

Accuracy of 3 Soft Tissue Prediction Methods After Double-Jaw Orthognathic Surgery in Class III Patients

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Purpose: We aimed to evaluate the accuracy and validity of conventional manual prediction method (CM) and 2-dimensional and 3-dimensional (3D) soft tissue prediction methods for Class III bimaxillary orthognathic surgery patients.

Methods: Twenty skeletal Class III patients were included in this study. Soft tissue prediction was achieved with a traditional manual technique, 2-dimensional software (Dolphin Imaging, version 11.5), and 3-dimensional software (SimPlant Master, version 16.0) on preoperative lateral cephalometric radiographs and cone beam computerized tomography (CBCT) images and then compared with postoperative lateral cephalometric radiographs obtained at least 6 months after surgery (mean, 11.5 ± 6.77 months). Forty-eight measurements were done to determine the reliability of the methods.

Results: All prediction methods have limited postsurgery prediction accuracy for the subnasal upper lip area. Most of the differences were not more than 3 mm for all study groups, except the 3D software, which predicted the upper lip area to be, on average, 3.08 ± 1.38 mm further back ($P < 0.001$). Although the conventional method predicted 20 of 48 measurements similar to the final results, the poorest predictions were found at the nasal and labiomental areas ($P < 0.001$). Two-dimensional software predicted 23 of 48 measurements very close to the final results but made significantly different predictions for the nasolabial and labiomental angles, labrale superius point, and the chin area.

Conclusions: The 3D method predicted, especially the upper lip area, to be significantly and clinically incorrect, and its soft tissue prediction was insufficient compared with the other 2 methods. The 3D software needs to be updated, especially in evaluating soft tissue A point and upper lip changes after surgery.

Key Words: orthognathic surgery, maxillo-mandibular surgery, facial aesthetic, 3D imaging, orthodontics

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For patients with severe skeletal and dental dysplasias, combined orthodontic-orthognathic surgical treatment is needed when orthodontic treatment alone is limited. Orthognathic surgery corrects dentofacial deformity and skeletal and dental irregularities and also restores the masticatory function. Severe malocclusions are associated with aesthetic impairment, functional problems, temporomandibular joint, and orofacial pain.¹ Accurate surgical planning and postoperative soft tissue prediction are so important for the craniofacial skeleton and masticatory muscle physiology and biomechanics. Also, the prediction achieved closest to surgical outcomes can allow the orthodontist to do accurate treatment planning and eliminate the patient's aesthetic concerns after orthognathic surgery. Optimal dental occlusion is the primary goal of therapy with traditional treatment, whereas, in the soft tissue-based treatment approach, normal

ratios and the adaptation of soft tissues are the primary objectives of the treatment.²

After orthognathic surgery, the predictability of soft tissue changes is difficult.³ Various hand tracing methods and software have been developed and used for the soft tissue prediction of surgical outcomes. Because 2-dimensional prediction can be made on lateral cephalometric radiographs, recently released 3-dimensional (3D) software also provides predictions using computerized tomography images. The popularity of this 3D software has increased nowadays, and it is used by orthodontists or maxillofacial surgeons more than the conventional manual prediction method (CM).⁴

This study aimed to determine the validity and reliability of the CM, 2-dimensional (2D) computerized method, and 3D computerized method for predicting the soft tissue profiles of patients who underwent double-jaw surgery (maxillary advancement with mandibular setback surgery).

MATERIALS AND METHODS

The sample consisted of 20 patients (10 women and 10 men, skeletal class III) who met the following criteria:

- No congenital anomaly
- Cervical vertebrae maturation indicators 6 completion stage for cervical spine maturation assessment
- No previous history of orthodontic treatment or orthognathic surgery
- All patients must be treated with bimaxillary surgery, including maxillary advancement by Le Fort I osteotomy (no maxillary impaction) and mandibular setback by bilateral sagittal split osteotomy (BSSO), without any additional surgical procedures (eg, genioplasty, malar augmentation, rhinoplasty)
- All cephalograms must be taken by the same operator at the same machine, taken just before the surgery and at least 6 months after orthognathic surgery in the natural head position with teeth in centric relation and relaxed lip posture with a clear shadow of the soft tissue (no artifacts).

Ethics committee approval was obtained from the Noninvasive Clinical Research Ethics Committee at Nevşehir Hacı Bektaş Veli University. The same orthodontic treatment protocol was used in all cases included for this study, and double-jaw surgery was achieved for all individuals by the same surgery team. Le Fort I osteotomy was done for maxillary advancement, and BSSO was used for the mandibular setback. The postsurgical orthodontic treatment was continued 4 weeks on average after the surgery.

