1             | 15,95±2,45            | 15,71±1,72  | 0,769 |

|                             |                |                                    |             |         |
|-----------------------------|----------------|------------------------------------|-------------|---------|
|                             | <sup>2</sup> p | 0,726                              | 0,056       |         |
| Nostril Widths right        | T0             | 7,32±2,40                          | 6,67±1,44   | 0,403   |
|                             | T1             | 8,19±2,60                          | 7,69±1,65   | 0,561   |
|                             | <sup>2</sup> p | 0,303                              | 0,005*      |         |
| Nostril Widths left         | T0             | 6,89±2,72                          | 6,19±1,11   | 0,387   |
|                             | T1             | 7,83±2,67                          | 6,87±1,38   | 0,258   |
|                             | <sup>2</sup> p | 0,310                              | 0,032*      |         |
| Columella Width             | T0             | 7,85±1,59                          | 8,02±1,17   | 0,764   |
|                             | T1             | 8,35±1,44                          | 8,42±1,18   | 0,887   |
|                             | <sup>2</sup> p | 0,215                              | 0,275       |         |
| Columella Height            | T0             | 13,48±1,19                         | 14,19±1,45  | 0,177   |
|                             | T1             | 13,85±1,87                         | 13,7±1,74   | 0,822   |
|                             | <sup>2</sup> p | 0,424                              | 0,261       |         |
| Columella Projection        | T0             | 129,25±5,14                        | 128,04±4,51 | 0,523   |
|                             | T1             | 130,27±4,77                        | 129,62±5,78 | 0,755   |
|                             | <sup>2</sup> p | 0,232                              | 0,030*      |         |
| <sup>1</sup> Student t test |                | <sup>2</sup> Paired samples t test |             | *p<0.05 |

There was no statistically significant difference in linear measurements' means between groups before and after orthognathic surgery (p>0.05).

*Both in the 1-5 mm of the advancement group and 5.5-10 mm of the advancement group, there was a statistically significant increase in alar width and alar base width from T0 to T1 (p:0.020; p<0.05).*

*Both in the 1-5 mm of the advancement group and 5.5-10 mm of the advancement group, there was no significant difference in subalare width, nasal height, nasal length, nasal tip projection, lower lip-E line, right and left nostril heights, columella width, columella height means from T0 to T1 (p>0.05).*

*In the 1-5 mm advancement group, there was no significant difference in upper lip-E line, lip length, subnasale projection, right and left nostril widths or columella projection's means from T0 to T1 (p>0.05).*

*The 1-5 mm advancement group showed a statistically significant increase in labiale superius projection means from T0 to T1 (p:0.046; p<0.05).*

*The 5.5-10 mm advancement group showed a statistically significant decrease in upper lip-E line means from T0 to T1 (p:0.001; p<0.05).*

In the 5.5-10 mm of the advancement group, there was a statistically significant increase in lip length, labiale superius projection, subnasale projection, right nostril width, left nostril width, and columella projection means from T0 to T1 (p:0.034; p<0.05), (p:0.001; p<0.05), (p:0.007; p<0.05), (p:0.005; p<0.05), (p:0.032; p<0.05), (p:0.030; p<0.05) respectively.

**Table 4: Evaluation of Perimetric Measurements According to the Amount of Maxillary Advancement**

| Perimetric Measurement      |                | Maxillary Advancement              |            | <sup>1</sup> p |
|-----------------------------|----------------|------------------------------------|------------|----------------|
|                             |                | 1-5 mm                             | 5.5-10 mm  |                |
|                             |                | Mean±SD                            | Mean±SD    |                |
| Nostril Show                | T0             | 26,41±3,51                         | 26,39±3,15 | 0,989          |
|                             | T1             | 25,67±3,1                          | 25,24±2,86 | 0,709          |
|                             | <sup>2</sup> p | 0,015*                             | 0,002*     |                |
| <sup>1</sup> Student t test |                | <sup>2</sup> Paired samples t test |            | *p<0.05        |

No statistically significant difference in nostril show means between groups from T0 to T1 (p>0.05).

Both in the 1-5 mm of the advancement group and 5.5-10 mm of the advancement group, there was a statistically significant decrease in the nostril show means from T0 to T1 (p:0.015; p<0.05) and (p:0.002; p<0.05) respectively.

#### 4.3. Evaluation of Linear, Angular and Perimetric Measurements According to the Growth Pattern

The sample was divided into two groups according to the patient's growth patterns. One group consisted of 16 patients with high-angle growth patterns, and the other consisted of 11 patients with low-angle growth patterns.

**Table 5: Evaluation of Angular Measurements According to the Growth Pattern**

| Angular Measurements        |                | High                               | Low          | <sup>1</sup> p |
|-----------------------------|----------------|------------------------------------|--------------|----------------|
|                             |                | Mean±SD                            | Mean±SD      |                |
| Nasofrontal Angle           | T0             | 159,27±4,08                        | 157,81±4,82  | 0,404          |
|                             | T1             | 157,08±4,65                        | 156,91±4,27  | 0,925          |
|                             | <sup>2</sup> p | 0,003*                             | 0,172        |                |
| Nasolabial Angle            | T0             | 118,49±9,56                        | 111,38±10,87 | 0,084          |
|                             | T1             | 116,97±10,43                       | 113,21±10,68 | 0,371          |
|                             | <sup>2</sup> p | 0,542                              | 0,352        |                |
| Columella Inclination       | T0             | 107,2±11,28                        | 98,7±10,26   | 0,057          |
|                             | T1             | 107,87±9,8                         | 100,25±10,81 | 0,068          |
|                             | <sup>2</sup> p | 0,794                              | 0,291        |                |
| <sup>1</sup> Student t test |                | <sup>2</sup> Paired samples t test |              | *p<0.05        |

There was no statistically significant difference in nasofrontal angle, nasolabial angle and columella inclination means between groups from T0 to T1 ( $p>0.05$ ).

There was no statistically significant difference in nasofrontal angle means between groups before and after orthognathic surgery ( $p>0.05$ ).

*There was no significant difference in the means of nasolabial angle and columella inclination from T0 to T1 ( $p>0.05$ ) in both the high-angle and low-angle groups.*

*The high-angle group showed a statistically significant decrease in nasofrontal angle means from T0 to T1 ( $p:0.003$ ;  $p<0.05$ ).*

*In the low-angle group, there was no significant difference in nasofrontal angle means from T0 to T1 ( $p>0.05$ ).*

**Table 6: Evaluation of Linear Measurements According to the Growth Pattern**

| Linear Measurements         |                | High        | Low         | <sup>1</sup> p |
|-----------------------------|----------------|-------------|-------------|----------------|
|                             |                | Mean±SD     | Mean±SD     |                |
| Alar Width                  | T0             | 31,17±4,32  | 34,52±4,05  | 0,053          |
|                             | T1             | 35,53±3,00  | 36,52±3,78  | 0,455          |
|                             | <sup>2</sup> p | 0,002*      | 0,001*      |                |
| Alar Base Width             | T0             | 28,07±2,21  | 30,81±4,41  | 0,079          |
|                             | T1             | 31,18±3,05  | 32,95±4,23  | 0,251          |
|                             | <sup>2</sup> p | 0,001*      | 0,004*      |                |
| Subalare Width              | T0             | 17,55±4,63  | 16,99±3,47  | 0,738          |
|                             | T1             | 17,60±2,35  | 19,17±2,66  | 0,117          |
|                             | <sup>2</sup> p | 0,966       | 0,155       |                |
| Nasal Height                | T0             | 60,90±2,90  | 60,32±4,27  | 0,702          |
|                             | T1             | 60,36±3,22  | 61,21±4,84  | 0,588          |
|                             | <sup>2</sup> p | 0,381       | 0,301       |                |
| Nasal Length                | T0             | 54,43±5,34  | 54,73±3,15  | 0,871          |
|                             | T1             | 54,29±3,44  | 55,29±4,28  | 0,508          |
|                             | <sup>2</sup> p | 0,911       | 0,326       |                |
| Nasal Tip Projection        | T0             | 24,18±2,34  | 25,38±2,55  | 0,217          |
|                             | T1             | 24,94±2,50  | 25,68±2,06  | 0,424          |
|                             | <sup>2</sup> p | 0,018*      | 0,370       |                |
| Upper lip-E line            | T0             | 0,51±0,21   | 0,58±0,12   | 0,312          |
|                             | T1             | 0,40±0,18   | 0,36±0,14   | 0,578          |
|                             | <sup>2</sup> p | 0,078       | 0,001*      |                |
| Lower lip-E line            | T0             | 0,08±0,29   | 0,20±0,23   | 0,250          |
|                             | T1             | 0,16±0,25   | 0,12±0,17   | 0,645          |
|                             | <sup>2</sup> p | 0,236       | 0,359       |                |
| Lip Length                  | T0             | 48,81±3,13  | 51,47±2,39  | 0,025*         |
|                             | T1             | 50,79±3,04  | 50,89±2,81  | 0,934          |
|                             | <sup>2</sup> p | 0,002*      | 0,317       |                |
| Labiale Superius Projection | T0             | 121,72±6,12 | 123,23±3,79 | 0,435          |
|                             | T1             | 124,12±6,60 | 125,68±3,96 | 0,488          |
|                             | <sup>2</sup> p | 0,010*      | 0,001*      |                |
| Subnasale Projection        | T0             | 118,41±5,76 | 119,04±4,39 | 0,764          |
|                             | T1             | 119,62±6,16 | 120,99±4,76 | 0,540          |
|                             | <sup>2</sup> p | 0,188       | 0,001*      |                |
| Nostril Heights right       | T0             | 14,28±2,43  | 14,82±3,51  | 0,636          |
|                             | T1             | 15,01±2,63  | 15,5±2,69   | 0,643          |
|                             | <sup>2</sup> p | 0,157       | 0,335       |                |
| Nostril Heights left        | T0             | 14,59±2,17  | 16,47±2,93  | 0,066          |
|                             | T1             | 15,18±2,01  | 16,79±1,92  | 0,048*         |
|                             | <sup>2</sup> p | 0,124       | 0,554       |                |
| Nostril Widths right        | T0             | 6,32±1,06   | 8,01±2,59   | 0,062          |
|                             | T1             | 7,41±1,57   | 8,73±2,72   | 0,123          |

