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Soft to hard tissue ratios after bimaxillary orthognathic surgery in class III patients

İskeletsel sınıf III ortognatik cerrahi hastalarında çift çene cerrahisi sonrası yumuşak – sert doku takip oranları

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ABSTRACT

Objective: The aim of this study was to assess the changes of facial soft tissue profile and determine the soft to hard tissue ratios, and develop a new mathematical formulation between hard and soft tissues for two dimensional simulation systems in Class III patients.

Methods: Twenty skeletal Class III patients were included in this study. Preoperative (T0) and posttreatment (T1) cephalometric variables were assessed on lateral cephalograms. Method error was determined by redigitizing 10 patients' measurements 3 weeks after initial digitization. Presurgical and postsurgical cephalometric measurements were compared with dependent two-sample t-test and statistical significance set at $P < .05$.

Results: Our material was homogeneous in terms of gender and maxillary and mandibular movement. In the maxilla the soft to hard tissue ratios were as follows; 23% for the tip of the nose, 45% for Sn, 70% for A*, and 60% for Ls. Sagitally, the soft to hard tissue ratios for mandible were; Li 77%, B* 101%, Pog* 83%, 81% for Gn*, and 95% for Me*point. According to the results, it was found that the soft tissue B point (B*) moved equally with the mandible (101%), and the tip of the nose (Pn) is the soft tissue point that was least affected by the movement of the underlying skeletal structure (0.23%).

Conclusion: The significant improvement in facial profiles of skeletal Class III orthognathic surgery patients after maxillary advancement and mandibular setback surgery is primarily related to the backward movement of the mandible. The correlation between soft and hard tissues in the mandible is higher than in the maxilla. As a result of our study, new formulations and soft to hard tissue ratios were developed for 2D prediction methods.

Key words: Soft to hard tissue ratios, bimaxillary surgery, profile changes

ÖZ

Amaç: Bu çalışmada, çift çene cerrahisi geçirmiş iskeletsel Sınıf III hastalarda yumuşak doku profilindeki değişiklikleri değerlendirmek ve yumuşak-sert doku takip oranlarını belirleyerek iki boyutlu simülasyon sistemleri için bir formülasyon oluşturmak amaçlanmıştır.

Yöntemler: Bu çalışmaya 20 iskeletsel Sınıf III hasta dâhil edilmiştir. Ameliyat öncesi (T0) ve ortodontik tedavi bittikten sonra (T1) sefalometrik değişkenler lateral sefalogramlarda ölçülmüştür. Yöntem hatası, ilk ölçümlerden üç hafta sonra on hastanın ölçümlerinin yeniden tekrarlanmasıyla belirlenmiştir. T0 ve T1 sefalometrik ölçümlerini karşılaştırmak için bağımlı iki örneklem t-testi kullanılmış ve istatistiksel anlamlılık $P < .05$ olarak belirlenmiştir.

Bulgular: Bireylerin cinsiyet, maksiller ve mandibular hareket açısından homojen dağılım gösterdiği belirlenmiştir. Sagital düzlemde maksilla için yumuşak-sert doku takip oranları; Burun ucu için %23, Subnasale için %45, yumuşak doku A* noktası için %70 ve üst dudak en ön noktası (Ls) için %60 olarak bulunmuştur. Mandibulada sagital düzlemde yumuşak-sert doku takip oranları ise; alt dudak en ön noktası (Li) için %77, yumuşak doku B* noktası için %101, yumuşak doku Pogonion* noktası için %83, yumuşak doku Gnathion* için %81 ve yumuşak doku Menton* noktası için %95 olarak bulunmuştur. Burun ucu alttaki iskelet yapısının hareketinden en az etkilenen anatomik alan olurken (%23), yumuşak doku B noktası (B*) iskeletsel B noktası ile neredeyse eşit oranda hareket eden anatomik nokta olmuştur (%101).

Sonuç: Maksilladaki yumuşak ve sert doku arasındaki korelasyonun mandibulaya göre daha düşük olduğu ve çift çene ortognatik cerrahi hastalarının yüz profillerindeki belirgin düzelmenin öncelikli sebebinin mandibulanın geriye doğru hareketi ile ilgili olduğu bulunmuştur. Bu çalışma ile çift çene cerrahisi sonrası yumuşak doku değişikliklerini tahmin etmek için formülasyonlar ve yumuşak-sert doku oranları geliştirilmiştir.

Anahtar Kelimeler: Yumuşak-sert doku oranları, çift çene cerrahisi, profil değişiklikleri.