Cephalometric Superimposition and Measurements

The lateral cephalometric radiographs were taken by the same operator on the same machine at immediate preoperative (2–4 days before surgery for surgical planning) and the posttreatment period (after the removal of fixed orthodontic appliances, at least 6 months after surgery; 11.5 ± 6.77 months on average) at the natural head position with teeth in centric relation and relaxed lip posture with a clear shadow of the soft tissue (no artifacts).

After the maxilla movement and mandible movement in the sagittal and vertical directions were determined, the predictions were made in 3 different ways: CM, 2D, and 3D prediction methods. The Frankfort horizontal plane was taken as the horizontal reference line (HRL), and

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the perpendicular to the HRL through the Porion point was taken as the vertical reference line. These reference planes were used as guides for measuring the projected distances of the reference landmarks (Fig. 1).

After maxillary movement and mandibular movement were determined using Björk's structural and local superimposition methods,^{5,6} the predicted profiles were created in 3 different protocols, and the cephalometric measurements after soft tissue prediction were compared with the actual final profile. Forty-eight measurements were made to determine the reliability of the methods. Thirty-eight of these measurements were linear (Fig. 1), 6 were angular (Fig. 2), and 4 were proportional. The presurgical profile and profile prediction photographs after 3 different prediction methods and actual postsurgical outcomes of female and male patients are shown in Figures 3 and 4.

Conventional Manual Prediction Method

The template method was used as a CM. Soft tissue prediction was achieved using the presented values of Epker et al⁷ and Proffit et al.⁸ The soft-to-hard tissue ratios used for CM are presented in Supplemental Digital Content, Supplementary Table 1 (<http://links.lww.com/SAP/A665>).

Two-Dimensional Computer-Assisted Prediction Method

Dolphin Imaging software (version 11.5; Dolphin Imaging and Management Solutions, Chatsworth, CA) was used as 2D computer-assisted prediction method. After the digitization of the landmarks to the analysis program, they were transferred to the simulation system (the software's visual treatment object). The software was then used to

superimpose the profile pictures taken pretreatment with digitally traced soft tissue landmarks of the pretreatment cephalometric radiograph. Dental landmarks were also traced and superimposed to account for orthodontic movements during treatment. Finally, the software generated a prediction profile photograph. This image was compared with the actual patient posttreatment profile photograph taken at least 6 months after surgery. In treatment simulation, the option “Le Fort I” was selected for maxillary movements, and option “BSSO” was selected for mandibular movements. After the maxillary and mandibular movement values were obtained by cephalometric superimpositions for each patient, these measures were entered into the system, and the prediction profiles were automatically realized by the software. We performed our measurements on this prediction profile.

Three-Dimensional Computer-Assisted Prediction Method

SimPlant Master software (version 16.0; Materialize, Leuven, Belgium) was used as 3D computer-assisted prediction method. In the SimPlant prediction method, cone beam computerized tomography (CBCT) images of our patients take on the routine records before the surgery were used. All CBCT images were taken in the standard position (patient in the supine position and with teeth in centric relation and relaxed lip posture) using the same device (Newtom VG; QR, Verona, Italy). For CBCT images, once the images are acquired, the Digital Imaging and Communications in Medicine (DICOM) files were imported into the 3D image analysis software. Next, in a process known as image segmentation, we identified and delineated the anatomical structures of interest in the CBCT image. In orthodontics and