|                             |                |                                    |             |         |
|-----------------------------|----------------|------------------------------------|-------------|---------|
|                             | <sup>2</sup> p | 0,009*                             | 0,470       |         |
| Nostril Widths left         | T0             | 5,58±0,82                          | 7,98±2,59   | 0,012*  |
|                             | T1             | 6,76±1,51                          | 8,25±2,71   | 0,077   |
|                             | <sup>2</sup> p | 0,010*                             | 0,789       |         |
| Columella Width             | T0             | 8,14±1,21                          | 7,62±1,60   | 0,343   |
|                             | T1             | 8,35±1,14                          | 8,44±1,56   | 0,865   |
|                             | <sup>2</sup> p | 0,487                              | 0,112       |         |
| Columella Height            | T0             | 13,77±1,55                         | 13,90±1,04  | 0,805   |
|                             | T1             | 14,02±1,80                         | 13,43±1,76  | 0,413   |
|                             | <sup>2</sup> p | 0,499                              | 0,426       |         |
| Columella Projection        | T0             | 128,24±5,59                        | 129,30±3,50 | 0,582   |
|                             | T1             | 129,25±5,87                        | 130,99±4,03 | 0,403   |
|                             | <sup>2</sup> p | 0,213                              | 0,015*      |         |
| <sup>1</sup> Student t test |                | <sup>2</sup> Paired samples t test |             | *p<0.05 |

There was no statistically significant difference in linear measurements' means between groups before and after orthognathic surgery (p>0.05).

*From T0 to T1, there was no significant difference in subtalar width, nasal height, nasal length, lower lip-E line, right and left nostril height, columella width, and columella height between the high-angle and low-angle groups (p>0.05).*

*In the high-angle group, there was a statistically significant increase in alar width, alar base width, nasal tip projection, lip length, labiale superius projection, right nostril width, left nostril width means from T0 to T1 (p:0.002; p<0.05), (p:0.001; p<0.05), (p:0.018; p<0.05), (p:0.002; p<0.05), (p:0.010; p<0.05), (p:0.009; p<0.05), (p:0.010; p<0.05) respectively.*

*In the low angle group, there was a statistically significant increase in alar width, alar base width, labiale superius projection, subnasale projection, and columella projection means from T0 to T1 (p:0.001; p<0.05), (p:0.004; p<0.05), (p:0.001; p<0.05), (p:0.001; p<0.05), (p:0.015; p<0.05) respectively.*

*In the high-angle group, there was no significant difference in the upper lip-E line, subnasale projection, and columella projection means from T0 to T1 (p>0.05).*

*In the low-angle group, there was no significant difference in nasal tip projection, lip length, or right and left nostril width's means from T0 to T1 (p>0.05).*

*The low-angle group showed a statistically significant decrease in upper lip-E line means from T0 to T1 (p:0.001; p<0.05).*

Low angle group's lip length means, left nostril height means, and left nostril width means are statistically significantly higher than the high angle group at T0 (p:0.025; p<0.05), (p:0.048; p<0.05), (p:0.012; p<0.05) respectively.

**Table 7: Evaluation of Perimetric Measurements According to the Growth Pattern**

| Perimetric Measurements     |                | High                               | Low        | <sup>1</sup> p |
|-----------------------------|----------------|------------------------------------|------------|----------------|
|                             |                | Mean±SD                            | Mean±SD    |                |
| Nostril Show                | T0             | 26,50±2,93                         | 26,25±3,87 | 0,848          |
|                             | T1             | 25,54±2,73                         | 25,35±3,35 | 0,877          |
|                             | <sup>2</sup> p | 0,001*                             | 0,027*     |                |
| <sup>1</sup> Student t test |                | <sup>2</sup> Paired samples t test |            | *p<0.05        |

No statistically significant difference in the nostril show means between groups before and after orthognathic surgery (p>0.05).

*Both in the high angle group and the low angle group, there was a statistically significant decrease from T0 to T1 (p:0.001; p<0.05), (p:0.027; p<0.05) respectively.*

#### 4.4. Evaluation of the Change in Angular, Linear and Perimetric Measurements from T0 to T1 According to the Amount of Maxillary Advancement

**Table 8: Evaluation of the Change in Angular, Linear and Perimetric Measurements from T0 to T1 According to the Amount of Maxillary Advancement**

|                             |              | Maxillary Advancement |                     |        |
|-----------------------------|--------------|-----------------------|---------------------|--------|
|                             |              | 1-5 mm                | 5.5-10 mm           | p      |
| Nasofrontal Angle           | Mean±SD      | -1,33±2,78            | -2,02±1,8           | 0,438  |
|                             | Median (IQR) | -1,75 (-3,30/1,32)    | -2,52 (-3,27/-0,27) |        |
| Nasolabial Angle            | Mean±SD      | 0,81±7,91             | -1,19±9,34          | 0,357  |
|                             | Median (IQR) | 3,18 (-6,61/7,99)     | -2,44 (-5,72/4,16)  |        |
| Columella Inclination       | Mean±SD      | 0,62±6,47             | 1,47±10,11          | 0,961  |
|                             | Median (IQR) | 1,93 (-4,95/6,67)     | -1,65 (-3,58/7,17)  |        |
| Alar Width                  | Mean±SD      | 3,77±5,31             | 3,01±1,67           | 0,698  |
|                             | Median (IQR) | 2,65 (1,67/3,66)      | 2,73 (1,59/4,05)    |        |
| Alar Base Width             | Mean±SD      | 2,76±2                | 2,65±2,06           | 0,884  |
|                             | Median (IQR) | 2,87 (1,72/3,48)      | 2,57 (1,14/3,75)    |        |
| Subalare Width              | Mean±SD      | 0,89±6,34             | 0,95±2,22           | 0,961  |
|                             | Median (IQR) | 0,55 (-0,88/2,85)     | 0,72 (-0,57/3,00)   |        |
| Nasal Height                | Mean±SD      | 0,8±2,37              | -0,77±2,59          | 0,109  |
|                             | Median (IQR) | 0,085 (-0,87/3,04)    | -0,52 (-2,63/0,31)  |        |
| Nasal Length                | Mean±SD      | 1,41±4,47             | -1,21±2,81          | 0,133  |
|                             | Median (IQR) | 0,35 (-1,17/2,13)     | -1,27 (-1,95/0,51)  |        |
| Nasal Tip Projection        | Mean±SD      | 0,6±1,15              | 0,56±1,14           | 0,981  |
|                             | Median (IQR) | 0,77 (-0,09/1,26)     | 0,85 (-0,19/1,25)   |        |
| Upper lip-E line            | Mean±SD      | -0,07±0,19            | -0,24±0,15          | ),035* |
|                             | Median (IQR) | -0,12 (-0,25/0,10)    | -0,24 (-0,35/-0,11) |        |
| Lower lip-E line            | Mean±SD      | 0,01±0,3              | 0,03±0,27           | 0,662  |
|                             | Median (IQR) | -0,10 (-0,22/0,15)    | -0,09 (-0,17/0,23)  |        |
| Lip Length                  | Mean±SD      | 0,19±1,83             | 1,73±2,62           | 0,099  |
|                             | Median (IQR) | 0,13 (-1,14/1,31)     | 1,34 (-0,21/3,81)   |        |
| Labiale Superius Projection | Mean±SD      | 1,62±2,74             | 3,28±2,24           | 0,145  |
|                             | Median (IQR) | 1,8 (-0,14/3,88)      | 3,37 (1,61/4,3)     |        |
| Subnasale Projection        | Mean±SD      | 0,93±3,16             | 2,14±2,38           | 0,437  |
|                             | Median (IQR) | 1,32 (-0,47/3,16)     | 1,28 (0,63/3,31)    |        |
| Nostril Heights right       | Mean±SD      | 0,82±2,28             | 0,59±1,81           | 0,790  |
|                             | Median (IQR) | 0,68 (-0,71/2,39)     | 0,59 (-0,60/1,89)   |        |
| Nostril Heights left        | Mean±SD      | 0,16±1,63             | 0,83±1,42           | 0,264  |
|                             | Median (IQR) | 0,12 (-1,17/1,48)     | 0,98 (-0,19/1,81)   |        |
| Nostril Widths right        | Mean±SD      | 0,87±3,02             | 1,02±1,08           | 0,438  |
|                             | Median (IQR) | 0,4 (-0,09/2,08)      | 0,78 (0,29/1,40)    |        |

|                                       |                     |                     |                     |       |
|---------------------------------------|---------------------|---------------------|---------------------|-------|
| <b>Nostril Widths left</b>            | <b>Mean±SD</b>      | 0,94±3,32           | 0,68±1              | 0,865 |
|                                       | <b>Median (IQR)</b> | 0,78 (-0,47/2,21)   | 0,67 (0,01/1,39)    |       |
| <b>Columella Width</b>                | <b>Mean±SD</b>      | 0,5±1,43            | 0,41±1,28           | 0,734 |
|                                       | <b>Median (IQR)</b> | 0,755 (-0,42/1,39)  | 0,47 (-0,71/1,49)   |       |
| <b>Columella Height</b>               | <b>Mean±SD</b>      | 0,37±1,67           | -0,5±1,51           | 0,152 |
|                                       | <b>Median (IQR)</b> | 0,475 (-0,35/1,51)  | 0,02 (-1,51/0,59)   |       |
| <b>Columella Projection</b>           | <b>Mean±SD</b>      | 1,01±3,02           | 1,58±2,31           | 0,734 |
|                                       | <b>Median (IQR)</b> | 1,5 (-0,50/3,20)    | 0,73 (0,17/2,68)    |       |
| <b>Nostril Show</b>                   | <b>Mean±SD</b>      | -0,74±0,99          | -1,16±1,07          | 0,409 |
|                                       | <b>Median (IQR)</b> | -0,93 (-1,39/-0,10) | -1,18 (-1,90/-0,22) |       |
| <i>Mann Whitney U test *p&lt;0.05</i> |                     |                     |                     |       |

There was no statistically significant difference in angular measurements' changes between groups before and after orthognathic surgery ( $p>0.05$ ).