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INTRODUCTION

Orthognathic surgery treatment is frequently used to treat severe Cl III malocclusions. Although orthognathic surgery is a serious surgical intervention with postoperative side effects such as nausea, pain, vomiting, hematoma, etc. corrects dentofacial deformity, skeletal and dental irregularities and also restores the masticatory function.[1] Severe skeletal Class III malocclusions are often accompanied by functional and aesthetic problems. Skeletal Class III deformities caused by maxillary deficiency have been usually treated with double jaw orthognathic surgery.[2] Optimal dental occlusion is the primary goal of therapy with traditional treatment, while in soft tissue-based treatment approach, normal ratios and the adaptation of soft tissues are the primary objectives of the treatment.[3] Esthetics does not depend solely on the hard tissue, there are so many factors that can affect the surgery results, so the soft tissue-based treatment approach has become very popular in recent years. In many studies in the literature, soft tissue changes after orthognathic surgery have been tried to be determined. But some of these studies have evaluated different surgical procedures together. In this study different types of surgery and different malocclusion types were not evaluated together, also soft to hard tissue ratios and mathematical formulations were developed in Class III patients who had only maxillary advancement and mandibular setback surgery.

The aims of this study were;

1. Evaluation of the skeletal and soft tissue changes in skeletal Class III patients treated with double-jaw orthognathic surgery (Maxillary advancement with Le Fort I osteotomy, Mandibular setback with bilateral sagittal split osteotomy, BSSO),

2. Establishment of a ratio and formulation between soft and hard tissues for 2D simulation systems.

MATERIAL AND METHODS

The sample consisted of 20 patients who met the following criteria:

a- No congenital anomalies (cleft lip and palate, syndromes, etc.) or tumoral formation,

b- The presence of upper and lower central incisors and these teeth positions should not be changed after surgery with orthodontic treatment,

c- Patients who underwent maxillary advancement surgery with only Le Fort 1 osteotomy and without maxillary impaction, mandibular setback surgery with BSSO (no additional surgery was performed e.g., genioplasty, malar augmentation, rhinoplasty) by the same surgical team and had not experienced any complications during surgery,

d- Lateral cephalograms were taken just before the surgery (T0) and after orthodontic debonding, at least six months after double-jaw orthognathic surgery (T1). Cephalometric films were taken from all patients in the standard position with teeth in centric relation and relaxed lip posture in the Natural Head Position (NHP). There was no artefact in the cephalometric films and that the soft tissue was clearly visible.

Ethics committee approval was obtained from the Non-invasive Clinical Research Ethics Committee at Nevşehir Hacı Bektaş Veli University. Power analyses were performed in the G*Power (version 3.1.9.2; Axel Buchner, Universität Düsseldorf, Düsseldorf, Germany) program. Accordingly, the sample size required to detect a medium-sized effect in the population with 80% power (effect size: 0.55) was found to be 16. Thirty-one consecutive skeletal Class III patients were examined in our study, but 20 of them met the including criteria.

Cephalometric superimposition and measurements

Cephalometric films were taken from all patients in standard conditions. Reference lines used in our study to determine the movement of soft and hard tissue points are as follows:

Horizontal reference line (HRL): a line between Porion and Orbitale points (Frankfort horizontal plane).

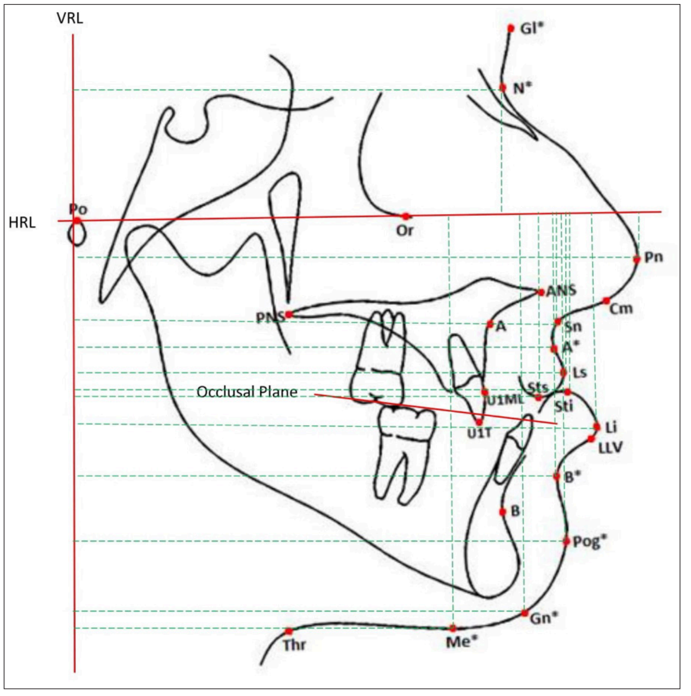

Figure 1. The anatomical landmarks (red points), reference lines (HRL: horizontal reference line, VRL: Vertical reference line) and linear mesurements between HRL-VRL and soft tissue points (intermittent green lines).

