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Hard Tissue Changes on Soft Tissue Harmony in Non-Extraction Camouflage Treatments for Angle Class III Malocclusion

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ABSTRACT

Purpose: The aim of this retrospective study was to observe the harmony between hard and soft tissue alterations on lateral cephalograms of patients with Class III malocclusion following orthodontic treatment.

Methods: Fifteen patients (7 male, 8 female; mean age: 21.4±0.49 years) who had Class III non-extraction camouflage treatment with intermaxillary elastics were included in the study. Pretreatment and posttreatment lateral cephalograms were evaluated for hard and soft tissue changes using NemoStudio NX-Pro software. Student's t-test, Pearson correlation analyses, and linear regression analyses were performed. Statistical significance was set at $p<0.05$.

Results: Strong negative correlations were identified between SN-GoMe values and UL Thickness (p=0.004), Pog'-TVL (p=0.012), and LLA-TVL (p=0.018), also between overbite and UL-E Line (p=0.013), H angle (p=0.002). UI-SN parameter showed strong positive correlation withand UL-E Line (p=0.014), and H angle (p=0.004). UI-OP showed strong positive correlation with H angle (p=0.004). The linear regression analysis showed that each unit increase in SN-GoMe caused 0.523-unit decrease in UL Thickness (p=0.004), UI-SN caused 0.177-unit increase in LL-E Line (p=0.039). Moreover, overbite caused 0.835-unit decrease in H angle (p=0.027) and 0.749-unit increase in G-Sn-Pog' (p=0.032).

Conclusion: Since changes in SN-GoMe angle, UI-SN angle, and overbite have a greater impact on soft tissues compared to other hard tissue alterations, they can provide clinicians with crucial information when planning Class III camouflage treatments.

Keywords: Orthodontics, Cephalometry, Angle Class III Malocclusion

ÖZET

Amaç: Bu retrospektif çalışmanın amacı, Sınıf III maloklüzyona sahip hastaların ortodontik tedavi sonrası lateral sefalogramlarında üzerinden sert ve yumuşak doku değişiklikleri arasındaki uyumu incelemektir.

Yöntem: Çalışmaya intermaksiller elastiklerle Sınıf III çekimsiz kamuflaj tedavisi uygulanan 15 hasta (7 erkek, 8 kadın; ortalama yaş: 21,4±0,49 yıl) dahil edilmiştir. Hastaların tedavi öncesi ve tedavi sonrası lateral sefalogramları NemoStudio NX-Pro yazılımı kullanılarak sert ve yumuşak doku değişiklikleri açısından değerlendirilmiştir. Student's t-testi, Pearson korelasyon analizi ve lineer regresyon analizleri uygulanmıştır. İstatistiksel anlamlılık seviyesi $p<0,05$ olarak belirlenmiştir.

Bulgular: SN-GoMe ile UL Kalınlığı (p=0,004), Pog'-TVL (p=0,012), LLA-TVL (p=0,018) arasında, overbite ve UL-E çizgisi (p=0,013), H açısı (p=0,002) arasında negatif yönde güçlü korelasyon bulunmuştur. UI-SN ile UL-E çizgisi (p=0,014) ve H açısı (p=0,004) arasında pozitif yönde güçlü korelasyon bulunmuştur. UI-OP ve H açısı arasında negatif yönde güçlü korelasyon bulunmuştur (p=0,004). Doğrusal regresyon analizi, SN-GoMe' deki bir birimlik artışın UL kalınlığında 0,523 birimlik bir azalmaya neden olduğunu (p=0,004) ve UI-SN' deki bir birimlik artışın LL-E çizgisinde 0,177 birimlik bir artışa neden olduğunu (p=0,039) göstermiştir. Ayrıca overbite'deki bir birimlik artışın, H açısında 0,835 birimlik bir azalmaya (p=0,027), G-Sn-Pog' değerinde ise 0,749 birimlik bir artışa neden olduğu (p=0,032) bulunmuştur.

Sonuç: SN-GoMe açısı, UI-SN açısı ve overbite değişiklikleri, yumuşak dokular üzerinde diğer sert doku değişikliklerine göre daha fazla etkiye sahip olduğundan, çekimsiz Sınıf III kamuflaj tedavisini planlamasında klinisyenlere önemli bilgiler sağlayabilir.

Anahtar Kelimeler: Ortodonti, Sefalometri, Angle Sınıf III Maloklüzyon

Class III malocclusion is a complex deformity that has skeletal or dental components. Treatment options vary depending on the growth and development period (1). In skeletal Class III malocclusion, the stage of growth and development and residual growth after treatment are important factors for treatment stability (2). The aim of early orthopedic treatment is to achieve the proper development of skeletal and dentoalveolar structures to reduce the possibility of a need for complex orthodontic treatment or orthognathic surgery. On the other hand, residual growth potential can result in the relapse of the corrections that have been achieved earlier, or orthognathic surgery may be needed later on in severe cases (3).