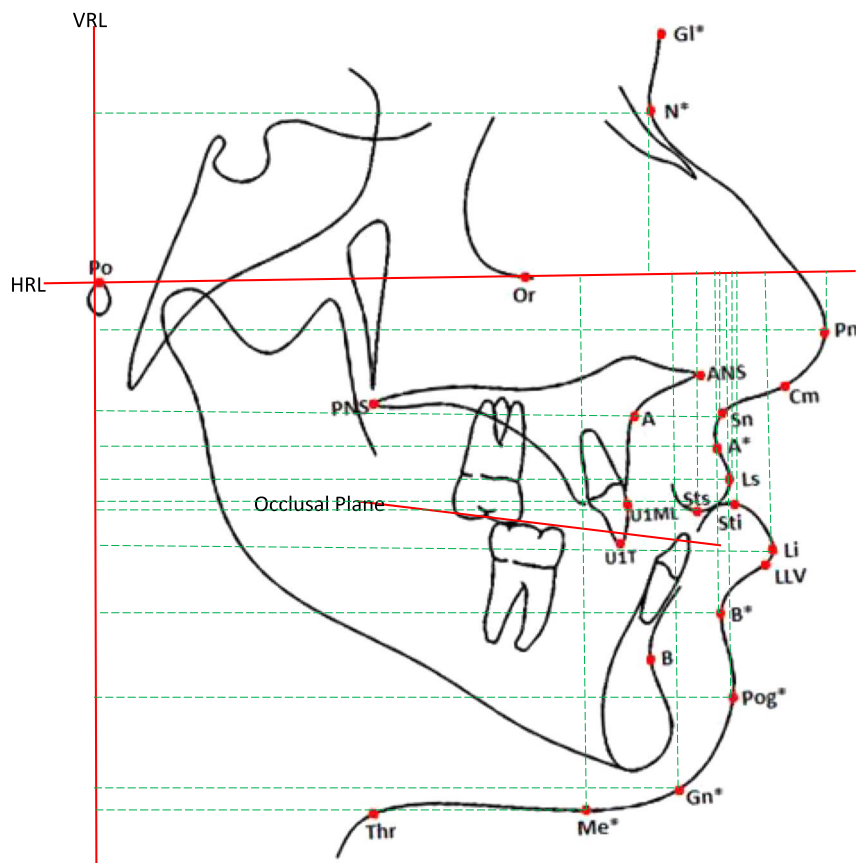


FIGURE 1. The anatomical landmarks (red points), reference lines, and linear measurements between HRL-VRL and soft tissue points (intermittent green lines). VRL, vertical reference line. full color online

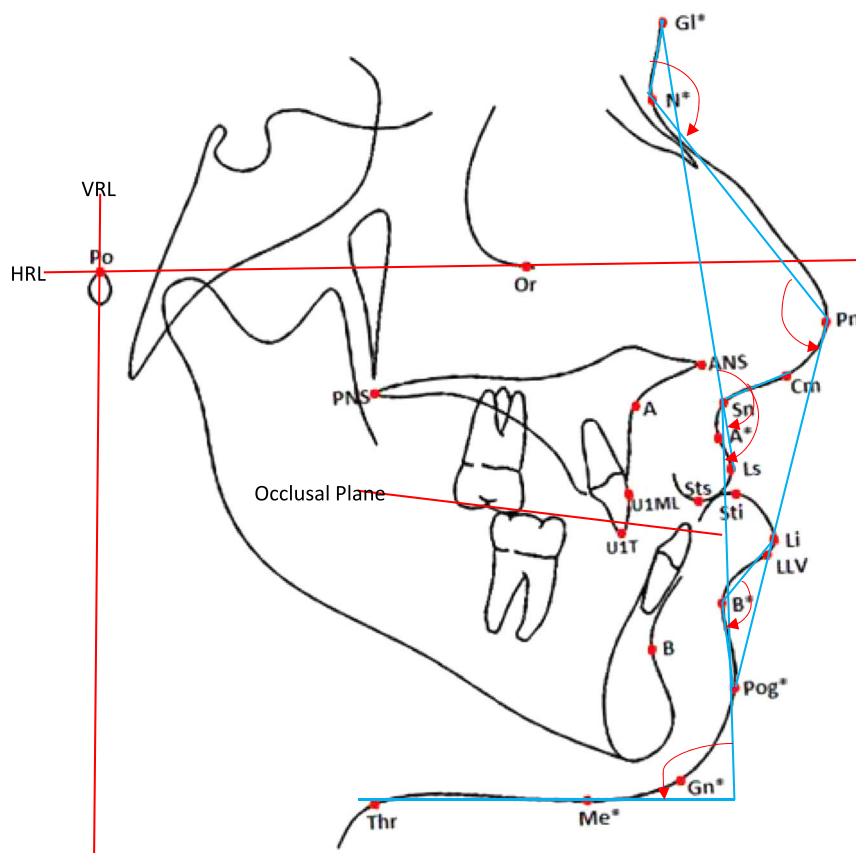


FIGURE 2. Angular measurements (the angles between the blue lines) (1, nasal angle: the angle between the GI*, N*, and Pn points; 2, nasolabial angle: the angle between the Sn, and Ls points; 3, labiomental angle: the angle between the Li, B*, and Pog* points; 4, soft tissue convexity angle: the angle between the N*, Pn, and Pog* points; 5, lower lip-chin-throat angle: the angle between the Sn-Pog* and Me*-Thr points; and 6, facial convexity angle: the angle between GI*, Sn, and Pog* points). GI* indicates Soft tissue Glabella point; N*, Soft tissue Nasion point; Pn, Pronasale: Tip of nose; Cm, Columella point; Sn, Subnasale point; Ls, Labrale superius; Li, Labrale inferius; B*, Soft tissue B point; Pog*, Soft tissue pogonion point; Me*, Soft tissue menton point; Thr, Throat point. [full color online](#)

orthognathic surgery, segmentation aims to obtain a 3D representation of the hard and soft tissues that are usable for virtual planning. The stages of the SimPlant prediction method are as follows: (a) the process of obtaining a 3D mask of hard and soft tissues in the “preparation” part of the SimPlant; (b) making surgical incisions (Le Fort I surgery was chosen for the maxilla, and BSSO for the mandible); and (c) the soft tissue prediction stage (for this purpose, in the simulation panel, first, the hard tissue fragments reproduced according to their new positions were selected, and second, after selecting, the soft tissue mask was obtained at the beginning of the soft tissue simulation).