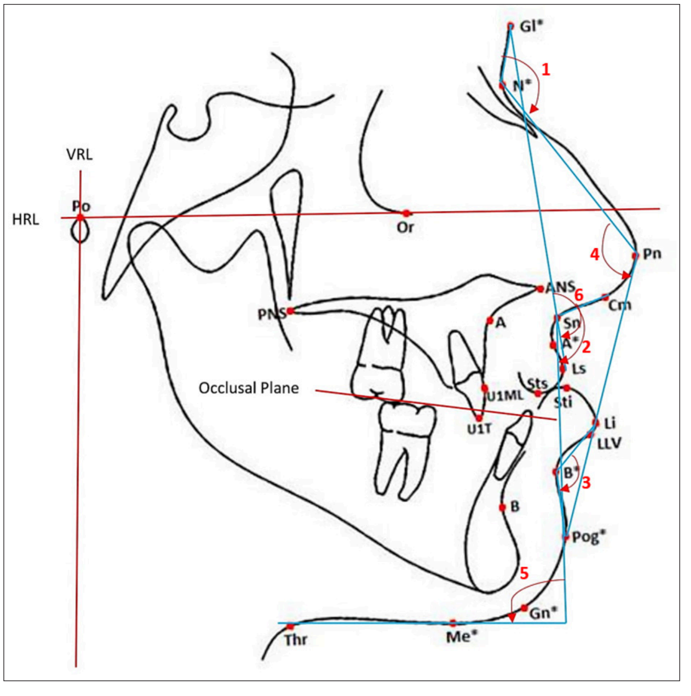

Figure 2. Angular measurements (The angles between the blue lines): 1. Nasal angle: The angle between the Gl*, N* and Pn points. 2. Nasolabial angle: The angle between the Cm, Sn and Ls points. 3. Labiomental angle: The angle between the Li, B* and Pog* points. 4. Soft tissue convexity angle: The angle between the N*, Pn and Pog* points. 5. Lower lip-chin-throat angle: The angle between the Sn-Pog* and Me*-Thr points. 6. Facial convexity angle: The angle between Gl*, Sn and Pog* points.

Figure 3. The presurgical and postsurgical profile photographs of a female patient included in this study

Vertical reference line (VRL): the perpendicular to the HRL through the Porion point.

The anatomic landmarks, the reference lines, and linear measurements between HRL-VRL and soft tissue points used in this study are shown in Figure 1. Lateral cephalograms were traced, and cephalometric reference points were determined conventionally with acetate tracing paper. Björk's structural superimposition method,[4] was used to transfer the reference lines from T0 to T1 radiographs. On the pre-op (T0) and post-op (T1) cephalograms, the difference of the vertical distances of A point for maxilla and B point for the mandible to the HRL and VRL was determined as the movement of maxilla and mandible in sagittally and vertically. Forty eight measurements were made in order to determine the facial soft tissue changes. Detailed descriptions of the measurements made in this study are given in Table 1. 38 linear (Figure 1), six angular (Figure 2), and four proportional measurements were done. The presurgical and postsurgical profile photographs of a female patient included in this study are shown in Figure 3.

Statistical analysis

The compliance of the data with normal distribution was analyzed with histogram, q-q graphics, and Shapiro-Wilk test. In the comparison of pre-op and post-op results, a dependent two-sample t-test was used. Data analysis was evaluated by R 3.1.1. (www.r-project.org) software, *P* significance level was adopted.

Linear sagittal changes between soft and hard tissues were determined proportionally using the following formula.

$$\frac{\text{T1} - \text{T0 mean of soft tissue changes}}{\text{T1} - \text{T0 mean of skeletal changes}} \text{ x } 100 = Ratio\%$$

Method error

All measurements were performed by the same researcher. Method error determined by the half of all material selected randomly was reevaluated again 3 weeks after completing all measurements. Intraclass correlation coefficients (ICC) were used in

Table 1. Description of the measurements.