After the active growth period of the patient, the decision for the treatment protocol depends on the severity of the case. Patients with acceptable facial profiles and mild Class III malocclusion can be treated with orthodontic camouflage to disguise the jaw discrepancy (4). However, orthognathic surgery is the only way to reach successful results for patients with unacceptable facial profiles and severe dentoskeletal discrepancies (5).

Today, the number of people seeking orthodontic treatment is increasing because social media is more involved in our lives, and patients realize that aesthetic results can be obtained with orthodontic treatment (6, 7). Therefore, the individual treatment plan of each patient should be prepared in a way that will positively contribute to the patient's facial aesthetics (8).

The conventional Class III camouflage treatment concept is the proclination of maxillary anterior teeth and the retroclination of mandibular anterior teeth to achieve a more balanced occlusion. Extraction is also indicated depending on the degree of crowding and the anchorage protocol (9). Various factors such as soft tissue phenotypes, as well as the position and angulation of the teeth, may contribute to the individual's facial harmony and balance (10). In the literature, the effects of different treatment protocols on soft tissues in different malocclusions have been examined (11-14). The differences between orthognathic surgery and camouflage treatment, as well as camouflage treatments with and without extraction, have been investigated in Class III malocclusion cases (15-18). However, to the best of our knowledge, no study has focused on hard-soft tissue interactions in patients receiving non-extraction Class III camouflage treatment, while it is clinically observed that the tooth movements and hard tissue changes induced in these treatments cause soft tissue response. Thus, this study aimed to examine the effects of hard tissue changes on soft tissues in patients who underwent Class III non-extraction camouflage treatment and provide information for clinicians to use in their orthodontic practice by determining which hard tissue changes affect soft tissues more.

Methods

Sample

This retrospective study was approved by the Ethics Committee of Marmara University, Faculty of Medicine (30.05.2025-09.2022.1465). Lateral cephalograms of patients who underwent Class III camouflage treatment between the years 2016 and 2022 were selected from the archive of … University, Department of Orthodontics.

The G*Power (Version 3.1.7, Heinrich-Heine-Universität, Düsseldorf, Germany) software was used for calculating the minimum required sample size based on the results of a previous study. The required sample size was calculated to be at least 13 patients (α=0.05, power of 90%, and effect size=0.87 according to 1.6 mm retrusion in LL-E Line in a previous study) (18).

The inclusion criteria were as follows:

- Age between 19 and 30
- Cervical vertebral maturation stage 5 or 6 according to cephalograms
- Angle Class III molar and canine relationship,
- ANB angle -5° and 0°,
- Wits appraisal between -11.8 mm and -3.4 mm,
- Overjet between -4 mm and 2 mm,
- Overbite between -1.5 mm and 4.5 mm
- Acceptable facial profile,
- Non-extraction comprehensive orthodontic treatment,
- High-quality pretreatment and posttreatment orthodontic records.

The exclusion criteria were as follows:

- Extracted or missing teeth,
- Non-compliant patients,

- Dentofacial anomalies or syndromes such as cleft lip and palate,
- Files with missing information or missing orthodontic records.

Following the screening of cases based on the inclusion and exclusion criteria, the final sample consisted of 15 patients (7 male, 8 female; mean age: 21.4±0.49 years). The mean treatment duration of the patients was 3.26±0.23 years.

According to the information obtained from the files, lateral cephalograms were taken before (T0) and after treatment (T1). All patients had been treated in a university hospital where treatment plans had been determined by a council of experienced specialists. 0.018″-slot fixed appliances were used. Following the leveling and aligning stages, 6.5 oz. Class III elastics with a diameter of 3/16″ were applied on 0.016x0.022′-in stainless steel wire in all patients to correct the anteroposterior relationship, and the patients were seen at 4-week intervals. At the end of the treatment, Class I molar and canine relationships, normal overjet and overbite, and maximum intercuspation were achieved. All patients were given fixed retainers.

Cephalometric Evaluation

One researcher (G.Y.) traced all lateral cephalograms using the NemoStudio NX-Pro software v.10.4.2 (Nemotec, Madrid, Spain). The calibration of lateral cephalograms at the two time points was further established with reference to the Sella-Nasion length for each patient. The cephalometric analyses that were used to evaluate skeletal, dental, and soft tissue changes are given in Table 1 and Figure 1.