Statistical Analysis

The compliance of the data with normal distribution was analyzed with histogram, q-q graphics, and Shapiro-Wilk test. In comparing prediction methods, dependent 2-sample *t* test was used, and for the repeated measurements, 1-way variance analysis was used. Multiple comparisons were performed using the Bonferroni test. In evaluating the compliance between methods, intraclass correlation coefficients (ICCs) were calculated with 95% confidence intervals. Data analysis was evaluated by R 3.1.1 software (www.r-project.org). $P < 0.05$ significance level was adopted.

Method Error

All measurements were performed by the same researcher (K.K. D.). To determine method error, half of all material was evaluated again

3 weeks after the completion of all drawings and measurements. The ICC was used to determine the method error of the measured values. Correlation coefficients *rs* were calculated by comparing the first and second measurements. Intraclass correlation coefficient determined in all measurements was found close to the value 1.00 (0.981–1.00). According to this, it was observed that the measurements of all 3 methods used in our study could be repeated with an insignificant error that would not affect the results, and the points determined were highly reliable points for repeatability.

RESULTS

The patients included in the study were evaluated in terms of age, sex, and maxillary and mandibular movements, and it was determined that the data showed a homogenous distribution in terms of these characteristics. Ten males and 10 females were included in our study, and the mean $\pm$ SD age was 24.89 ± 9.20 years for males and 22.47 ± 4.40 years for females in the T0 period. After orthognathic surgery, the average sagittal advancement in the maxilla is 5.09 ± 1.44 mm. There was no change in the maxilla in the vertical direction because the maxillary impaction or down fracture was not applied. The mandible moved an average of 4.19 ± 2.39 mm backward in the sagittal direction and 1.15 ± 0.63 mm upward in the vertical direction. The change in the vertical direction of the mandible is thought to be related to changing occlusal relationships. Within-group distribution in terms of age, sex, and average maxilla and

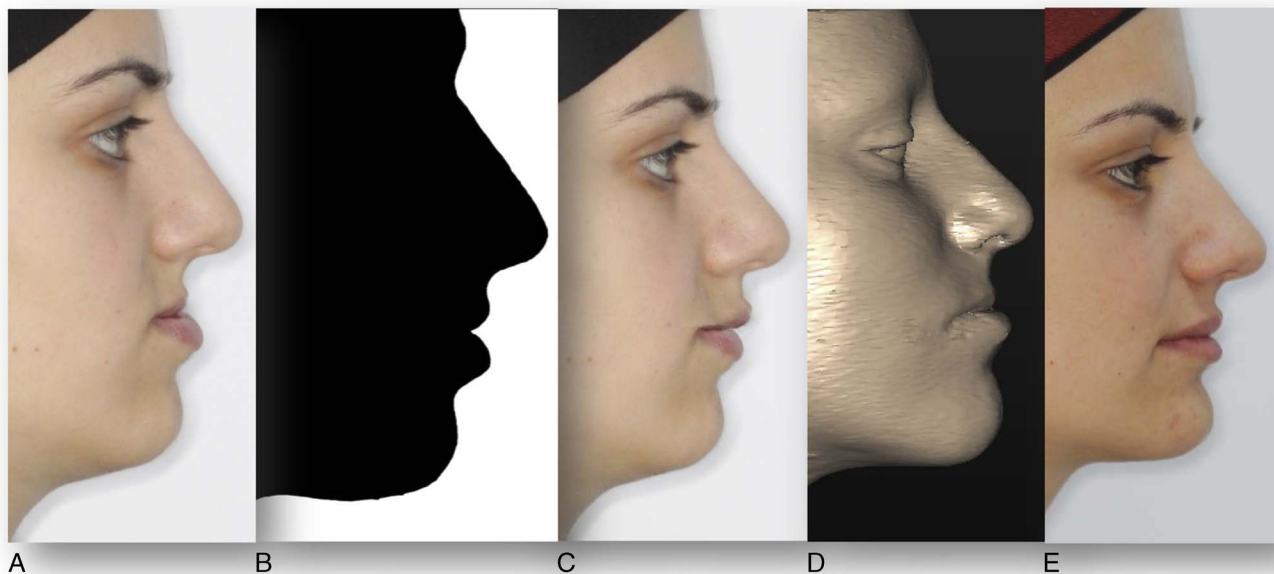


FIGURE 3. (A) Preoperative profile, (B) conventional prediction, (C) 2D prediction, (D) 3D prediction, and (E) postoperative profile of a female patient in this study. [full color online](#)

mandible movements is presented in Supplemental Digital Content, Supplementary Table 2 (<http://links.lww.com/SAP/A665>).