MEASUREMENTS	
	Upper face evaluation
Upper face height	The perpendicular distance between the soft tissue Glabella (Gl *) and Subnasale (Sn) points.
N*-HRL	The perpendicular distance of the soft tissue Nasion point (N*) to the horizontal reference line (HRL).
N*-VRL	The perpendicular distance of the soft tissue Nasion point (N*) to the vertical reference line (VRL).
	Nasal evaluation
Pn-HRL	The perpendicular distance of the Pronasale (Pn) point to the horizontal reference line.
Pn-VRL	The perpendicular distance of the Pronasale (Pn) point to the vertical reference line.
Nasal length	The distance between the Sn and Pn points.
Nasal projection	The perpendicular distance of the Pn point to the N * -Sn line.
Nasal angle	The angle between the Gl *, N * and Pn points.
Nasolabial angle	The angle between the Cm (Columella), Sn and Ls (Labrale superious) points.
	Upper lip evaluation
Upper lip thickness	The distance between the Ls point and the most labial (U1ML) surface of the upper incisor.
Upper lip length	The perpendicular distance between the Sn and Sts (Stomion superious) points.
Sn-HRL	The perpendicular distance of the Sn point to the horizontal reference line.
Sn-VRL	The perpendicular distance of the Sn point to the vertical reference line.
A*-HRL	The perpendicular distance of the soft tissue A point (A*) to the horizontal reference line.
A*-VRL	The perpendicular distance of the soft tissue A point (A*) to the vertical reference line.
Ls-HRL	The perpendicular distance of the Ls point to the horizontal reference line.
Ls-VRL	The perpendicular distance of the Ls point to the vertical reference line.
Sts-HRL	The perpendicular distance of the Sts point to the horizontal reference line.
Sts-VRL	The perpendicular distance of the Sts point to the vertical reference line.
	Lower face evaluation
Lower face height	The perpendicular distance between the Sn and soft Menton (Me*) points.
	Lower lip evaluation
Lower lip length	The perpendicular distance between the Stomion inferious point (Sti) and the Soft tissue B point (B*).
Lower lip thickness	The perpendicular distance between the Labrale inferious point (Li) and the upper incisor tip (U1T).
Sti-HRL	The perpendicular distance of the Sti point to the horizontal reference line.
Sti-VRL	The perpendicular distance of the Sti point to the vertical reference line.
Li-HRL	The perpendicular distance of the Li point to the horizontal reference line.
Li-VRL	The perpendicular distance of the Li point to the vertical reference line.
	Labiomental region evaluation
B*-HRL	The perpendicular distance of the B* point to the horizontal reference line.
B*-VRL	The perpendicular distance of the B* point to the vertical reference line.
Labiomental sulcus depth	The perpendicular distance of the B * point to the Soft tissue Pogonion (Pog *) -Li line.
Labiomental angle	The angle between the Li, B * and Pog * points.
	Chin region evaluation
Pog*-HRL	The perpendicular distance of the Pog* point to the horizontal reference line.
Pog*-VRL	The perpendicular distance of the Pog* point to the vertical reference line.
Gn*-HRL	The perpendicular distance of the soft tissue Gnathion point (Gn*) to the horizontal reference line.
Gn*-VRL	The perpendicular distance of the soft tissue Gnathion point (Gn*) to the vertical reference line.

Table 1. Description of the measurements.(continued)

Me*-HRL	The perpendicular distance of the soft tissue Menton point (Me*) to the horizontal reference line.
Me*-VRL	The perpendicular distance of the soft tissue Menton point (Me*) to the vertical reference line.
LLV-Me*	The perpendicular distance between the lower lip vermilion (LLV) and Me* points.
Total face evaluation	
Sn-Sto	The perpendicular distance between the Sn and Stomion (Sto) points.
Sn-LLV	The perpendicular distance between the Sn and LLV points.
Sto-Me*	The perpendicular distance between the Sto and Me* points.
Interlabial distance	The difference between the distance of Sti point to HRL and the distance of Sts point to HRL (Sti-HRL - Sts-HRL).
Soft tissue convexity angle	The angle between the Sn-Pog* and Me*- Thr (Throat point) lines.
LCT (Lower lip/chin/ throat) angle	The angle between the Li, B * and Pog * points.
Facial convexity angle	The angle between the Gl*, Sn and Pog * points.
Lower lip /Upper lip length	The ratio between the lower lip and upper lip lengths (Norm: 4/3).
Sn-Sto/Sto-Me*	The ratio between the Sn-Sto and Sto-Me* distances (Norm: 1/2).
Sn-LLV/LLV-Me*	The ratio between the Sn-LLV and LLV-Me* distances (Norm: 1/0.9).
Upper face/Lower face height	The ratio between the Gl*-Sn and Sn-Me* distances (Norm: 1/1).