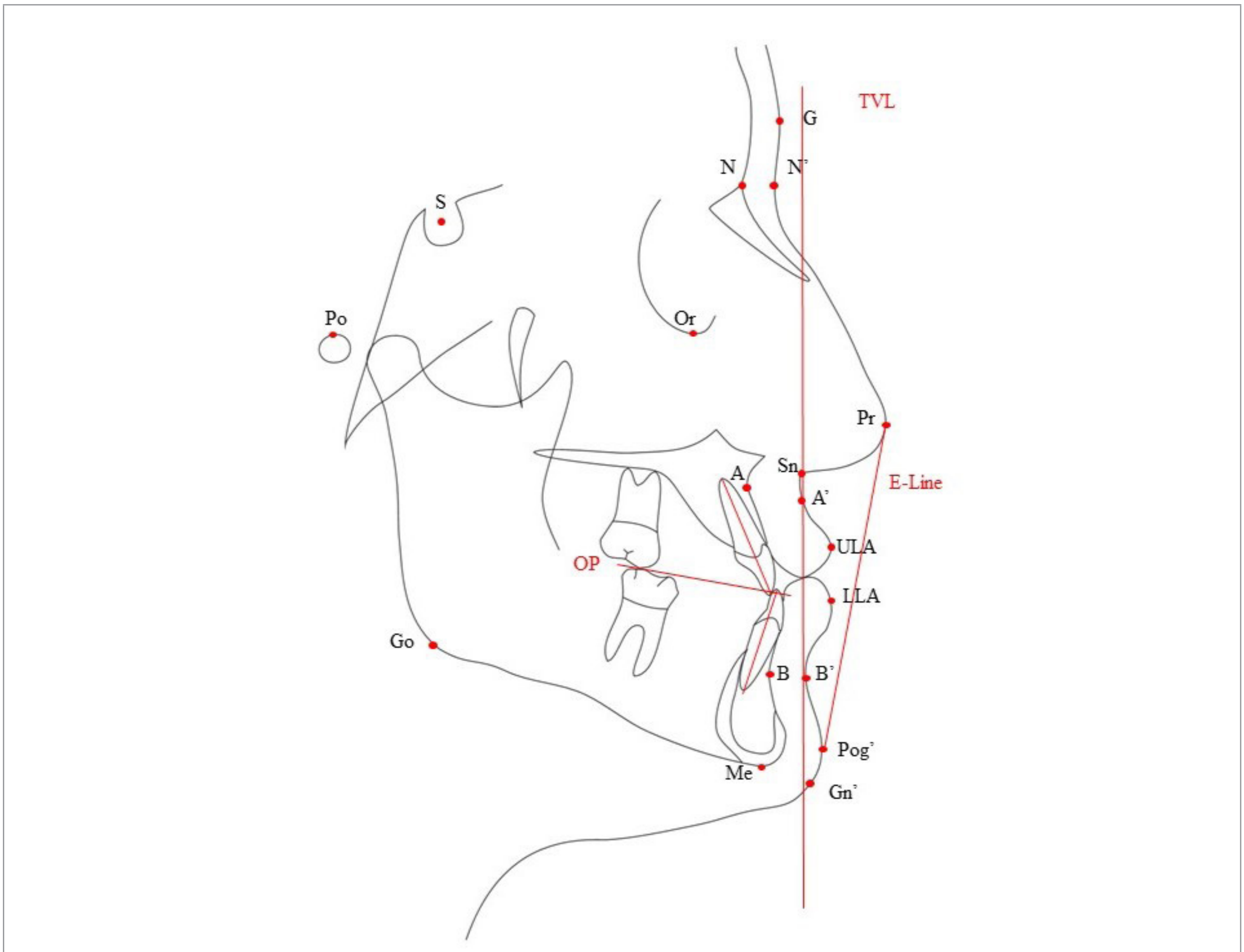

Figure 1: Landmarks used in cephalometric analysis

Table 1: Cephalometric measurements and definitions

CEPHALOMETRIC MEASUREMENTS	DEFINITION
	SKELETAL-SAGITTAL
SNA (°)	Angle formed between S, N, and A points
SNB (°)	Angle formed between S, N, and B points
ANB (°)	Arithmetic difference of SNA angle and SNB angle
Wits (mm)	Distance between projections from points A and B, drawn perpendicular to the functional occlusal plane
ACB-Corpus Length (mm)	Distance between S and N-distance between Go and Gn
N⊥A (mm)	A true vertical line dropped from N and horizontal distance parallel to this true vertical line measured from point A
	SKELETAL-VERTICAL
SN-GoMe (°)	Angle formed between S-N line and Go-Me line
FMA (°)	Angle formed between Po-Or line and Go-Me line
SN-OP (°)	Angle formed between S-N line and the functional occlusal plane
	DENTAL
UI-SN (°)	Angle formed between S-N line and upper centrals axis line
IMPA (°)	Angle formed between lower central axis line and Go-Me line
UI-OP (°)	Angle formed between upper central axis line and the functional occlusal plane
LI-OP (°)	Angle formed between lower central axis line and the functional occlusal plane
I-I (°)	Angle formed between upper central axis line and lower central axis line
Overjet (mm)	Distance between the incisal edges of maxillary and mandibular incisors, parallel to the functional occlusal plane
Overbite (mm)	Distance between the incisal edges of maxillary and mandibular incisors, perpendicular to the functional occlusal plane
	SOFT TISSUE
Nasolabial Angle (°)	Angle formed by a line tangential to the base of the nose and a line tangential to the upper lip
UL-E Line (mm)	Distance between upper lip anterior (ULA) to E-Line (line between pronasale and pogonion)
LL-E Line (mm)	Distance between lower lip anterior (LLA) to E-Line (line between pronasale and pogonion)
UL Thickness (mm)	Horizontal thickness of upper lip overlying the incisors at the level of vermilion border
UL Base (mm)	Lip thickness near the base of alveolar process, about 3 mm below point A
UL Strain (mm)	Arithmetic difference between upper lip base and upper lip thickness
LL Thickness (mm)	Horizontal thickness of upper lip overlying the incisors at the level of vermilion border
LL Base (mm)	Lip thickness near the base of alveolar process, at about point B
LL Strain (mm)	Arithmetic difference between lower lip base and lower lip thickness
H Angle (°)	Angle formed between N′ and Pog′, tangential to the upper lip anterior
Soft Tissue Profile (°)	Angle formed between soft G, Sn, and Pog′
A′-TVL (mm)	Distance from A′ to True Vertical Line
B′-TVL (mm)	Distance from B′ to True Vertical Line