In the 5.5-10 mm advancement group, the upper lip-E line measurement decrease is statistically significantly higher than the 1-5 mm advancement group ( $p:0.035$ ;  $p<0.05$ ).

There was no statistically significant difference in the changes in other linear measurements between groups before and after orthognathic surgery ( $p>0.05$ ).

No statistically significant difference in nostril show measurement change between groups before and after orthognathic surgery ( $p>0.05$ ).

#### 4.5. Evaluation of the Change in Angular, Linear and Perimetric Measurements from T0 to T1 According to the Growth Pattern

**Table 9: Evaluation of the Change in Angular, Linear and Perimetric Measurements from T0 to T1 According to the Growth Pattern**

|                                    |                     | <b>High</b>        | <b>Low</b>          | <b>p</b> |
|------------------------------------|---------------------|--------------------|---------------------|----------|
| <b>Nasofrontal Angle</b>           | <b>Mean±SD</b>      | -2,19±2,46         | -0,9±2,02           | 0,076    |
|                                    | <b>Median (IQR)</b> | 2,76 (-3,44/-1,36) | -0,9 (-2,48/1,25)   |          |
| <b>Nasolabial Angle</b>            | <b>Mean±SD</b>      | -1,52±9,74         | 1,84±6,23           | 0,199    |
|                                    | <b>Median (IQR)</b> | -2,16 (-7,02/4,48) | 3,6 (-4,61/7,75)    |          |
| <b>Columella Inclination</b>       | <b>Mean±SD</b>      | 0,68±10,2          | 1,54±4,58           | 0,767    |
|                                    | <b>Median (IQR)</b> | -1,49 (-7,45/7)    | 2,26 (-2,33/3,88)   |          |
| <b>Alar Width</b>                  | <b>Mean±SD</b>      | 4,36±4,79          | 2,01±1,53           | 0,068    |
|                                    | <b>Median (IQR)</b> | 3,07 (2,27/4,85)   | 2,38 (1,02/2,94)    |          |
| <b>Alar Base Width</b>             | <b>Mean±SD</b>      | 3,1±2,01           | 2,13±1,91           | 0,459    |
|                                    | <b>Median (IQR)</b> | 2,78 (1,85/3,8)    | 2,57 (0,47/3,47)    |          |
| <b>Subalare Width</b>              | <b>Mean±SD</b>      | 0,05±4,69          | 2,18±4,7            | 0,805    |
|                                    | <b>Median (IQR)</b> | 0,59 (-0,91/2,54)  | 0,65 (-0,76/3,44)   |          |
| <b>Nasal Height</b>                | <b>Mean±SD</b>      | -0,53±2,37         | 0,89±2,7            | 0,139    |
|                                    | <b>Median (IQR)</b> | -0,67 (-2,36/0,82) | 0,29 (-0,78/4,04)   |          |
| <b>Nasal Length</b>                | <b>Mean±SD</b>      | -0,14±4,93         | 0,56±1,81           | 0,217    |
|                                    | <b>Median (IQR)</b> | 0,01 (-2,24/0,63)  | 0,21 (-1,27/2,06)   |          |
| <b>Nasal Tip Projection</b>        | <b>Mean±SD</b>      | 0,76±1,15          | 0,31±1,08           | 0,459    |
|                                    | <b>Median (IQR)</b> | 0,92 (0,33/1,22)   | 0,19 (-0,52/1,34)   |          |
| <b>Upper lip-E line</b>            | <b>Mean±SD</b>      | -0,11±0,23         | -0,22±0,09          | 0,199    |
|                                    | <b>Median (IQR)</b> | -0,14 (-0,26/0,09) | -0,23 (-0,27/-0,12) |          |
| <b>Lower lip-E line</b>            | <b>Mean±SD</b>      | 0,09±0,28          | -0,08±0,27          | 0,045*   |
|                                    | <b>Median (IQR)</b> | 0,02 (-0,12/0,26)  | -0,14 (-0,23/-0,08) |          |
| <b>Lip Length</b>                  | <b>Mean±SD</b>      | 1,98±2,09          | -0,58±1,83          | 0,004*   |
|                                    | <b>Median (IQR)</b> | 1,53 (0,29/3,83)   | -0,84 (-2,37/0,95)  |          |
| <b>Labiale Superius Projection</b> | <b>Mean±SD</b>      | 2,4±3,26           | 2,45±1,32           | 0,882    |
|                                    | <b>Median (IQR)</b> | 2,67 (-0,35/5,16)  | 2,72 (1,24/3,71)    |          |
| <b>Subnasale Projection</b>        | <b>Mean±SD</b>      | 1,21±3,5           | 1,95±1,43           | 0,430    |
|                                    | <b>Median (IQR)</b> | 0,92 (-0,92/4,04)  | 2,39 (0,85/2,8)     |          |
| <b>Nostril Heights right</b>       | <b>Mean±SD</b>      | 0,73±1,97          | 0,68±2,21           | 0,941    |
|                                    | <b>Median (IQR)</b> | 0,52 (-0,4/1,96)   | 0,66 (-0,74/2,35)   |          |
| <b>Nostril Heights left</b>        | <b>Mean±SD</b>      | 0,6±1,46           | 0,31±1,7            | 0,805    |
|                                    | <b>Median (IQR)</b> | 0,94 (-0,6/1,52)   | 0,21 (-1,42/1,9)    |          |
| <b>Nostril Widths right</b>        | <b>Mean±SD</b>      | 1,09±1,45          | 0,72±3,18           | 0,430    |
|                                    | <b>Median (IQR)</b> | 0,82 (0,17/1,65)   | 0,42 (-0,04/1,45)   |          |
| <b>Nostril Widths left</b>         | <b>Mean±SD</b>      | 1,18±1,61          | 0,28±3,34           | 0,336    |

|                                       |                     |                     |                     |       |
|---------------------------------------|---------------------|---------------------|---------------------|-------|
|                                       | <b>Median (IQR)</b> | 0,88 (0,27/1,44)    | 0,67 (-1,3/1,83)    |       |
| <b>Columella Width</b>                | <b>Mean±SD</b>      | 0,2±1,15            | 0,82±1,55           | 0,278 |
|                                       | <b>Median (IQR)</b> | 0,46 (-0,74/1,23)   | 0,95 (-0,51/2,13)   |       |
| <b>Columella Height</b>               | <b>Mean±SD</b>      | 0,25±1,42           | -0,47±1,89          | 0,374 |
|                                       | <b>Median (IQR)</b> | 0,35 (-0,79/1,35)   | 0,02 (-1,61/1,18)   |       |
| <b>Columella Projection</b>           | <b>Mean±SD</b>      | 1,01±3,11           | 1,68±1,92           | 0,444 |
|                                       | <b>Median (IQR)</b> | 0,4 (-0,26/2,95)    | 1,27 (0,17/2,75)    |       |
| <b>Nostril Show</b>                   | <b>Mean±SD</b>      | -0,97±0,98          | -0,9±1,15           | 0,730 |
|                                       | <b>Median (IQR)</b> | -1,21 (-1,72/-0,24) | -0,72 (-1,44/-0,03) |       |
| <i>Mann Whitney U test *p&lt;0.05</i> |                     |                     |                     |       |

There was no statistically significant difference in angular measurements' changes between groups before and after orthognathic surgery ( $p>0.05$ ).

In the high-angle group, the increase in upper lip-E line and lip length measurements are statistically significantly higher than the low angle group from T0 to T1 ( $p:0.045$ ;  $p<0.05$ ), ( $p:0.004$ ;  $p<0.05$ ) respectively.

There was no statistically significant difference in linear measurements' changes between groups before and after orthognathic surgery ( $p>0.05$ ).

No statistically significant difference in nostril show measurement change between groups before and after orthognathic surgery ( $p>0.05$ ).

#### 4.6. Evaluation of the Change in Angular, Linear and Perimetric Measurements from T0 to T1 in Group of 1-5 mm Advancement According to the Growth Pattern

**Table 10: Evaluation of the Change in Angular, Linear and Perimetric Measurements from T0 to T1 in Group of 1-5 mm Advancement According to the Growth Pattern**

|                             |              | 1-5 mm             |                     | p      |
|-----------------------------|--------------|--------------------|---------------------|--------|
|                             |              | High Angle (n:8)   | Low Angle (n:6)     |        |
| Nasofrontal Angle           | Mean±SD      | -1,56±3,18         | -1,04±2,41          | 0,796  |
|                             | Median (IQR) | -2,3 (-3,99/1,51)  | -0,74 (-3,35/1,33)  |        |
| Nasolabial Angle            | Mean±SD      | -1,43±8,2          | 3,8±7,04            | 0,245  |
|                             | Median (IQR) | -0,25 (-7,02/5,05) | 5,68 (-2,16/9,45)   |        |
| Columella Inclination       | Mean±SD      | -0,72±7,19         | 2,41±5,44           | 0,439  |
|                             | Median (IQR) | 1,18 (-8,41/5,94)  | 1,93 (-2,57/7,88)   |        |
| Alar Width                  | Mean±SD      | 5,1±6,71           | 1,99±1,9            | 0,439  |
|                             | Median (IQR) | 2,89 (1,89/6,36)   | 2,54 (0,62/3,22)    |        |
| Alar Base Width             | Mean±SD      | 3,03±2,09          | 2,41±2,02           | 0,796  |
|                             | Median (IQR) | 2,88 (1,89/3,5)    | 2,76 (0,99/3,82)    |        |
| Subalare Width              | Mean±SD      | -0,66±6,34         | 2,96±6,26           | 0,897  |
|                             | Median (IQR) | 0,67 (-1,13/2,11)  | 3,29 (-0,89/6,84)   |        |
| Nasal Height                | Mean±SD      | 0,32±2,57          | 1,44±2,12           | 0,245  |
|                             | Median (IQR) | -0,53 (-1,45/2,55) | 3,71 (-0,29/4,05)   |        |
| Nasal Length                | Mean±SD      | 1,9±5,81           | 0,76±1,98           | 0,897  |
|                             | Median (IQR) | 0,35 (-1,46/2,25)  | 3,85 (-1,17/2,39)   |        |
| Nasal Tip Projection        | Mean±SD      | 0,86±1,05          | 0,25±1,27           | 0,439  |
|                             | Median (IQR) | 0,92 (0,36/1,22)   | 3,33 (-1,07/1,47)   |        |
| Upper lip-E line            | Mean±SD      | 0,02±0,2           | -0,2±0,06           | 0,061  |
|                             | Median (IQR) | 0,07 (-0,19/0,2)   | -0,21 (-0,26/-0,13) |        |
| Lower lip-E line            | Mean±SD      | 0,1±0,36           | -0,12±0,13          | 0,302  |
|                             | Median (IQR) | 0 (-0,2/0,36)      | -0,12 (-0,24/-0,04) |        |
| Lip Length                  | Mean±SD      | 1,41±1,32          | -1,43±0,84          | 0,002* |
|                             | Median (IQR) | 1,09 (0,29/2,37)   | -1,31 (-2,38/-0,72) |        |
| Labiale Superius Projection | Mean±SD      | 1,28±3,48          | 2,07±1,49           | 0,699  |
|                             | Median (IQR) | 1,3 (-1,29/4,94)   | 2,35 (0,54/3,11)    |        |
| Subnasale Projection        | Mean±SD      | 0,22±3,82          | 1,87±1,9            | 0,439  |
|                             | Median (IQR) | 1,2 (-2,46/3,64)   | 1,62 (0,22/3,34)    |        |
| Nostril Heights right       | Mean±SD      | 0,59±2,19          | 1,13±2,58           | 0,796  |
|                             | Median (IQR) | 0,86 (-1,16/2,1)   | 3,68 (-0,86/3,29)   |        |