Table 2. Descriptive statistics of patients.

Variable	Mean values	Minimum	Maximum
Gender (Man/Woman)	10/10		
Age T0 (year)	23.68±7.14	18.08	50.00
Man	24.89±9.20	19.25	50.00
Woman	22.47±4.40	18.08	33.50
Age T1 (year)	24.66±7.37	19.50	51.42
Man	25.75±9.40	19.80	51.42
Woman	23.57±4.87	19.50	36.00
Maxilla sagittal movement (mm)	5.09±1.44	2.90	7.20
Mandible sagittal movement (mm)	-4.19±2,39	-2.00	-8.80
Mandible vertikal movement (mm)	1.15 ±0.63	0.00	2.00

Data represented as n (%) or mean ± SD.

Table 3. The soft to hard tissue ratios and formulations of the upper face.

Soft Tissue (S)		Hard Tissue (H)		Ratio (S/H), %	Regression Analysis		
	Δ		Δ		Mathematical Formulations	r	r2
Pn-VRL	1.09***	A-VRL	5.09***	22.88	Pn-VRL = 0.66 + 0.08 A-VRL	0.130	0.017
Sn-VRL	2.24***	A-VRL	5.09***	45.26	Sn-VRL = 0.88 + 0.27 A-VRL	0.373	0.139
A*-VRL	3.43***	A-VRL	5.09***	69.82	A*-VRL = 1.94 + 0.29 A-VRL	0.281	0.079
Ls-VRL	3.02***	A-VRL	5.09***	59.96	Ls-VRL = 0.53 + 0.49 A-VRL	0.530	0.281

Δ: Mean differences. * $P < .05$, ** $P < .01$, *** $P < .001$

Table 4. Soft tissue changes of the upper face after orthognathic surgery.

MEASUREMENTS	Pre-op (n=20)	Post-op (n=20)	Δ	P
Upper face evaluation				
Upper face height	69.54±4.33	69.52±3.85	-.01±.96	.949
N*-HRL	28.92±3.16	28.97±3.10	.05±.29	.436
N*-VRL	92.18±5.70	92.10±5.80	-.08±.43	.407
Nasal Evaluation				
Pn-HRL	17.14±4.89	16.35±4.57	-.78±.70***	<.001
Pn-VRL	119.47±6.47	120.57±6.62	1.09±.93***	<.001
Nasal length	19.18±1.75	18.99±1.77	-.19±.74	.256
Nasal projection	17.81±1.69	17.68±1.83	-.14±.75	.425
Nasal angle	137.31±8.38	136.80±8.06	-.51±3.70	.545
Nasolabial angle	100.05±12.01	99.88±11.20	-.18±9.14	.933
Upper Lip Evaluation				
Upper lip thickness	15.11±2.32	12.76±1.79	-2.35±1.58***	<.001
Upper lip length	20.92±2.45	21.16±2.72	.24±1.32	.428
Sn-HRL	27.93±3.69	27.36±3.63	-.57±.97*	.016
Sn-VRL	103.61±6.56	105.84±6.24	2.24±1.03***	<.001
A*-HRL	35.61±4.77	35.88±4.68	.27±1.37	.395
A*-VRL	102.10±6.57	105.53±6.59	3.43±1.50***	<.001
Ls-HRL	42.24±4.76	42.03±5.06	-.21±1.39	.516
Ls-VRL	105.71±70	108.73±7.04	3.02±1.33***	<.001
Sts-HRL	48.99±4.63	49.06±5.08	.07±1.46	.832
Sts-VRL	99.45±6.82	101.23±5.87	1.78±2.42*	.004

Δ: Mean differences. Data represented as mean ± standard deviation. * $P < .05$, ** $P < .01$, *** $P < .001$

order to determine the method error, and correlation coefficients “rs” were calculated by comparing the first and second measurements with each other. ICC determined in all measurements was found fairly close to the value 1,00 (0,981-1,00). According to this, it was observed the measurements 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 study included 20 patients. The patients included in the study were evaluated in terms of age, sex, maxillary and mandibular movements, and it was determined that the data showed a homogenous distribution in terms of these characteristics. Within-group distribution in terms of age, sex, and average maxilla and mandible movements are presented in Table 2. In the sagittal direction, the mean maxillary movement was 5.09±1.44 mm, and vertically there was no change in the maxilla.