Pog′-TVL (mm)	Distance from Pog′ to True Vertical Line
ULA-TVL (mm)	Distance from ULA to True Vertical Line
LLA-TVL (mm)	Distance from LLA to True Vertical Line
UL Angle (°)	Angle formed between ULA, Sn, and Pog′

Statistical Analyses

The SPSS software for Windows (version 22.0, IBM Corp, Armonk, NY, USA) was used for the statistical analyses. The Shapiro-Wilk test was used to assess the conformity of the parameters to normal distribution. Student's t-test was used to evaluate changes over time. Pearson's correlation analysis was used to determine the correlations between soft and hard tissue changes. Linear regression analysis was performed to examine the effects of hard tissue changes on soft tissue changes using the enter method. Statistical significance was set at $p<0.05$.

Results

All parameters were re-measured at one-month intervals by the same researcher (G.Y.). The intraclass correlation coefficient (ICC) was calculated for each variable to evaluate the accuracy of the measurements, and it varied from 0.868 to 1.000, revealing a high level of agreement.

The changes in skeletal and dental parameters observed as a result of treatment are shown in Table 2. Significant increases in Wits, UI-SN angle, overjet, and overbite and significant decreases in ACB-Corpus, SN-GoMe, SN-OP, and UI-OP were observed (Table 2) ($p<0.05$).

Table 2: Treatment effects on skeletal and dental parameters in T0-T1

Parameters	T0	T1	ΔT0-T1	p
SNA (°)	79.87±4.21	80±4.75	0.13±1.25	0.685
SNB (°)	81.07±4.38	80.87±4.31	-0.20±1.15	0.510
ANB (°)	-1.20±1.26	-0.87±1.30	0.33±0.90	0.173
Wits (mm)	-6.25±2.5	-4.13±1.92	2.13±1.68	**0.000***
ACB-Corpus (mm)	9.65±8.24	6.01±7.56	-3.64±4.66	**0.009***
N⊥A (mm)	-2.89±3.76	-2.59±4.23	0.30±1.27	0.376
SN-GoMe (°)	36.4±6.64	35.13±6.59	-1.27±1.39	**0.003***
SN-OP (°)	16.93 ±5.7	14.87±5.22	-2.07±2.09	**0.002***
UI-SN (°)	106.8±6	111.73 ±6.9	4.93±6.09	**0.007***
IMPA (°)	85.47±4.39	85.33±6.47	-0.13±5.21	0.922
UI-OP (°)	56.8±4.44	52.2±4.65	-4.60±4.15	**0.001***
LI-OP (°)	72.53±6.09	71.8±8	-0.73±5.73	0.628
I-I (°)	131.4±7.77	127.87 ±9.43	-3.53±9.52	0.173
Overjet (mm)	0.72±1.55	2.93±0.69	2.21±1.84	**0.000***
Overbite (mm)	0.55±1.68	1.79±0.78	1.25±1.70	**0.013***

*Student's t-test, T0: Initial, T1: Post-treatment, SD: Standard deviation, *p<0.05*

In the evaluations of hard and soft tissue changes with Pearson's correlation analysis, the degree of change in SN-GoMe angle had strong negative correlations with the degrees of changes in UL Thickness, Pog'-TVL, and LLA-TVL (p=0.004, p=0.012, and p=0.018, respectively) and a moderate negative correlation with the degree of change in B'-TVL (p=0.048) (Table 3, Figure 2a).