|                             |                     |                    |                     |       |
|-----------------------------|---------------------|--------------------|---------------------|-------|
| <b>Nostril Heights left</b> | <b>Mean±SD</b>      | 0,56±1,65          | -0,38±1,58          | 0,302 |
|                             | <b>Median (IQR)</b> | 0,75 (-0,91/1,62)  | -0,04 (-1,98/0,63)  |       |
| <b>Nostril Widths right</b> | <b>Mean±SD</b>      | 1±1,66             | 0,69±4,46           | 0,699 |
|                             | <b>Median (IQR)</b> | 0,75 (-0,06/1,63)  | 0,02 (-1,59/3,96)   |       |
| <b>Nostril Widths left</b>  | <b>Mean±SD</b>      | 1,58±2,06          | 0,08±4,6            | 0,366 |
|                             | <b>Median (IQR)</b> | 0,88 (0,41/2,61)   | -0,07 (-2,79/3,21)  |       |
| <b>Columella Width</b>      | <b>Mean±SD</b>      | 0,2±1,3            | 0,89±1,61           | 0,439 |
|                             | <b>Median (IQR)</b> | 0,51 (-0,99/1,25)  | 1,07 (-0,5/2,31)    |       |
| <b>Columella Height</b>     | <b>Mean±SD</b>      | 0,72±1,34          | -0,09±2,08          | 0,651 |
|                             | <b>Median (IQR)</b> | 0,77 (-0,23/1,71)  | 0,48 (-1,37/1,34)   |       |
| <b>Columella Projection</b> | <b>Mean±SD</b>      | 0,56±3,62          | 1,61±2,13           | 0,699 |
|                             | <b>Median (IQR)</b> | 1 (-2,91/4,07)     | 1,5 (-0,26/3,31)    |       |
| <b>Nostril Show</b>         | <b>Mean±SD</b>      | -0,66±1,09         | -0,84±0,93          | 0,699 |
|                             | <b>Median (IQR)</b> | -0,79 (-1,34/0,11) | -0,94 (-1,55/-0,29) |       |

*Mann Whitney U test \*p<0.05*

In the 1-5 mm maxillary advancement group;  
There was no statistically significant difference in angular measurement changes between high-angle and low-angle groups before and after orthognathic surgery ( $p>0.05$ ).

In the high-angle group, the increase in lip length measurement is statistically significantly higher than in the low-angle group from T0 to T1 ( $p:0.002$ ;  $p<0.05$ ).

There was no statistically significant difference in linear measurements' changes between high-angle and low-angle groups before and after orthognathic surgery ( $p>0.05$ ).

No statistically significant difference in nostril show measurement changes between high-angle and low-angle groups before and after orthognathic surgery ( $p>0.05$ ).

**4.7. Evaluation of the Change in Angular, Linear and Perimetric Measurements from T0 to T1 in Group of 5.5-10 mm Advancement According to the Growth Pattern**

**Table 11: Evaluation of the Change in Angular, Linear and Perimetric Measurements from T0 to T1 in Group of 5.5-10 mm Advancement According to the Growth Pattern**

|                                    |                     | 5.5-10 mm           |                     | p      |
|------------------------------------|---------------------|---------------------|---------------------|--------|
|                                    |                     | High Angle (n:8)    | Low Angle (n:5)     |        |
| <b>Nasofrontal Angle</b>           | <b>Mean±SD</b>      | -2,82±1,4           | -0,73±1,69          | 0,013* |
|                                    | <b>Median (IQR)</b> | -3,1 (-3,44/-2,61)  | -0,9 (-2,36/0,99)   |        |
| <b>Nasolabial Angle</b>            | <b>Mean±SD</b>      | -1,62±11,67         | -0,52±4,73          | 0,380  |
|                                    | <b>Median (IQR)</b> | -3,35 (-7,9/2,92)   | -2,44 (-4,65/4,57)  |        |
| <b>Columella Inclination</b>       | <b>Mean±SD</b>      | 2,07±12,91          | 0,5±3,61            | 0,998  |
|                                    | <b>Median (IQR)</b> | -1,73 (-6,69/11,92) | 2,26 (-3,32/3,45)   |        |
| <b>Alar Width</b>                  | <b>Mean±SD</b>      | 3,63±1,7            | 2,03±1,16           | 0,057  |
|                                    | <b>Median (IQR)</b> | 3,35 (2,57/4,85)    | 2,09 (0,89/3,13)    |        |
| <b>Alar Base Width</b>             | <b>Mean±SD</b>      | 3,18±2,08           | 1,8±1,93            | 0,380  |
|                                    | <b>Median (IQR)</b> | 2,54 (1,83/4,52)    | 2,57 (-0,21/3,43)   |        |
| <b>Subalare Width</b>              | <b>Mean±SD</b>      | 0,76±2,42           | 1,25±2,08           | 0,884  |
|                                    | <b>Median (IQR)</b> | 0,44 (-0,91/3,27)   | 2,1 (-0,82/2,9)     |        |
| <b>Nasal Height</b>                | <b>Mean±SD</b>      | -1,39±1,93          | 0,23±3,41           | 0,464  |
|                                    | <b>Median (IQR)</b> | -0,8 (-2,64/-0,12)  | -0,2 (-2,52/3,19)   |        |
| <b>Nasal Length</b>                | <b>Mean±SD</b>      | -2,18±2,99          | 0,33±1,78           | 0,143  |
|                                    | <b>Median (IQR)</b> | -1,49 (-5,47/0,34)  | 0,21 (-1,39/2,1)    |        |
| <b>Nasal Tip Projection</b>        | <b>Mean±SD</b>      | 0,67±1,3            | 0,38±0,94           | 0,770  |
|                                    | <b>Median (IQR)</b> | 0,92 (0,05/1,22)    | -0,09 (-0,4/1,39)   |        |
| <b>Upper lip-E line</b>            | <b>Mean±SD</b>      | -0,24±0,18          | -0,24±0,12          | 0,942  |
|                                    | <b>Median (IQR)</b> | -0,24 (-0,4/-0,11)  | -0,27 (-0,35/-0,12) |        |
| <b>Lower lip-E line</b>            | <b>Mean±SD</b>      | 0,07±0,19           | -0,03±0,4           | 0,078  |
|                                    | <b>Median (IQR)</b> | 0,02 (-0,1/0,25)    | -0,21 (-0,24/0,27)  |        |
| <b>Lip Length</b>                  | <b>Mean±SD</b>      | 2,55±2,62           | 0,44±2,27           | 0,188  |
|                                    | <b>Median (IQR)</b> | 3,46 (-0,05/4,72)   | 0,95 (-1,6/2,22)    |        |
| <b>Labiale Superius Projection</b> | <b>Mean±SD</b>      | 3,51±2,79           | 2,91±1,06           | 0,661  |
|                                    | <b>Median (IQR)</b> | 3,63 (1,21/6,44)    | 2,96 (1,98/3,82)    |        |
| <b>Subnasale Projection</b>        | <b>Mean±SD</b>      | 2,19±3,07           | 2,05±0,74           | 0,464  |
|                                    | <b>Median (IQR)</b> | 0,92 (0,39/4,04)    | 2,4 (1,28/2,66)     |        |
| <b>Nostril Heights right</b>       | <b>Mean±SD</b>      | 0,88±1,87           | 0,13±1,8            | 0,661  |
|                                    | <b>Median (IQR)</b> | 0,36 (-0,38/1,96)   | 3,59 (-1,58/1,62)   |        |

|                             |                     |                     |                    |       |
|-----------------------------|---------------------|---------------------|--------------------|-------|
| <b>Nostril Heights left</b> | <b>Mean±SD</b>      | 0,63±1,37           | 1,15±1,59          | 0,380 |
|                             | <b>Median (IQR)</b> | 0,95 (-0,27/1,46)   | 1,4 (-0,23/2,41)   |       |
| <b>Nostril Widths right</b> | <b>Mean±SD</b>      | 1,19±1,3            | 0,76±0,63          | 0,558 |
|                             | <b>Median (IQR)</b> | 0,82 (0,29/1,68)    | 0,6 (0,19/1,4)     |       |
| <b>Nostril Widths left</b>  | <b>Mean±SD</b>      | 0,78±0,98           | 0,51±1,13          | 0,770 |
|                             | <b>Median (IQR)</b> | 0,82 (-0,11/1,44)   | 0,67 (-0,37/1,31)  |       |
| <b>Columella Width</b>      | <b>Mean±SD</b>      | 0,21±1,06           | 0,72±1,66          | 0,464 |
|                             | <b>Median (IQR)</b> | 0,4 (-0,74/1,09)    | 0,85 (-0,93/2,32)  |       |
| <b>Columella Height</b>     | <b>Mean±SD</b>      | -0,23±1,41          | -0,93±1,74         | 0,242 |
|                             | <b>Median (IQR)</b> | 0,24 (-1,09/0,62)   | -1,4 (-2,37/0,75)  |       |
| <b>Columella Projection</b> | <b>Mean±SD</b>      | 1,46±2,66           | 1,77±1,87          | 0,420 |
|                             | <b>Median (IQR)</b> | 0,4 (-0,04/2,78)    | 0,84 (0,45/3,55)   |       |
| <b>Nostril Show</b>         | <b>Mean±SD</b>      | -1,27±0,82          | -0,97±1,48         | 0,464 |
|                             | <b>Median (IQR)</b> | -1,44 (-1,99/-0,52) | -0,72 (-2,32/0,25) |       |
| <i>Mann Whitney U test</i>  |                     | <i>*p&lt;0.05</i>   |                    |       |

In the 5.5-10 mm advancement group;

The decrease in nasofrontal angle measurement in the high-angle group is statistically significantly higher than in the low-angle group (p:0.013; p<0.05).