In evaluating the ICC, in which the compliance of the methods with the actual results was evaluated on an individual basis, it was observed that the 3 methods showed high compliance with the final results in many linear measurements (ICC, 0.981–1.00). The lowest correlation coefficient value was seen in the upper lip thickness measurement ($r_s = 0.981$). It was determined that, in proportional (ICC, 0.524–0.967) and angular measurements (ICC, 0.759–0.963), according to linear measurements, a lower correlation was observed. The lowest correlation values were observed in the 3D prediction method.

The Comparison of Soft Tissue Measurements of the Upper Face

The comparison of the prediction methods and postsurgery results of the upper face is presented in Supplemental Digital Content, Supplementary Table 3 (<http://links.lww.com/SAP/A665>). For the nasal measurements, 2D was found more successful in comparison with the 2 other prediction methods. The nasolabial angle was measured by the 3 methods that differ from the actual final results. The CM and 2D predicted the upper lip to be thicker, and the 3D program predicted it to be, on average, 1.87 ± 0.90 mm thinner.

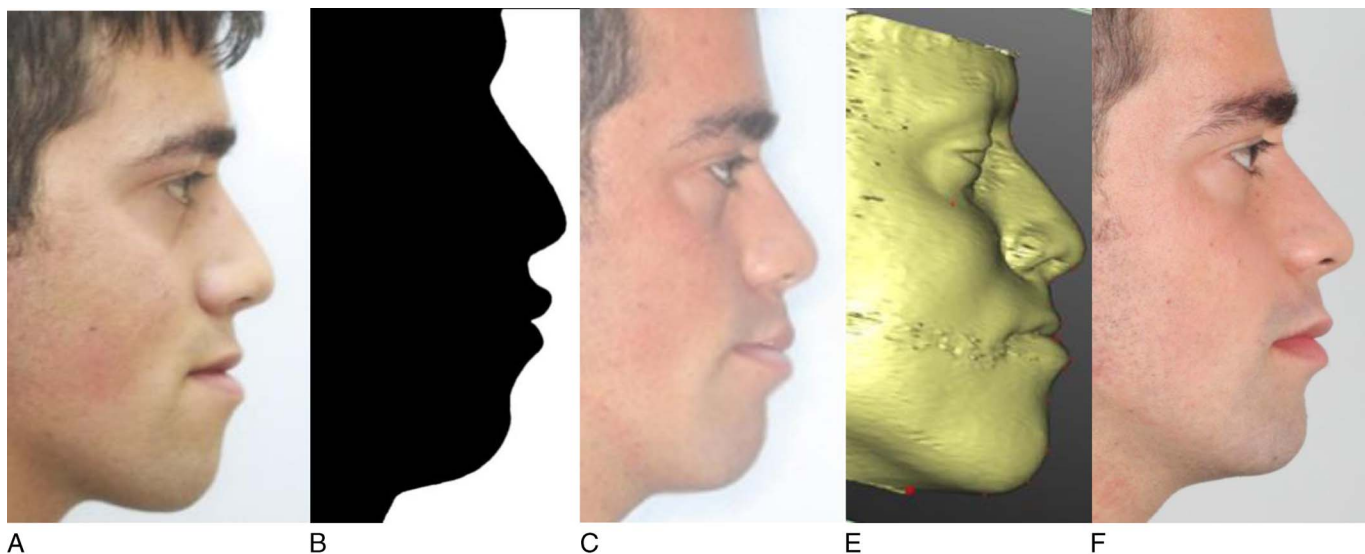


FIGURE 4. (A) Preoperative profile, (B) conventional prediction, (C) 2D prediction, (D) 3D prediction, and (E) postoperative profile of a male patient in this study. [full color online](#)

Whereas 2D correctly predicted soft tissue A* point in sagittal and vertical planes, the CM predicted it to be 1.11 ± 1.31 mm above and 3D predicted it to be, on average, 3.08 ± 1.38 mm further back, and this difference is statistically significant ($P < 0.001$).