Table 3: Evaluation of the relationships between hard and soft tissue measurements

Soft Tissue Parameters		Wits	ACB-Corpus	SN-GoMe	SN-OP	UI-SN	UI-OP	Overjet	Overbite
Nasolabial angle	r	0.010	-0.119	-0.097	-0.099	-0.405	0.404	**-0.554**	**0.513**
	p	0.972	0.673	0.732	0.726	0.135	0.135	**0.032***	**0.041***
UL-E Line	r	-0.208	0.201	-0.242	0.044	**0.619**	**-0.552**	0.259	**-0.621**
	p	0.456	0.472	0.385	0.876	**0.014***	**0.033***	0.352	**0.013***
LL-E Line	r	-0.197	0.197	-0.393	-0.069	**0.537**	-0.471	0.020	-0.323
	p	0.482	0.482	0.147	0.806	**0.039***	0.076	0.943	0.240
UL Thickness	r	-0.266	0.108	**-0.698**	-0.123	-0.246	0.349	-0.446	0.277
	p	0.338	0.702	**0.004***	0.663	0.376	0.203	0.095	0.318
UL Base	r	-0.329	-0.212	-0.409	-0.269	0.317	-0.256	0.101	0.059
	p	0.231	0.447	0.130	0.332	0.250	0.357	0.720	0.833
UL Strain	r	-0.088	-0.260	0.153	-0.146	0.455	-0.476	0.413	-0.152
	p	0.756	0.349	0.585	0.604	0.088	0.073	0.126	0.590
LL Thickness	r	0.248	0.073	-0.347	-0.315	-0.009	0.195	0.338	-0.113
	p	0.372	0.796	0.205	0.252	0.975	0.486	0.218	0.688
LL Base	r	-0.249	-0.146	-0.452	-0.129	0.142	-0.096	-0.374	0.354
	p	0.371	0.604	0.091	0.648	0.615	0.735	0.169	0.196
LL Strain	r	-0.349	-0.149	0.079	0.212	0.077	-0.217	**-0.514**	0.326
	p	0.202	0.596	0.780	0.447	0.784	0.436	**0.040***	0.235
H angle	r	-0.099	0.224	0.025	0.140	**0.701**	**-0.702**	0.465	**-0.733**
	p	0.726	0.422	0.930	0.618	**0.004***	**0.004***	0.081	**0.002***
G-Sn-Pog′	r	-0.021	-0.396	-0.031	-0.218	-0.438	0.439	-0.434	**0.554**
	p	0.939	0.144	0.911	0.435	0.102	0.101	0.106	**0.032***
A′-TVL	r	-0.171	-0.251	-0.131	-0.109	0.105	-0.040	0.199	-0.086
	p	0.543	0.366	0.641	0.699	0.709	0.889	0.477	0.759
B′-TVL	r	-0.129	-0.359	**-0.499**	-0.493	0.149	0.008	-0.467	0.417
	p	0.646	0.189	**0.048***	0.062	0.597	0.976	0.079	0.122
Pog′-TVL	r	-0.338	-0.458	**-0.627**	-0.341	-0.060	0.202	-0.369	**0.511**
	p	0.218	0.086	**0.012***	0.213	0.831	0.469	0.175	**0.041***
ULA-TVL	r	-0.261	-0.129	-0.131	-0.036	0.466	-0.402	0.242	-0.353
	p	0.347	0.648	0.641	0.897	0.080	0.137	0.384	0.197
LLA-TVL	r	-0.291	-0.161	**-0.600**	-0.333	0.399	-0.291	-0.158	0.099
	p	0.293	0.567	**0.018***	0.225	0.141	0.293	0.574	0.726
UL angle	r	-0.211	-0.082	-0.079	0.063	0.411	-0.372	0.348	-0.372
	p	0.451	0.771	0.778	0.823	0.128	0.172	0.204	0.173