There was no statistically significant difference in other angular measurement changes between the high-angle and low-angle groups before and after orthognathic surgery (p>0.05).

There was no statistically significant difference in linear measurements' changes between high-angle and low-angle groups before and after orthognathic surgery (p>0.05).

No statistically significant difference in nostril show measurement changes between high-angle and low-angle groups before and after orthognathic surgery (p>0.05).

#### 4.8. Evaluation of the Change in Angular, Linear and Perimetric Measurements from T0 to T1 in the High Angle Group According to the Amount of Maxillary Advancement

**Table 12: Evaluation of the Change in Angular, Linear and Perimetric Measurements from T0 to T1 in the High Angle Group According to the Amount of Maxillary Advancement**

|                                    |                     | <b>High Angle</b>   |                       | <b>p</b> |
|------------------------------------|---------------------|---------------------|-----------------------|----------|
|                                    |                     | <b>1-5 mm (n:8)</b> | <b>5.5-10mm (n:8)</b> |          |
| <b>Nasofrontal Angle</b>           | <b>Mean±SD</b>      | -1,56±3,18          | -2,82±1,4             | 0,208    |
|                                    | <b>Median (IQR)</b> | -2,3 (-3,99/1,51)   | -3,1 (-3,44/-2,61)    |          |
| <b>Nasolabial Angle</b>            | <b>Mean±SD</b>      | -1,43±8,2           | -1,62±11,67           | 0,674    |
|                                    | <b>Median (IQR)</b> | -0,25 (-7,02/5,05)  | -3,35 (-7,9/2,92)     |          |
| <b>Columella Inclination</b>       | <b>Mean±SD</b>      | -0,72±7,19          | 2,07±12,91            | 0,753    |
|                                    | <b>Median (IQR)</b> | 1,18 (-8,41/5,94)   | -1,73 (-6,69/11,92)   |          |
| <b>Alar Width</b>                  | <b>Mean±SD</b>      | 5,1±6,71            | 3,63±1,7              | 0,674    |
|                                    | <b>Median (IQR)</b> | 2,89 (1,89/6,36)    | 3,35 (2,57/4,85)      |          |
| <b>Alar Base Width</b>             | <b>Mean±SD</b>      | 3,03±2,09           | 3,18±2,08             | 0,916    |
|                                    | <b>Median (IQR)</b> | 2,88 (1,89/3,5)     | 2,54 (1,83/4,52)      |          |
| <b>Subalare Width</b>              | <b>Mean±SD</b>      | -0,66±6,34          | 0,76±2,42             | 0,999    |
|                                    | <b>Median (IQR)</b> | 0,67 (-1,13/2,11)   | 0,44 (-0,91/3,27)     |          |
| <b>Nasal Height</b>                | <b>Mean±SD</b>      | 0,32±2,57           | -1,39±1,93            | 0,294    |
|                                    | <b>Median (IQR)</b> | -0,53 (-1,45/2,55)  | -0,8 (-2,64/-0,12)    |          |
| <b>Nasal Length</b>                | <b>Mean±SD</b>      | 1,9±5,81            | -2,18±2,99            | 0,141    |
|                                    | <b>Median (IQR)</b> | 0,35 (-1,46/2,25)   | -1,49 (-5,47/0,34)    |          |
| <b>Nasal Tip Projection</b>        | <b>Mean±SD</b>      | 0,86±1,05           | 0,67±1,3              | 0,875    |
|                                    | <b>Median (IQR)</b> | 0,92 (0,36/1,22)    | 0,92 (0,05/1,22)      |          |
| <b>Upper lip-E line</b>            | <b>Mean±SD</b>      | 0,02±0,2            | -0,24±0,18            | 0,031*   |
|                                    | <b>Median (IQR)</b> | 0,07 (-0,19/0,2)    | -0,24 (-0,4/-0,11)    |          |
| <b>Lower lip-E line</b>            | <b>Mean±SD</b>      | 0,1±0,36            | 0,07±0,19             | 0,599    |
|                                    | <b>Median (IQR)</b> | 0 (-0,2/0,36)       | 0,02 (-0,1/0,25)      |          |
| <b>Lip Length</b>                  | <b>Mean±SD</b>      | 1,41±1,32           | 2,55±2,62             | 0,345    |
|                                    | <b>Median (IQR)</b> | 1,09 (0,29/2,37)    | 3,46 (-0,05/4,72)     |          |
| <b>Labiale Superius Projection</b> | <b>Mean±SD</b>      | 1,28±3,48           | 3,51±2,79             | 0,248    |
|                                    | <b>Median (IQR)</b> | 1,3 (-1,29/4,94)    | 3,63 (1,21/6,44)      |          |
| <b>Subnasale Projection</b>        | <b>Mean±SD</b>      | 0,22±3,82           | 2,19±3,07             | 0,600    |
|                                    | <b>Median (IQR)</b> | 1,2 (-2,46/3,64)    | 0,92 (0,39/4,04)      |          |
| <b>Mean±SD</b>                     |                     | 0,59±2,19           | 0,88±1,87             | 0,834    |

|                              |                     |                    |                     |       |
|------------------------------|---------------------|--------------------|---------------------|-------|
| <b>Nostril Heights right</b> | <b>Median (IQR)</b> | 0,86 (-1,16/2,1)   | 0,36 (-0,38/1,96)   |       |
| <b>Nostril Heights left</b>  | <b>Mean±SD</b>      | 0,56±1,65          | 0,63±1,37           | 0,916 |
|                              | <b>Median (IQR)</b> | 0,75 (-0,91/1,62)  | 0,95 (-0,27/1,46)   |       |
| <b>Nostril Widths right</b>  | <b>Mean±SD</b>      | 1±1,66             | 1,19±1,3            | 0,674 |
|                              | <b>Median (IQR)</b> | 0,75 (-0,06/1,63)  | 0,82 (0,29/1,68)    |       |
| <b>Nostril Widths left</b>   | <b>Mean±SD</b>      | 1,58±2,06          | 0,78±0,98           | 0,674 |
|                              | <b>Median (IQR)</b> | 0,88 (0,41/2,61)   | 0,82 (-0,11/1,44)   |       |
| <b>Columella Width</b>       | <b>Mean±SD</b>      | 0,2±1,3            | 0,21±1,06           | 0,834 |
|                              | <b>Median (IQR)</b> | 0,51 (-0,99/1,25)  | 0,4 (-0,74/1,09)    |       |
| <b>Columella Height</b>      | <b>Mean±SD</b>      | 0,72±1,34          | -0,23±1,41          | 0,294 |
|                              | <b>Median (IQR)</b> | 0,77 (-0,23/1,71)  | 0,24 (-1,09/0,62)   |       |
| <b>Columella Projection</b>  | <b>Mean±SD</b>      | 0,56±3,62          | 1,46±2,66           | 0,674 |
|                              | <b>Median (IQR)</b> | 1 (-2,91/4,07)     | 0,4 (-0,04/2,78)    |       |
| <b>Nostril Show</b>          | <b>Mean±SD</b>      | -0,66±1,09         | -1,27±0,82          | 0,294 |
|                              | <b>Median (IQR)</b> | -0,79 (-1,34/0,11) | -1,44 (-1,99/-0,52) |       |
| <i>Mann Whitney U test</i>   |                     | <i>*p&lt;0.05</i>  |                     |       |

In the high-angle group,

There was no statistically significant difference in angular measurements' changes between different maxillary advancement groups before and after orthognathic surgery ( $p>0.05$ ).

In the 1-5 mm advancement group, the increase in lip length measurement is statistically significantly higher than in the 5.5-10 mm advancement group from T0 to T1 ( $p:0.031$ ;  $p<0.05$ ).

There was no statistically significant difference in other linear measurements' changes between different maxillary advancement groups before and after orthognathic surgery ( $p>0.05$ ).

No statistically significant difference in nostril show measurement changes between different maxillary advancement groups before and after orthognathic surgery ( $p>0.05$ ).