Compared with the actual final results, the CM predicted labrale superius point (Ls) point to be 0.79 ± 1.39 mm above on average, the 2D method predicted it to be 1.12 ± 1.41 mm further on average, and the 3D method predicted it to be 3.06 ± 1.42 mm backward on average ($P < 0.05$).

The Comparison of Soft Tissue Measurements of the Lower Face

The comparison of the lower face prediction methods and postsurgery results is presented in Supplemental Digital Content, Supplementary Table 4 (<http://links.lww.com/SAP/A665>). All 3 methods' lower lip length was predicted to be statistically significantly different from the actual final results ($P < 0.05$). The 3D method correctly predicted stomion inferius point in sagittal and vertical planes, but the CM predicted it to be 1.16 ± 1.33 mm below, and 2D predicted it to be, on average, 0.73 ± 1.44 mm below, and this difference is statistically significant ($P < 0.05$). Whereas 2D and the CM correctly predicted the thickness of the lower lip, 3D predicted the lower lip to be, on average, 0.90 ± 1.20 mm thinner.

The labiomental angle was predicted by the 3 methods with the biggest error. Two-dimensional measured the labiomental angle to be 13.05 degrees higher on average, the CM measured it 15.52 degrees higher on average, and 3D measured it 18.49 degrees higher on average ($P < 0.05$).

Total Face Measurements

The comparison of the 3 prediction methods and postsurgery results of total face measurements is presented at Supplemental Digital Content, Supplementary Table 5 (<http://links.lww.com/SAP/A665>). A comparison of soft tissue prediction measurements between the 3 groups is presented in Supplemental Digital Content, Supplementary Table 6 (<http://links.lww.com/SAP/A665>). Soft tissue convexity angle was measured similarly to the actual final results by the 3 prediction methods ($P > 0.05$). Whereas the facial convexity angle was predicted by 3D and 2D, similar to the actual final results, the CM predicted it to be, on average, 2.82 ± 3.12 degrees smaller depending on its prediction of Soft tissue pogonion point (Pog*) point further back.

Whereas 3D predicted Lip-Chin-Throat angle 4.20 ± 6.43 degrees smaller than the actual results depending on its prediction of Subnasale (Sn) point further back, the other methods measured it similar with the final results.

The only method that predicted the upper to lower face height ratio, similar to the actual final results, was 2D ($P = 0.349$). The CM and 3D method measured this ratio bigger than the final results. Although the 3 methods measured the ratio of Subnasale-Lower lip vermilion distance to Lower lip vermilion-Soft tissue Menton distance ratio similarly among themselves ($P > 0.05$), they made different predictions from the actual final results ($P < 0.05$).

DISCUSSION

One of the most important factors affecting the success of the treatment in surgical cases is the stage of surgical planning. Many software have been developed to predict orthognathic surgery, and some studies showed that soft tissue predictions made with computer software do not always fully comply with the actual outcome.^{9–12} The main aim of this study was to evaluate the reliability of postorthognathic surgery soft tissue prediction by CM, 2D, and 3D methods in skeletal class III cases treated with maxillary advancement, mandibular setback surgery. To eliminate the effect of growth on the prediction of treatment results,

mature patients were included in our study, and maturity was determined by cervical vertebrae maturation indicators method.¹³

In the literature, the importance of homogeneity of the study sample has been presented.^{10,11,14–16} The investigation of various skeletal malocclusions in one study may also lead to incorrect results.^{15–17} Therefore, the cases with the only type of malocclusion (skeletal class III) were included in our study. The type of skeletal malocclusion was determined in the cephalometric analysis performed, and the patients with the angle between hard tissue A, hard tissue Nasion and hard tissue B point angles smaller than 0 degrees were included in the study. Malar augmentation, rhinoplasty, and other adjunctive surgical procedures were not used for the sample of our study, which can negatively affect the formed soft tissue prediction profile.^{10,15,18–20} In studies using cephalometric measurements, various reference planes were used to examine vertical and horizontal changes.^{1,20–29} Frequently used ones among these planes are Sella Nasion plane or the plane ± 7 degrees angled to this plane^{10,11,19,20,24,25,30–33} and Frankfort horizontal^{9,15,34} as the horizontal reference plane, and the planes drew from Nasion or Sella point to these planes as the vertical plane.^{9,10,15,19,24,25,30,32,34} Frankfort horizontal was selected as an HRL, and the perpendicular to the HRL through the Porion point was taken vertical reference line. The reason for choosing internal reference lines was to provide standardization in 2D and 3D prediction methods.