*Pearson's correlation analysis, *p<0.05*

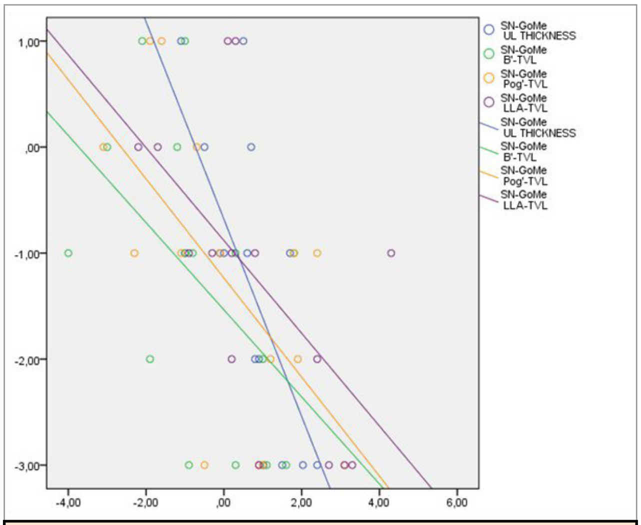

Figure 2a: Scatter plots showing the correlations between SN-GoMe and soft tissue variables

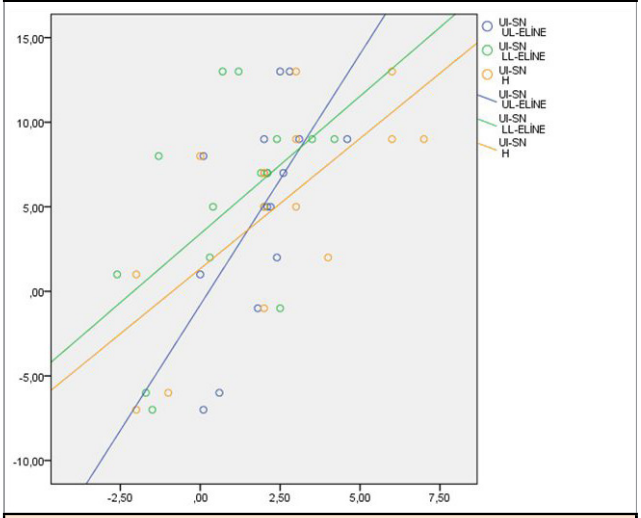

Figure 2b: Scatter plots showing the correlations between UI-SN and soft tissue variables

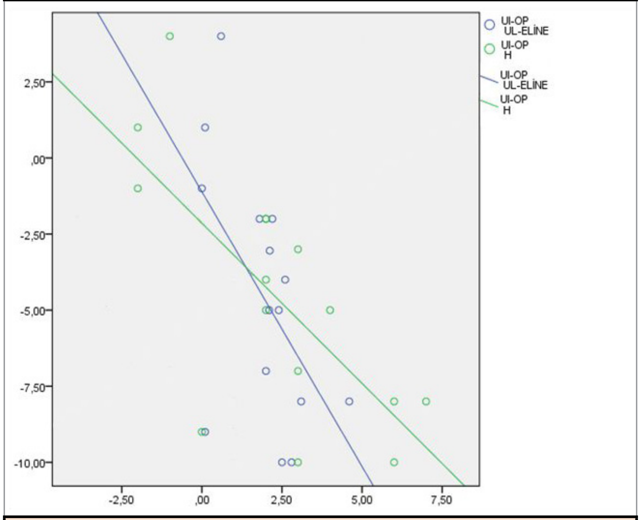

Figure 2c: Scatter plots showing the correlations between UI-OP and soft tissue variables

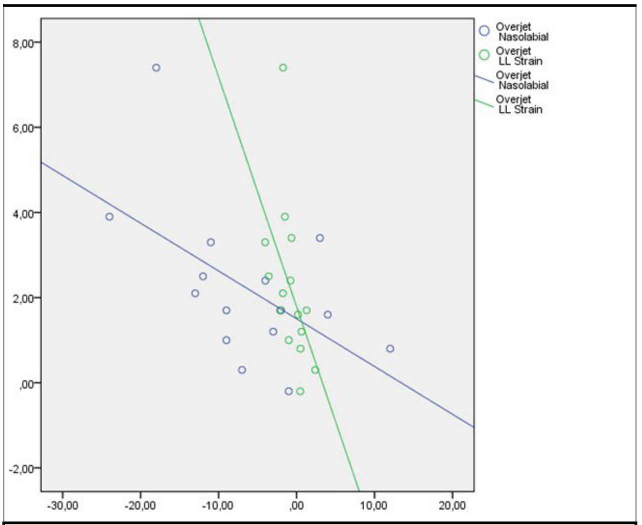

Figure 2d: Scatter plots showing the correlations between Overjet and soft tissue variables