#### 4.9. Evaluation of the Change in Angular, Linear and Perimetric Measurements from T0 to T1 in the Low Angle Group According to the Amount of Maxillary Advancement

**Table 13: Evaluation of the Change in Angular, Linear and Perimetric Measurements from T0 to T1 in the Low Angle Group According to the Amount of Maxillary Advancement**

|                             |              | Low Angle           |                     | p     |
|-----------------------------|--------------|---------------------|---------------------|-------|
|                             |              | 1-5 mm (n:6)        | 5.5-10mm (n:5)      |       |
| Nasofrontal Angle           | Mean±SD      | -1,04±2,41          | -0,73±1,69          | 0,855 |
|                             | Median (IQR) | -0,74 (-3,35/1,33)  | -0,9 (-2,36/0,99)   |       |
| Nasolabial Angle            | Mean±SD      | 3,8±7,04            | -0,52±4,73          | 0,273 |
|                             | Median (IQR) | 5,68 (-2,16/9,45)   | -2,44 (-4,65/4,57)  |       |
| Columella Inclination       | Mean±SD      | 2,41±5,44           | 0,5±3,61            | 0,715 |
|                             | Median (IQR) | 1,93 (-2,57/7,88)   | 2,26 (-3,32/3,45)   |       |
| Alar Width                  | Mean±SD      | 1,99±1,9            | 2,03±1,16           | 0,715 |
|                             | Median (IQR) | 2,54 (0,62/3,22)    | 2,09 (0,89/3,13)    |       |
| Alar Base Width             | Mean±SD      | 2,41±2,02           | 1,8±1,93            | 0,855 |
|                             | Median (IQR) | 2,76 (0,99/3,82)    | 2,57 (-0,21/3,43)   |       |
| Subalare Width              | Mean±SD      | 2,96±6,26           | 1,25±2,08           | 0,998 |
|                             | Median (IQR) | 0,29 (-0,89/6,84)   | 2,1 (-0,82/2,9)     |       |
| Nasal Height                | Mean±SD      | 1,44±2,12           | 0,23±3,41           | 0,361 |
|                             | Median (IQR) | 0,71 (-0,29/4,05)   | -0,2 (-2,52/3,19)   |       |
| Nasal Length                | Mean±SD      | 0,76±1,98           | 0,33±1,78           | 0,584 |
|                             | Median (IQR) | 0,85 (-1,17/2,39)   | 0,21 (-1,39/2,1)    |       |
| Nasal Tip Projection        | Mean±SD      | 0,25±1,27           | 0,38±0,94           | 0,997 |
|                             | Median (IQR) | 0,33 (-1,07/1,47)   | -0,09 (-0,4/1,39)   |       |
| Upper lip-E line            | Mean±SD      | -0,2±0,06           | -0,24±0,12          | 0,582 |
|                             | Median (IQR) | -0,21 (-0,26/-0,13) | -0,27 (-0,35/-0,12) |       |
| Lower lip-E line            | Mean±SD      | -0,12±0,13          | -0,03±0,4           | 0,647 |
|                             | Median (IQR) | -0,12 (-0,24/-0,04) | -0,21 (-0,24/0,27)  |       |
| Lip Length                  | Mean±SD      | -1,43±0,84          | 0,44±2,27           | 0,100 |
|                             | Median (IQR) | -1,31 (-2,38/-0,72) | 0,95 (-1,6/2,22)    |       |
| Labiale Superius Projection | Mean±SD      | 2,07±1,49           | 2,91±1,06           | 0,273 |
|                             | Median (IQR) | 2,35 (0,54/3,11)    | 2,96 (1,98/3,82)    |       |
| Subnasale Projection        | Mean±SD      | 1,87±1,9            | 2,05±0,74           | 0,464 |
|                             | Median (IQR) | 1,62 (0,22/3,34)    | 2,4 (1,28/2,66)     |       |
| Nostril Heights right       | Mean±SD      | 1,13±2,58           | 0,13±1,8            | 0,465 |
|                             | Median (IQR) | 0,68 (-0,86/3,29)   | 0,59 (-1,58/1,62)   |       |
| Nostril Heights left        | Mean±SD      | -0,38±1,58          | 1,15±1,59           | 0,100 |

|                             |                     |                     |                    |       |
|-----------------------------|---------------------|---------------------|--------------------|-------|
|                             | <b>Median (IQR)</b> | -0,04 (-1,98/0,63)  | 1,4 (-0,23/2,41)   |       |
| <b>Nostril Widths right</b> | <b>Mean±SD</b>      | 0,69±4,46           | 0,76±0,63          | 0,584 |
|                             | <b>Median (IQR)</b> | 0,02 (-1,59/3,96)   | 0,6 (0,19/1,4)     |       |
| <b>Nostril Widths left</b>  | <b>Mean±SD</b>      | 0,08±4,6            | 0,51±1,13          | 0,855 |
|                             | <b>Median (IQR)</b> | -0,07 (-2,79/3,21)  | 0,67 (-0,37/1,31)  |       |
| <b>Columella Width</b>      | <b>Mean±SD</b>      | 0,89±1,61           | 0,72±1,66          | 0,715 |
|                             | <b>Median (IQR)</b> | 1,07 (-0,5/2,31)    | 0,85 (-0,93/2,32)  |       |
| <b>Columella Height</b>     | <b>Mean±SD</b>      | -0,09±2,08          | -0,93±1,74         | 0,361 |
|                             | <b>Median (IQR)</b> | 0,48 (-1,37/1,34)   | -1,4 (-2,37/0,75)  |       |
| <b>Columella Projection</b> | <b>Mean±SD</b>      | 1,61±2,13           | 1,77±1,87          | 0,995 |
|                             | <b>Median (IQR)</b> | 1,5 (-0,26/3,31)    | 0,84 (0,45/3,55)   |       |
| <b>Nostril Show</b>         | <b>Mean±SD</b>      | -0,84±0,93          | -0,97±1,48         | 0,998 |
|                             | <b>Median (IQR)</b> | -0,94 (-1,55/-0,29) | -0,72 (-2,32/0,25) |       |

*Mann Whitney U test*

In the low-angle group,  
There was no statistically significant difference in angular measurements' changes between different maxillary advancement groups before and after orthognathic surgery ( $p>0.05$ ).

There was no statistically significant difference in other linear measurements' changes between different maxillary advancement groups before and after orthognathic surgery ( $p>0.05$ ).

No statistically significant difference in the nostril show measurement changes between different maxillary advancement groups before and after orthognathic surgery ( $p>0.05$ ).

## 5. DISCUSSION

### 5.1. Discussion of the Aim

Orthodontic therapy aims to preserve or enhance a patient's facial symmetry.<sup>84</sup> The combination of orthodontics with orthognathic surgery enhances the ability to modify face appearance. However, despite the possibility of achieving ideal repositioning of the jaws by orthognathic surgery, it is crucial to emphasize that the final look of a patient's soft tissues may not perfectly align with the movements of the jaw.

Imaging is crucial for assessing and planning the treatment of patients undergoing orthognathic surgery, as this procedure enhances the facial appearance of individuals with skeletal disharmony and leads to alterations in the soft tissues. Using imaging techniques, orthodontists and surgeons can accurately display the relevant anatomic structures for accurate diagnosis and treatment planning. Long ago, only 2D techniques could be used to measure three-dimensional objects. To measure an item in three dimensions, it was necessary to develop 3D imaging technology.<sup>17</sup> Recent innovations such as 3D photogrammetry and laser surface scanning provide viable solutions to these problems. Full data sets can be collected digitally, quickly, painlessly, and stored for later examination. One such three-dimensional photogrammetry device is the 3dMD digital imaging system, which integrates 3D surface pictures in two milliseconds.<sup>65</sup> Numerous articles published to date have examined the dependability and precision of the 3dMDface system.<sup>2,3,10-17</sup>

Our team collects all records before and after orthodontic treatment, including 3D images from the 3dMd camera. The evaluation of these changes in the nasomaxillary complex led us to believe that the facial soft tissue response in skeletal class III patients treated by leFort I should be evaluated.<sup>3</sup> Thus, the findings of this study would inform the team regarding the predictability of postoperative outcomes using stereophotogrammetry.

Therefore, this retrospective study aimed to evaluate the modifications in soft tissues of patients with skeletal class III malocclusion who had maxillary advancement surgery and compare the magnitude of these changes across other groups.

## 5.2. Discussion of Materials and Methods

The number of studies examining the efficacy of facial aesthetics treatments increases daily. Historically, radiography and two-dimensional pictures were employed to record postoperative alterations. Due to the human body's three-dimensional nature, any alterations caused by facial expressions or surgery likewise occur in three dimensions. Numerous strategies have been devised to surpass the constraints of conventional two-dimensional imaging. This category includes digital stereophotogrammetry, morphoanalysis, 3D ultrasonography, laser scanning, moiré topography, 3D magnetic resonance imaging, 3D cephalometry, and 3D computed tomography.<sup>15</sup>

Three-dimensional photogrammetry is an effective technique for evaluating alterations in the nasomaxillary complex after orthognathic surgery.<sup>10</sup> During this process, the texture map or the color information is mathematically integrated into the shape data, depending on the imaging equipment utilized. This captures a sequence of photos throughout both the pre-and post-operative stages while facilitating a quantitative assessment of the facial soft tissue.

In our research, digital stereophotogrammetry was utilized. This technology is secure and does not require any penetration. It efficiently captures high-resolution photos of external surfaces, with each frame taking less than two milliseconds. Stereophotogrammetry utilizes multiple photographic planes to rebuild an object in three-dimensional space. This offers a technique for measuring linear lengths, surface distances, surface areas, and volumes.<sup>65</sup> Furthermore, the projection of three-dimensional coordinates can be utilized to perform diverse statistical shape analysis, enabling the detection of alterations in the craniofacial complex throughout treatment.<sup>9</sup> Using imaging software to measure specific locations' area, volume, and skin texture is possible, an advantage over 2-dimensional approaches.<sup>15</sup> Moreover, this technology is superior to laser scanning techniques for identifying the surface texture of soft tissue.<sup>85</sup> This benefit permits the accurate placement of landmarks. Consequently, it provides more precise measurements.