The soft to hard tissue ratios and formulations of the upper face in the sagittal direction are presented in Table 3. Soft tissue changes of the upper face after orthognathic surgery are presented in Table 4. Pronasale (Pn) was affected less with the movement of the maxilla (22.88%), while soft tissue A point (A*) moved forward 69.82% of skeletal A point as a result of the maxillary advancement. The most significant differences in soft tissue variables were observed in Pn-VRL, Pn-HRL, upper lip thickness, Sn-VRL, A*-VRL, and Ls-VRL ($P < 0.001$). The mathematical formulation of the Ls point created according to the maxillary hard tissue movement is as follows; Ls-VRL = 0.53 + 0.49 x (A-VRL).

After surgery, mean mandibular movement was 4.19±2.39 mm in the sagittal direction and 1.15±0.63 mm upward from the reason of changed occlusal interferences. The soft to hard tissue ratios and mathematical formulations of the lower face in the sagittal direction are presented in Table 5. Soft tissue changes of the lower face after orthognathic surgery are presented in Table 6. For lower face variables, Labiale inferior (Li) was affected less with the movement of the mandible (76.99%), while soft tissue B point (B*) moved equally with the mandible (100.62%). The most significant differences in soft tissue variables were observed in Li-VRL, lower lip thickness, B*-VRL, labiomental sulcus depth, and labiomental angle, Pog*-VRL, Gn*-VRL, and Me*-VRL ($P < 0.001$). The mathematical formulation of the Li point created according to the movement of the mandibular hard tissue in the sagittal plane is as follows; Li-VRL = -0.20 + 0.72 x (B-VRL).

After surgery, all patients had an orthognathic profile. Facial convexity angle decreased 6.65±3.80°, and soft tissue convexity an-

Table 5. The soft to hard tissue ratios and formulations of the lower face.

Soft Tissue (S)		Hard Tissue (H)		Ratio (S/H). %	Regression Analysis		
	Δ		Δ		Mathematical Formulations	r	r2
Li-VRL	-3.22***	B-VRL	-4.19***	76.99	Li-VRL = -0.20+0.72 B-VRL	0.752	0.565
B*-VRL	-3.90***	B-VRL	-4.19***	100.62	B*-VRL = -0.54+0.80 B-VRL	0.809	0.654
Pog*-VRL	-3.06***	B-VRL	-4.19***	82.62	Pog*-VRL = 1.55+1.10 B-VRL	0.909	0.827
Gn*-VRL	-2.82***	B-VRL	-4.19***	81.31	Gn*-VRL = 1.08+0.93 B-VRL	0.816	0.666
Me*-VRL	-3.04***	B-VRL	-4.19***	95.32	Me*-VRL = 1.13+1.00 B-VRL	0.668	0.446

Δ: Mean differences. * $P < .05$, ** $P < .01$, *** $P < .001$

Table 6. Soft tissue changes of the lower face after orthognathic surgery.

MEASUREMENTS	Pre-op (n=20)	Post-op (n=20)	Δ	P
Lower face evaluation				
Lower face height	72.69±7.80	71.70±7.57	-.99±2.69	.114
Lower lip evaluation				
Lower lip thickness	21.07±2.94	13.00±2.18	-8.07±2.64***	<.001
Lower lip length	20.66±3.07	18.90±2.79	-1.76±1.94***	.001
Sti-HRL	47.94±4.87	48.93±5.12	.98±1.62*	.014
Sti-VRL	101.97±5.83	101.47±5.91	-.50±2.37	.357
Li-HRL	56.41±5.76	56.94±5.69	.53±2.03	.257
Li-VRL	110.69±6.82	107.46±6.49	-3.22±2.30***	<.001
Labiomental region evaluation				
B*-HRL	68.75±7.48	67.86±7.35	-.89±2.56	.139
B*-VRL	103.71±6.69	99.80±6.05	-3.90±2.38***	<.001
Labiomental sulcus depth	4.77±1.33	5.89±1.33	1.12±1.14***	<.001
Labiomental angle	139.17±14.62	124.57±12.11	-14.6±12.34***	<.001
Chin region evaluation				
Pog*-HRL	81.76±8.76	80.20±8.56	-1.56±2.04**	.003
Pog*-VRL	106.24±6.75	103.17±5.68	-3.06±2.90***	<.001
Gn*-HRL	95.39±9.11	94.02±9.02	-1.37±2.50*	.024
Gn*-VRL	100.37±7.08	97.55±6.48	-2.82±2.73***	<.001
Me*-HRL	100.89±9.49	99.58±9.55	-1.31±2.36*	.022
Me*-VRL	86.23±7.76	83.19±6.97	-3.04±3.57***	.001
LLV-Me*	42.03±6.01	40.92±5.17	-1.11±2.38	.051

Δ: Mean differences. Data represented as mean ± standard deviation. * $P < .05$, ** $P < .01$, *** $P < .001$

Table 7. The other facial changes after the surgery.