Two-dimensional method predicted the nasal tip most accurately. Similarly to the results of our study, Ahmad Akhoundi et al²⁵ stated that the nasal tip was predicted most accurately by Dolphin Imaging (version 10), the CM predicted the nasal tip in 77.5% of the cases in the horizontal plane and 82.5% of the cases in the vertical plane with a different range between -1 and 1 mm, and the CM remained insufficient in the prediction of the nasal tip. However, Nadjmi et al³⁵ concluded that the greatest errors were related to pronasale, gnathion, menton, and stomion superior at the sagittal direction for Dolphin Imaging (version 10). The reason of differences for pronasale measurement may be related to the limited sample size (13 patients) and the evaluation of cases undergoing single and double-jaw surgery in the same group. In addition, Nadjmi et al³⁵ obtained postoperative records 4 months after surgery, in which edema on the soft tissues after surgery may still be a period in which the effect does not fully pass.

The nasolabial angle prediction of the 3 methods was different from the actual results. Our study evaluated the nasolabial angle as the angle between Columella point, Subnasale point, and Labrale superius points. The main reason for this significant difference in 2D software depends on the prediction of Ls point more anterior than the actual results. Because the 3D method predicts the Ls point further back, it measured the nasolabial angle greater than the final results. Similarly, Aboul-Hosn Centenero et al³⁶ stated that SimPlant Master method was insufficient in the prediction of the nasolabial angle, and there was a significant difference between the final results. Similarly, Nadjmi et al,³⁵ in their study investigating the reliability of 2D Dolphin Imaging and 3D Maxilim programs in soft tissue prediction, reported that both methods made incorrect predictions in nasolabial and mentolabial angles; the prediction error in Dolphin software was 9 degrees, and this difference was clinically significant.³⁵

Whereas 2D software correctly predicted soft tissue A* in the sagittal and vertical planes, CM predicted it to be, on average, 1.11 mm further above. Three-dimensional software predicted A* point to be, on average, 3 mm posteriorly. Ahmad Akhoundi et al²⁵ found that soft tissue A* point was predicted by Dolphin and CM more correctly in the vertical dimension compared with the horizontal dimension.

Two-dimensional software predicted Ls anteriorly, and 3D predicted it more posteriorly (on average, 3.06 mm). Conventional method predicted the Ls point further above. Similar to the results of our study, Lu et al³⁷ reported that the upper lip was predicted by Dolphin (version 6), on average, 0.8 mm in front and 1.7 mm at below. Unlike the results of our study,

Kolokitha⁴ reported that the upper lip was positioned more in front of the predictions made by the CM. However, it can be considered that this different result was originated from the predicted patients who underwent only class III single jaw (mandibular setback) surgery.

Among the 3 methods, 2D software made the most accurate predictions (23 of 48 measurements are similar to the actual final results), then the CM (20 of 48 measurements are similar to the actual final results), and the last one is 3D software (16 of 48 measurements are similar to the actual final results) when compared with the actual final results. The main disadvantage of the CM in comparison with other methods is its difficult application. Whereas predictions made by the 2 other methods take an average of 10 minutes for 1 patient, the CM takes the period close to about 1 hour. The CM does not require a high cost as other programs, and it allows the application of soft-hard tissue ratios of all types required during the prediction and making an “artistic drawing” in the lips’ area. However, while making the prediction, it is required to evaluate each patient’s lower lip and chin area in a specific and detailed manner. When compared with 3D systems, both CM and 2D prediction method have insufficiencies. Three-dimensional prediction method has the advantage of being able to diagnose from all directions (anteroposterior, inferior-superior), so especially in facial asymmetry cases, 3D systems have superiority.³⁸ Three-dimensional systems also allow to produce 3D printing splints for orthognathic surgery that can reduce operative time and improve postoperative recovery.³⁹ Three-dimensional surgical planning is very suitable for new developments to be added to the system, such as it is complemented intraoperative navigation.⁴⁰ Its main disadvantages are the cost of the software, that CBCT contains a higher radiation dose compared with lateral cephalometric films, and that preoperative preparation is longer than 2D software.³⁹

Compared with other prediction methods, we observe that the SimPlant method was less successful than the other 2 methods for soft tissue prediction. SimPlant Master evaluated, especially the upper lip area, more posteriorly and needs new updates of soft tissue prediction. Similar to the results of our study, Aboul-Hosn Centenero et al³⁶ stated that SimPlant system did not show sufficient reliability in soft tissue prediction. They reported that linear measurements in the bone structures gave more accurate results than angular, dental, and soft-tissue measurements, and the software did not give accurate prediction results, especially in the soft tissue area.