In our study, 3D images were captured through the 3dMD system (3dMD Inc., Atlanta, GA, USA).<sup>10</sup> The 3dMD system generates highly repeatable images and can

accurately collect 3D landmark data.<sup>65</sup> Despite having numerous advantages, this strategy also has disadvantages. The high cost of the equipment and the need for a special room are the primary disadvantages of this method.<sup>59</sup> In addition, a specialized piece of software is required to evaluate the recorded data, and because this device is immobile, users must visit the facilities where it is installed. Patients should refrain from making facial expressions during record-keeping. Expressions can degrade the quality of an audio recording and cause distortion. Therefore, subjects must be in a resting position when being recorded.<sup>63</sup> For this purpose, the 3D images were examined to determine whether the patients rested in the same position before and after surgery. In addition, only high-quality, non-distorted 3D images were evaluated for this research. Our study evaluated changes in the nasomaxillary complex using linear, angular, and perimetric measurements. The correct identification of these measurements' constituent landmarks is essential for providing accurate measurements. Therefore, the definition of these landmarks is contingent on precisely determining the anatomical points, the person performing the evaluation, and the recording quality.<sup>71</sup> All landmarks were identified by the same examiner, who was trained in 3D image processing and data processing using the 3dMd camera and 3dMd Vultus software due to the significance of the examiner's knowledge and experience. The examiner adhered to the same standards for acquiring 3D images, and any images acquired outside of these standards were excluded from this study. Throughout the scan, the patients' heads were positioned in their typical head posture (NHP) and their usual way of closing their jaws. To attain this occlusion, participants were instructed to swallow in a typical way, loosen their facial muscles, and position their molars in a standard closure.<sup>86</sup> In addition, the patients were instructed to walk and relax before their head motions were gradually decreased until they were in a self-balanced position to reach the NHP.<sup>86</sup> Because it operates on a single surface, the landmark can be precisely positioned in a single step using 2D photographs. When using 3D images, the positions of the landmarks on the three planes must be controlled. As a result, in our study, each marker was initially placed on the frontal plane before being controlled on the sagittal and horizontal planes. Previous research uses the intraclass correlation coefficients to assess the repeatability of the landmarks and related measurements. These coefficients revealed a high level of reproducibility and reliability.

6,10,16,17,87

According to the power analysis results, our study group should include at least 27 individuals with skeletal class III malocclusion. To examine changes in the nasomaxillary complex, we included only patients who underwent maxillary advancement surgery. To be compatible with power analysis, our study group included 27 individuals whose treatments were completed between 2018 and 2021. There were difficulties in ensuring accurate and timely record retrieval. The archive was searched for pre- and post-surgical stereophotogrammetric images (3dMDface System - Atlanta, GA, USA) of 27 patients (8 males, 19 females). Images were collected at monthly intervals over six months. In the previous studies, the number of study subjects was 38<sup>10</sup>, 13<sup>14</sup>, 28<sup>3</sup>, 15<sup>2</sup>, 32<sup>15</sup>, 36<sup>17</sup>, 44<sup>11</sup>, respectively. The duration of previously done studies<sup>3,10,11,14,15</sup> was the same as in our research, which is six months.

The relatively small sample size is a limitation of this study because not all patients provided the necessary records. Nonetheless, we compared the three-dimensional alterations of different soft tissue landmarks based on the amount of advancement and the growth pattern. Long-term monitoring of these alterations and increased population size may help understand soft tissue remodeling.<sup>88</sup>

As described in the Materials and Methods section, 3D images were acquired at two time intervals for each patient in our study: before surgery (T0) and six months after surgery (T1). Supposing that facial swelling would be gone entirely after six months.<sup>89</sup> We have chosen this six-month duration. Consequently, the baseline for soft tissue measurements was the condition six months after surgery.

Our subjects were in operation from April 2018 until December 2021. Although it would have been ideal for all subjects to have been operated on by the same surgeon, they were operated on by different surgeons in different Istanbul, Turkey, healthcare facilities. Because the surgeries were performed in various healthcare facilities, preoperative and postoperative drug regimens may have exhibited minimal variation. However, the operating surgeons employed similar operating principles and techniques to achieve the ideal skeletal harmony of the face.

### 5.3. Discussion of Results

In our study, we evaluated the changes in the soft tissues of the nasomaxillary complex according to patients' growth patterns and the amount of maxillary advancement. We also compared the magnitude of changes between patients with the same growth pattern and those with the same amount of acceleration. These assessments were conducted using angular, linear, and perimetric measurements.

In our study, since the gender and age distributions were unequal (19 female patients and 8 male patients), we checked to see if there was a statistically significant difference between the sexes; however, there was no statistically significant difference in the mean age distribution between the sexes ( $p>0.05$ ). In addition to this, we evaluated the differences between T0 and T1 in eight different ways.

First, we evaluated angular, linear, and perimetric measurements based on maxillary advancement from T0 to T1. We divided our population into two groups by the amount of maxillary advancement: the minor and the major advancement groups. The minor progression group consists of 14 patients, while the major progression group consists of 13 patients. Minor advancements ranged between 1 and 5 millimeters, while major advancements ranged between 5.5 and 10 millimeters. Le Fort 1 advancement is recognized to enhance the face profile in the nasolabial area. Nevertheless, there have been reports of negative consequences, such as an increase in the size of the alar bases, elongation of the nasal tip, and the flattening, thinning, and shortness of the upper lip.<sup>12</sup> In both groups, the measurements of parameters including alar width, alar base width, and labiale superius projection increase, while nostril show decreases. When the maxilla moves forward without rotating and rotates upwards and downwards, the alar base and alar width expand. These changes occur despite using an alar cinching suture, intended to reduce the amount of alar base flare commonly caused by maxillary advancement.<sup>15</sup> To provide adequate control over postoperative nasal width, the most common technique involves placing an intraoral suture through the muscle and soft tissue under the alar base on either side of the piriform rim.<sup>10</sup> The effects of orthognathic surgery on facial soft tissue have been extensively studied. It was consistently observed that the nose's alar base and interalar widths increased following maxillary advances and impactions.<sup>2,3,10,12,15–</sup>

<sup>17,84,87,90,91</sup> One cause of this increase is the elevation of the muscles and ligaments from the anterior surface of the maxillary periosteum to stabilize the alar region. <sup>86,92</sup>

Unlike our research, using CBCT scans, Kim et al. assessed soft tissue alterations in patients who underwent either mandibular surgery alone or bimaxillary surgery. <sup>3</sup> They hypothesized that patients who underwent isolated mandibular surgery exhibited a minor decrease in the alar base region, but its magnitude was clinically inconsiderable. <sup>88</sup> This decrease in alar width may be due to the surgical approach to the maxilla instead of the maxilla's actual movement. <sup>88,93</sup>

The mean rise in alar width observed in all subjects in this investigation supports the conclusions of prior studies that suggest that forward movements of the upper jaw lead to an augmentation in the width of the nose in the horizontal direction. <sup>84</sup> There was no observed decrease in alar breadth among patients with LeFort I osteotomy. Given that certain publications have proposed that the increases are primarily due to muscle shortening and lateral retraction resulting from the manipulation of muscles around the mouth and nose during surgery, it is probable that multiple factors induce the rise in transverse nasal dimensions. <sup>84,93–95</sup>

Increased labiale superius projection may result from the anterior movement of the upper jaw and, consequently, the upper lip. The most frequent complaint following LeFort I is a widened nose. <sup>93,96–98</sup> Contrary to Worasakwutiphong's study, the nasal area revealed a significant increase, which was associated with a decrease in columella inclination and an increase in the nasolabial angle. <sup>10</sup> This increase in nostril show was associated with a reduction in columella inclination and an increase in the nasolabial angle. <sup>10</sup> The 5.5 to 10 mm advancement group is the only group in which the nasofrontal angle and upper lip-E line are reduced. The decrease in the nasofrontal angle was comparable to the findings of Worasakwutiphong's study. <sup>10,16</sup> Metzler et al. <sup>12</sup> also observed that following LeFort I, both the nasal protrusion prominence and the nasofrontal angle were reduced. Irrespective of the amount of maxillary advancement, the results remained uniform among all patients and were associated with the elevation of the alar base achieved through inferior rotation of the nasal tip. <sup>2</sup> Few studies have attempted to explain why the nasofrontal angle varies. Due to the LeFort I operation, the nasofrontal junction would be very stable. It can be assumed that most changes in the

nasofrontal angle would be due to shifts in the nasal portion of this angle. In other words, alterations in the nasofrontal angle appear independent of skeletal movements and have been shown to result from changes to the nasal septum during soft tissue degloving.<sup>99</sup>

Columella projection, subnasale projection, lip length, and nostril widths only increased in the 5.5 to 10 mm advancement group. Similar to the previous study, the major advancement group showed increased nostril width and columella projection. From the submental view, the nostrils became more rounded, demonstrating a decrease in height and an increase in width.<sup>12,16</sup> Other measurements revealed no difference between the groups. Similar to the prior study, the height and length of the nose remained unchanged. Other measurements showed no difference between the groups. Similar to the preceding research, the height and length of the nose remained unchanged.<sup>10</sup> After LeFort I surgery, mixed nasal alterations have been documented in the literature, particularly in nasal tip projection and nasolabial angle cases. Variations in the patient's demographics, clinical diagnosis, surgical technique, and evaluation tool could be to blame. Similar to our research, other studies' nasal tip projection remains unchanged.<sup>100,101</sup> Other studies on nasal tip projection in orthognathic surgery produced various results. Even though they were based on cephalometric analysis, some researchers observed a 30 to 60 percent increase in nasal tip protrusion about maxillary advancement.<sup>102,103</sup> However, using a 3D imaging system, Honrado et al.<sup>15</sup> observed a trend toward a decrease in nasal tip projection in patients who underwent maxillary advancement with upward rotation.

In line with our research, Foroughi et al. found no statistically significant variation in the nasolabial angle following leFort I when relying simply on cephalometric assessment.<sup>15</sup> Additionally, unlike our study, they also adjusted the ANS. In addition, according to Betts' research on 32 patients who underwent LeFort I osteotomies, most of the nasolabial angle decreased or remained constant.<sup>104</sup>

In contrast, Lai et al.<sup>105</sup> reported a notable augmentation in the nasolabial angle following maxillary advancement with clockwise rotation without ANS reduction, like our study. DeSesa et al.<sup>16</sup> observed a rise in the nasolabial angle. In addition, Nagori et al.<sup>106</sup>, Marsan et al.<sup>107</sup> found a decrease in the nasolabial angle following maxillary advancement. The decline is mainly attributed to the lip apparatus's forward movement

rather than the ANS's diminution. In addition, Honrado et al.<sup>15</sup> also documented a reduction in the nasolabial angle among patients with maxillary advancement and upward rotation. Nevertheless, the variation in these findings could be attributed to disparities in age, gender, ethnicity, and the duration elapsed between the surgical procedure and the acquisition of the ultimate image. Consistent with our research, Louis et al. discovered no link between the extent of alteration in the nasolabial angle and the magnitude of maxillary advancement.