MEASUREMENTS	Pre-op (n=20)	Post-op (n=20)	Δ	P
Sn-Sto	20.04±3.00	21.25±2.75	1.21±1.73**	.006
Sn-LLV	30.39±3.45	31.20±3.54	.81±2.24	.122
Sto-Me*	52.37±5.34	50.58±5.68	-1.80±2.29**	.002
Interlabial distance	1.26±.90	0.29±.50	-.97±.90***	<.001
Soft tissue convexity angle	139.68±5.84	133.47±3.74	-6.22±4.57***	<.001
LCT (Lower lip/chin/throat) angle	93.38±10.82	100.73±9.82	7.35±6.71***	<.001
Facial convexity angle	176.12±5.42	169.47±5.08	-6.65±3.80***	<.001
Lower lip /Upper lip length	.99±.13	.89±.09	-.10±.11***	.001
Sn-Sto/Sto-Me*	.38±.04	.42±.04	.04±.04***	<.001
Sn-LLV/LLV-Me*	.73±.11	.76±.08	.03±.07	.074
Upper face/Lower face height	.96±.09	.97±.09	.01±.04	.124

Δ: Mean differences. Data represented as mean ± standard deviation. * $P < .05$, ** $P < .01$, *** $P < .001$

gle decreased 6.22±4.57°, LCT (lip-chin-throat) angle increased 7.35±6.71° ($P < .001$). The other facial changes after the surgery are presented in Table 7.

DISCUSSION

The number of male and female patients included in our study was equal. However, in some studies, the number of female patients was more than the male patient's cause females are motivated by improved appearance and masticatory function after surgery.[5,6] Our study consists of 20 patients, and the reason for the small sample size is the strict selection criteria applied to eliminate some of the drawbacks of the retrospective study design and make a homogenous sample group.

Although some studies stated that there was no difference between patients with and without genioplasty,[7,8] since additional surgeries change soft tissues, we excluded these patients who had secondary surgery. To eliminate the variables related to the type of operation, only patients who underwent purely double jaw orthognathic surgery were included in our study. In addition, the maxillary impaction (6 patients) and single jaw surgeries (2 patients) were excluded.

After surgery, the edema could significantly affect the soft-to-hard tissue ratios and soft tissue profile. Therefore, to eliminate the edema and to make a correct analysis, there was a need for at least six months after surgery.[7,9] In the present study, final cephalograms were taken 11.5±6.77 months after surgery.

In order to ensure that the changes after surgery in hard tissue and determine the soft to hard tissue ratios objectively; the pre-op (T0) and post-op (T1) lateral cephalograms were overlaid using the Bjork's local and structural superimposition methods[4,10] and the reference planes were transferred from pre-op films to the post-op films objectively.

To determine maxillary movement, the distances of point A to the vertical and horizontal reference lines were measured. Since the ANS region in the maxilla can be shaved during surgery and thus deformable[11], the A point was selected for maxillary movement, which is more stable. In our evaluation, there was no clinical or radiographic damage at the skeletal A point. The determination of an ideal soft to hard tissue ratio is the first condition for making an ideal surgical prediction. Chew et al.[12] reported that skeletal Class III patients undergoing bimaxillary orthognathic surgery had much more difficulties than Class II patients. This study aimed to establish the predictive soft to hard tissue ratios that can be used in patients underwent Class III bimaxillary jaw surgery.

After surgery, all of the patients had an orthognathic profile. While soft tissue convexity angle decreased 6.22° and the facial convexity angle decreased 6.65°. These findings are consistent with other studies in the literature.[2,13,14]

The tip of nose (Pn) was elevated 0.78 mm and moved 1.09 mm forward. The soft to hard tissue ratio for the pronasale was 22.88% in the sagittal plane. Pn is the least affected area by underlying skeletal tissue movement. In agreement with the other studies in the literature, the forward movement of Pn (Pn-VRL) and subnasale (Sn-VRL) was less than that of the upper lip (Ls-VRL).[2,15] Also, according to some authors, the change of the Pn after maxillary advancement surgery is usually temporary.[16] In the maxilla, the ANS region was shaved by the amount of advancement and the V-Y closure technique was used as the soft tissue closure technique. It is thought that the surgical technique used affects the maxillary soft tissue following ratios.