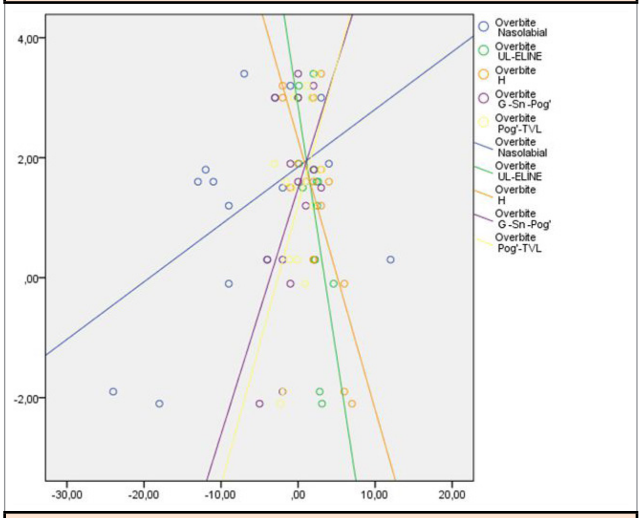

Figure 2e: Scatter plots showing the correlations between Overbite and soft tissue variables

The change in UI-SN angle had strong positive correlations with UL-E Line and H angle (p=0.014 and p=0.004, respectively) and a moderate positive correlation with LL-E Line (p=0.039) (Table 3, Figure 2b). The change in UI-OP angle had a strong negative correlation with H angle (p=0.004) and a moderate negative correlation with UL-E Line (p=0.033) (Table 3, Figure 2c).

The change in overjet had moderate negative correlations with nasolabial angle and LL Strain (p=0.032 and p=0.040, respectively) (Table 3, Figure 2d). Moreover, while the change in overbite had moderate positive correlations with nasolabial angle, G-Sn-Pog', and Pog'-TVL (p=0.041, p=0.032, and p=0.041, respectively), it showed strong negative correlations with UL-E Line and H angle (p=0.013 and p=0.002, respectively) (Table 3, Figure 2e).

Finally, linear regression analysis was performed to investigate the effects of significant correlation values. It was observed that a one-unit increase in SN-GoMe angle corresponded to a 0.523-unit decrease in UL Thickness, and a one-unit increase in UI-SN angle corresponded to a 0.177-unit increase in LL-E Line (p=0.004 and p=0.039, respectively) (Table 4). Additionally, a one-unit increase in overbite corresponded to a 0.835-unit decrease in H angle and a 0.749-unit increase in G-Sn-Pog′ (p=0.027 and p=0.032, respectively) (Table 4).

Table 4: Linear regression analysis of the significant correlation values

		β_0 (95% CI)	Std. Error	t	p	R^2	Adjusted R^2
Nasolabial angle	(Constant)	-3.861 (-15.482 – 7.76)	5.333	-0.724	0.483	34.7%	
	Overjet	-1.889 (-5.19 – 1.413)	1.515	-1.246	0.236		23.9%
	Overbite	1.413 (-2.163 – 4.989)	1.641	0.861	0.406		
UL-E Line	(Constant)	1.927 (0.688 – 3.166)	0.563	3.423	**0.006***	49.7%	35.9%
	UI-SN	0.096 (-0.171 – 0.363)	0.121	0.792	0.445		
	UI-OP	0.02 (-0.353 – 0.394)	0.17	0.121	0.906		
	Overbite	-0.3 (-0.723 – 0.124)	0.192	-1.558	0.148		
LL-E Line	(Constant)	0.067 (-1.213 – 1.347)	0.592	0.113	0.912	28.8%	23.3%
	UI-SN	0.177 (0.01 – 0.344)	0.077	2.293	**0.039***		
UL Thickness	(Constant)	-0.032 (-0.625 – 0.561)	0.275	-0.117	0.909	48.7%	44.7%
	Sn-GoMe	-0.523 (-0.845 - -0.201)	0.149	-3.51	**0.004***		
LL Strain	(Constant)	-0.303 (-1.691 – 1.085)	0.642	-0.471	0.645	26.4%	20.8%
	Overjet	0.49 (0 – 0.98)	0.227	2.161	0.05		
H Angle	(Constant)	1.99 (-0.119 – 4.099)	0.958	2.077	0.062	69.3%	61%
	UI-SN	0.002 (-0.452 – 0.457)	0.206	0.011	0.991		
	UI-OP	-0.299 (-0.934 – 0.337)	0.289	-1.034	0.324		
	Overbite	-0.835 (-1.555 - -0.115)	0.327	-2.554	**0.027***		
G-Sn-Pog′	(Constant)	-1.534 (-2.921 - -0.146)	0.642	-2.388	**0.033***	30.7%	25.4%
	Overbite	0.749 (0.075 – 1.422)	0.312	2.402	**0.032***		

*Linear regression analysis, *p<0.05*

Discussion

When it comes to the treatment of skeletal Class III malocclusion in adults, the patient's opinion about their profile is an important determiner (1). If the main problem is profile according to the patient, orthognathic surgery may be the only treatment option (19).