In contrast to our study, Worasakwutiphong et al.<sup>10</sup> found that the 3D assessment of class III individuals who underwent bimaxillary surgery showed a notable decrease in nasal tip projection. This decrease was observed in both cleft and non-cleft patients, regardless of whether maxillary advancement was performed with or without impaction. When explaining the process to patients, it is crucial to remember that even minor modifications to the nasal tip projection might change how the nose looks in various individuals.

Unlike our study, Sabri et al. reported a significant reduction in nasal height. The slight impaction of the maxilla, caused by the 2 mm space generated by the burr used to divide the maxilla, might explain this occurrence in the mentioned research.<sup>86</sup> According to our research, Vasudavan et al.<sup>108</sup> observed no significant differences in nasal height, alar base width, nasolabial angle, or columellar width.

When we compared the change in measurements from T0 to T1 between these groups, we found only one significant difference: The upper lip-E line measurement decreased significantly more in the group with 5.5-10 mm of advancement than in the group with 1-5 mm of advancement ( $p=0.035$ ;  $p0.05$ ). The second step was to divide our population into two groups: those with a high-angle growth pattern and those with a low-angle growth pattern. 16 and 11 were the respective sizes of the two groups. Per the growth pattern, the upper lip-E line and lip length increase were statistically greater than in low angle ( $p:0.045$ ;  $p0.05$ ) and ( $p:0.004$ ;  $p0.05$ ), respectively. Also, in the minor advancement group, the increase in lip length was higher in high angle group than in the low angle group ( $p:0.002$ ;  $p<0.05$ ). Furthermore, the lowering in the nasofrontal angle was more pronounced in the high-angle group compared to the low-angle group within the significant advancement group. ( $p:0.013$ ;  $p0.05$ ). According to the amount of

advancement, the increase in lip length in the high-angle group was greater in the minor advancement group ( $p=0.031$ ;  $p<0.05$ ).

Maxillary superior repositioning and forward movement might result in an upward movement of the nasal tip and an expansion of the alar base.<sup>109</sup> No matter the degree of maxillary advancement or the location of the impaction (anterior or posterior), consistent changes were observed in the tip of the nose, nasal breadth, and upward nasal rotation. A change in the location of the anterior nasal spine likely mediates this fact. Despite all of these facts, there were no changes in nasal tip projection or nasal length in our study, which contradicts previous research.<sup>12,17,108–110</sup>

According to Almuzian et al., the surgical impact on the shape and prominence of the nose tip in the sagittal plane was unimportant. However, there was a considerable rise in the forward direction for the projection of the subnasale and labiale superius following the surgery. Hence, in line with our discoveries, they determined that LeFort I maxillary advancement has a significant impact on the nasolabial soft tissue envelope, primarily in terms of its sagittal dimension; however, subnasale projection and labiale superius projection increased significantly in a forward direction after surgery.<sup>111</sup> The only significant change in the nostril width measurements was observed in the major advancement group, where an increase was observed on both the right and left sides, consistent with previous research.<sup>12,110</sup> Postoperatively, the vertical dimension remained constant, whereas the breadth of the nostrils exhibited a substantial rise. From a clinical perspective, the modified connection between the alar and columellar regions enhanced the lateral nostrils' visibility. This condition is caused by the combined effects of columellar caudal buckling, which occurs due to maxillary advancement, and alar retraction/upward rotation, which appears as a result of soft tissue degloving. Significantly, the breadth of the columella remained unchanged in the substantial advancement group, while the projection of the columella increased. These findings agreed with DeSesa's study<sup>16</sup>. However, columella height remained relatively constant across all groups, whereas it decreased in that study.

We discovered increased labiale superius projection in major and minor advancement groups. This finding aligns with the research conducted by Metzler, where

the projection of the upper lip showed a 50% increase in the overall mobility of the upper jaw.<sup>12</sup>

When comparing the alterations in the nasolabial region between two groups, one with an advancement magnitude of 1-5 mm and the other with an advancement magnitude of 5.5-10 mm, no statistically significant differences in measures were found. Based on our research, a 5 mm advancement will lead to the alterations mentioned above, which do not escalate directly with additional advancement.

Our research shows that as LeFort I advances, the changes in soft tissue become increasingly intricate in three dimensions, which was not previously fully understood through two-dimensional studies. Regarding the planning of future soft tissue prediction, our objective anthropometric analysis shows that changes in the anatomy of nasolabial soft tissue may be predicted and compared when maxillary advancements of up to 10 mm are made. A maxillary advancement threshold of 5 mm may not lead to substantial alterations in soft tissue in patients with Class III malocclusion.

Based on these discoveries, we advise conducting more investigations with bigger sample numbers to more precisely evaluate the alterations in nasal soft tissue resulting from the LeFort I advancement, considering factors such as age, sex, ethnicity, and other characteristics that can impact nasal soft tissue modifications. Identifying and quantifying the three-dimensional soft tissue response to LeFort I is crucial for optimizing the treatment strategy and achieving the desired cosmetic outcome. Furthermore, as previously said, this allows for effective patient guidance and the provision of intraoperative measures or future interventions in anticipation of unfavorable outcomes. Another possible limitation of the current imaging technique is comprehending the skeletal source of changes in soft tissues.

Further complicating variables for this investigation encompasses the lack of a control group, inaccuracies in the design and execution of the operational guidance, and alterations in the anatomical landmarks. Furthermore, conducting longitudinal follow-up studies would be valuable, considering the absence of evidence in the existing literature about the enduring consequences of these treatments. The variations in societal perceptions of beauty result in the potential impact of alterations in the nasal soft tissue on the aesthetic aspects of individuals from diverse racial backgrounds. Hence, the

surgeon must be aware of these alterations and duly apprise patients of their choices after the surgery. This study will provide more exact 3D strategizing, accurate anticipation of the result of surgery, and finally, the attainment of the most visually aesthetically pleasing outcomes.



## 6. CONCLUSION

Our study was conducted to evaluate the changes in the soft tissues of the nasomaxillary complex after LeFort I orthognathic surgery. Maxillary advancement with LeFort I release the nasolabial muscles and detaches the alar base from the underlying bone, resulting in changes in the nasomaxillary soft tissue. Therefore, LeFort I may induce various outcomes based on the amount of anterior movement, soft tissue characteristics, and the patient's growth pattern.

Based on this retrospective study's findings, the following conclusions were drawn:

- During a LeFort I advancement, significant and repeatable linear changes were seen in the minor and major advancement groups. These changes included increased alar width, alar base width, and labiale superius projection.
- The dimension of the nostril show reduced in both the minor and major progression groups.
- The reduction in the upper lip-E line measurement is much higher in the major advancement group compared to the minor advancement group.
- During the period from T0 to T1, the high-angle group had a significantly larger rise in the upper lip-E line and lip length measurements.
- The nasofrontal angle decreased significantly in the major advancement and the high-angle group.
- Following orthognathic surgery, the three-dimensional stereophotogrammetry device is an efficient, accurate, and powerful tool for assessing alterations in the nasomaxillary region without any radiation exposure to the patient.

A limitation of our study was the relatively small sample size. This limitation may have resulted in a less apparent variance among the data subgroups. Subsequent studies may be focused on examining the impact of age, gender, and ethnicity and the presence or absence of craniofacial syndromes and a variety of skeletal movements and, most of all, may be investigated in a larger data group. Enlarging the sample size and more than six months of continuous follow-up of these changes could provide a better understanding of the transformation of the nasomaxillary soft tissue. This objective 3D

comprehension will facilitate precise planning and aid in optimizing final aesthetic results.

The null hypothesis is not supported. After orthognathic surgery, significant changes would be expected in the soft tissue of the nasomaxillary complex in terms of angular, linear, and perimetric measurements.



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## 8. APPENDICES

### 8.1. Ethical Approval



T.C.  
MARMARA ÜNİVERSİTESİ  
Sağlık Bilimleri Fakültesi  
Girişimsel Olmayan Klinik Çalışmalar Etik Kurulu

PROJENİN ADI : "Maksiller İlerletme Sonrası Nasomaksiller Kompleksin 3 Boyutlu Değerlendirilmesi"  
PROJENİN YÜRÜTÜCÜSÜ : Prof. Dr. Didem NALBANTGİL  
PROJEDEKİ ARAŞTIRICILAR : Pınar SAYIN  
ONAY TARİHİ VE SAYISI : 29.12.2022/149

Sayın: Prof. Dr. Didem NALBANTGİL

"149" protokol numaralı "Maksiller İlerletme Sonrası Nasomaksiller Kompleksin 3 Boyutlu Değerlendirilmesi" isimli projeniz Fakültemiz Etik Kurulu tarafından incelenmiş ov birliği ile etik yönden uygun olduğuna karar verilmiştir.

Prof. Dr. Mehveç TABİM  
Etik Kurul Başkanı



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## 8.2. Curriculum Vitae

### Kişisel Bilgiler

|     |       |        |       |
|-----|-------|--------|-------|
| Adı | Pınar | Soyadı | Sayın |
|     |       |        |       |

### Öğrenim Durumu

| Derece        | Alan          | Mezun Olduğu Kurumun Adı         | Mezuniyet Yılı |
|---------------|---------------|----------------------------------|----------------|
| Doktora       | Ortodonti     | Yeditepe Üniversitesi            | 2024           |
| Yüksek Lisans | Diş Hekimliği | Yeditepe Üniversitesi            | 2018           |
| Lisans        | Diş Hekimliği | Yeditepe Üniversitesi            | 2018           |
| Lise          | -             | Özel Saint Joseph Fransız Lisesi | 2013           |

| Bildiği Yabancı Dilleri | Yabancı Dil Sınav Notu (#) |
|-------------------------|----------------------------|
| Fransızca               | B2                         |
| İngilizce               |                            |

# Başarılmış birden fazla sınav varsa (KPDS, ÜDS, TOEFL; EELTS vs), tüm sonuçlar yazılmalıdır