The soft to hard tissue ratio for Sn (Subnasale) was 45.26% in the sagittal plane. Epker[17] was stated that the movement of Subnasale area is associated with the thickness of the upper lip; if the upper lip thickness is equal to or less than 17 mm before the surgery, Sn movement will be observed at 50% of the A point, and if it is greater than 17 mm, 33% of the A point will be observed.

Contrary to our study, Lee et al.[18] reported that the forward movement of Sn region (0.378 mm) after Le Fort I osteotomy was not significant. One reason why different rates are stated in different studies is that the ratio of soft to hard tissue movement depends on the amount of the maxillary movement in the sagittal plane. When the maxillary movement is more than 4 mm in the sagittal plane, approximately two times higher rates are observed in the maxillary soft tissue region.[19]

There was a significant decrease in the thickness of the upper lip. The decrease in upper lip thickness is a finding observed after many Class III double jaw surgeries, and this finding is consistent with other studies in the literature.[20-22] Similarly to our study, Naumova et al.[23], reported that there was an average 2 mm reduction in upper lip thickness after vertical ramus osteotomy. However, upper jaw surgery was not performed, and attributed this reduction is caused by the pseudoposition of the upper lip as a result of compensation in Class III patients. Also, it has been reported that thin lips have a higher following soft to hard tissue ratios than thick lips.[24,25]

In our study, no significant change was observed in the nasolabial angle after surgery (*P* = .933). Similarly, Coban et al.[26] evaluated the changes in the nose in three dimensions after Le Fort I osteotomy in patients with skeletal Class III malocclusion concluded that there was no change was observed in the nasolabial angle. In contrast, in another study in which combined anterior segmental osteotomies were performed, it was reported that the nasolabial angle increased by an average of 15.5°.[27] The nasolabial angle change differs according to the surgical technique applied in the maxilla.

After maxillary osteotomies, the variability of soft tissue changes is related to the individual differences in the postoperative recovery period, differential response of various parts of the soft tissues, and surgical technique. Since surgical incisions are made closer to the upper lip in the maxilla than the mandible, the effect of scar tissue formed on these incision lines on the upper lip area is much more than on the lower lip and chin area. In addition, tight attachments at the base of the nose restrict the movement of the upper lip vertically and horizontally.[2,14,28]

The B* point's soft to hard tissue ratio agree with previous studies in the literature.[2,21,29] Contrary to our study, Marsan et al.[30] reported the B* point's soft to hard tissue ratio by 59%. This rate is much lower than reported in the literature before. Also, they stated that there was a poor correlation between other soft and hard tissue points in their studies.

The labiomental sulcus depth increased by the mean of 1.12 mm, and the labiomental angle decreased by 14.6° at the end of the treatment. This decrease in the labiomental angle was related to the upward movement of the mandible[20] and the increase of labiomental sulcus depth is very typical for mandibular setback surgery also may be associated with the decrease in lower face height.[30,31,32] Soft tissues at the chin area are significantly influenced by the preoperative thickness of this site, and the adaptation of mental and superhyoid muscles to the new position of the mandible may explain another reason for this finding.[24,33]

Lower face height decreased by the mean of 0.99 mm at the end of the treatment. This reduction is attributed to the upward movement of the mandible with adaptation to the new occlusal plane. Similarly, Marsan et al.[30] and Mobarak et al.[31] found that there was a decrease in the lower face height after orthognathic surgery and that this decrease was associated with the upward movement of the mandible.

The upper to lower facial height ratio increased significantly at the end of treatment. This increase is related to the decrease in the lower face height. Our findings are consistent with other studies in the literature.[31,32,34]

There are some limitations to our study. In this study, we developed direct formulations and soft to hard tissue ratios from lateral cephalograms. However, in 3D prediction methods, it is not possible to predict soft tissue changes following skeletal tissue by mathematical formulation or continuous equations and soft to hard tissue ratios like 2D prediction methods due to various geometric complexities. These formulations and soft to hard tissue ratios can't use for 3D methods. 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 that our inclusion criteria also we want to create a homogeneous study group. By increasing the number of cases, the development of formulations and ratios in different types of surgery can also be evaluated.

CONCLUSIONS

Maxillary advancement and mandibular setback surgery effectively improve soft tissue profile in skeletal Class III patients.

All the Class III patients had an orthognathic profile after double jaw surgery, and the significant improvement in facial profiles of skeletal Class III orthognathic surgery patients after maxillary advancement and mandibular setback surgery is primarily related to the backward movement of the mandible.

The soft to hard tissue movement correlation in the maxilla is lower than the mandible.

The soft to hard tissue ratios and mathematical formulations obtained from this study would contribute to the database for 2D soft tissue prediction programs.

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