In 3D prediction methods, it is impossible to predict soft tissue changes following skeletal tissue by direct formulation or continuous equations and soft-to-hard tissue ratios like CM because of various geometric complexities. There are different methods developed for this purpose. Purely geometrical models, multilayer mass-spring models (MSMs), finite element models (FEMs), and mass tensor models (MTMs) are these methods.⁴¹ The most common prediction programs are based on MSMs, MTMs, and FEMs. SimPlant uses MSM and MTM methods that discretize objects into masses and springs, with relatively little computational time required to simulate the surgery, thus making them suitable for clinical applications; the disadvantages are that the lack of a biomechanical basis-spring constant has no direct correlation to material properties, and volume conservation of the soft tissues cannot be modeled. Finite element model relies on discretized objects and also represents mathematically defined subdivisions of a continuum problem; thus, properties can be assigned to each element. These features make FEM biomechanically relevant, reliable, and accurate but also incur high computational costs.⁴² The other possible reason for the increased prediction errors is that the 3D software program was based on Whites and was used with no ethnic modification, although ethnic differences affect the soft tissue movement in orthognathic surgery. This may have caused more errors in predictions in Asians. Thus, more studies on soft tissue prediction methods are needed to provide better algorithmic data.³⁸ A 3D software that can be modified according to ethnic differences and allows manual osteotomy lines can be developed.

It should be accepted that there are some limitations to our study. In this study, we compared the CM and 2D and 3D prediction methods

of different programs. Currently, these 3 methods are used to predict orthognathic surgery patients in our faculty, but it is very difficult to evaluate 2D and 3D methods in the same standardization. In addition, the CBCT images used in our study were taken in the supine position. Although the supine patient position in the computerized tomography scanner may lead to altered soft tissue conditions⁴³ to ensure that the soft tissues are affected minimally from this position, CBCT images were taken.

In contrast, the teeth positioned in centric relation similar to the lateral cephalograms. In future studies, it can be considered to evaluate 2D and 3D prediction of the same program, or different 3D prediction methods can be evaluated. In addition, although the sample size is similar to other articles in the literature, it will be useful to conduct further studies with a high number of cases. One of the reasons for our limited sample size is our inclusion criteria, and also, we want to create a homogeneous study group. By increasing the number of cases, the evaluation of prediction methods in different types of surgery can also be evaluated.

When the reliability of the prediction methods between the sexes was compared, there was no difference between the groups, so the data belonging to men and women were collected in a single group. To determine the reliability of these prediction methods depending on variables such as the amount of movement in the maxilla or mandible and age, which are among the other parameters in our study, further studies are needed with a higher number of samples.

Many researchers in the literature remark that prediction errors not exceeding 3 mm are not clinically significant.^{1,19,29,44} In our study, inaccurate predictions exceeding 3 mm were made only by the 3D prediction method. These inaccurate predictions were in the upper lip area. In the literature, soft tissue predictions achieved by traditional methods and computer software were evaluated and concluded that no prediction method could predict each point in such an excellent way for it to be the same as the treatment result.^{9–11,14–19,29,30} To make an ideal prediction of the final appearance and the treatment success, overbite, and overjet degree, the presence or absence of lip seal, contraction, or tension degree in muscles, subcutaneous tissues, skin tissue, and ethnic differences must be taken into account before surgery.⁴⁵ According to the findings of our study:

1. Whereas the prediction made by the CM subnasal area, Ls and Soft tissue Menton (Me*) point, soft tissue convexity, and LCT angle were predicted with the high reliability, the nasal tip, Soft tissue Pogonion point (Pog*) and Soft tissue Gnathion point (Gn*) points, facial convexity, labiomental and nasolabial angles were predicted inaccurately.
2. The application time of CM is longer than the other 2 methods and lasts about 1 hour. Its visualization ability is very limited compared with other methods (it only offers a black and white profile image that restricts preoperative patient communication).
3. Two-dimensional Dolphin Imaging method made high reliable predictions in the measurements of the nasal tip, A* point, Labrale inferius (Li) point, LCT angle, soft tissue, and facial convexity angle, upper and lower face height, and it made inaccurate predictions of the nasolabial and labiomental angle, Ls point and in the chin area.
4. The 3D SimPlant Master method predicted, especially the upper lip area, to be significantly and clinically backward.
5. In 3D SimPlant Master software, it is necessary to make new computational strategies in which racial and individual differences will be taken into consideration for soft tissue prediction.
6. The accuracy of current prediction methods still requires further improvement in clinically critical regions, especially for the lips. New computational strategies for 3D prediction methods such as realistic lip sliding effect and probabilistic finite element modeling can improve the prediction accuracy in the area around the lips. For 2D soft tissue prediction programs, new algorithms and equations can be developed taking into account the individual differences (age, sex, race, soft tissue thickness, movement amounts of the jaws).

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