One of the main factors affecting the results of the treatment is soft tissue alteration induced by orthodontic tooth movements. Therefore, during the camouflage treatment, the procedure should be planned considering the effects of tooth movements on the soft tissues (20).

The aim of this study was to examine the effects of hard tissue changes that occur during camouflage treatment on soft tissues. Although 3D imaging techniques provide more detailed information, cephalograms are more commonly used tools in clinical practice. The cephalometric measurements that were preferred in this study are widely used all over the world and provide the clinician with information about the general diagnosis at first glance (21, 22). If the nature of the relationship between hard and soft tissues is known during treatment planning, a more accurate plan can be established. In this study, except for Wits, none of the sagittal skeletal values were subjected to the Pearson's correlation test since none of them showed a significant change according to the Student's t-test. However, it should be noted that all patients were mild to moderate skeletal Class III adult cases, so significant differences were not expected in their sagittal skeletal values (23).

The soft tissue and lip profile may be impacted by elements like elastic strength, bracket presripciton and torque selection, anchorage regimen, and extraction during treatment. Despite the fact that the literature has a variety of studies looking at soft tissue alterations, no publication uses a comparable methodology (24-26).

Li et al. reported that the impact of soft and hard tissue parameters on soft tissue evaluation of skeletal Class III patients are yet unknown. They also emphasized on the need of further investigation regarding the contribution of incisor positions in facial harmony during the camouflage treatment of skeletal Class III malocclusions (27). In the vertical dimension, as the SN-GoMe angle increased, a decrease in UL Thickness and increases in Pog′-TVL, LLA-TVL, and B′-TVL values were observed, which might be due to the posterior rotation of the mandible. Moreover, these correlations were found to be strong. The increase in Pog′-TVL and LLA-TVL are expected to contribute to the improvement of the lip profile in skeletal Class III patients, but the decrease in UL Thickness may create an effect that complicates the profile aesthetics. The benefits of these strong effects to the treatment should be considered well during the first examination of the patient. Therefore, if there is the right indication, a slight increase in the vertical dimension could be considered to help improve the profile.

In this study, a strong correlation was found between the UI-SN angle values of the patients and their UL-E Line and H angle values, which showed that the higher the incisor inclination was, the more the upper lip moved forward as expected. As a morphological feature in skeletal Class III patients, the upper lip is turned back and inward, and the lower lip is turned anteriorly and outward, which is aimed to be improved after the orthodontic treatment (28). Therefore, if the maxillary incisor angles are not suitable for camouflage treatment, the desired improvement in the lip profile may not be achieved. Additionally, there was a moderate correlation between UI-SN and LL-E Line in our study. So, maxillary incisor inclination may also affect the prominence of the lower lip. Since maxillary incisor proclination can affect both lips, the clinician should examine the initial lip posture accordingly to improve the lip profile.

Similar to the UI-SN angle findings, UI-OP had a strong correlation with H angle and UL-E Line, but at this point, the occlusal plane's inclination must be considered. The results of this study showed that the upper lip becomes more prominent as the occlusal plane becomes steeper. Additionally, there was a moderate negative correlation between overjet and nasolabial angle, which showed that the increase in overjet caused a decrease in the nasolabial angle as expected. The relationship between overjet and nasolabial angle on different mechanics and malocclusions has also been reported to be similar to the results in our study (29, 30). Moreover, a moderate negative correlation was found between overjet and LL Strain. It is a mechanically predicted outcome and has been mentioned in the literature before that the lower lip becomes protruded more as overjet increases (31). Therefore, the clinician is advised to make sure that the applied mechanics should only be kept at a level for relieving lower lip incompetency, not over-protruding the lip and disturbing the patient's profile. The overbite change results had strong negative correlations with UL-E Line and H angle and moderate positive correlations with nasolabial angle, G-Sn-Pog′, and Pog′-TVL. As an increase in the maxillary incisor angle will cause a decrease in overbite, a decrease in UL-E Line and nasolabial angle and an increase in H angle would be a predictable outcome as in this study. In the examinations of the influence of overbite changes on hard tissues, the correlation seen in G-Sn-Pog′ and Pog′-TVL changes was normal. This result was important in terms of the improvement of the lip profile, as well as the compensation of the deficiency in the upper lip profile caused by maxillary retrusion.

As seen in Table 3, it is clear that H angle was highly correlated with multiple hard tissue changes (UI-SN, UI-OP, and overbite). The hard tissue measurements that affected multiple soft tissues with strong correlations were SN-GoMe (UL Thickness, Pog′-TVL, LLA-TVL) and UI-SN angles (UL-E Line, LL-E Line, and H angle). Therefore, if profile improvement is anticipated following camouflage treatment, the Sn-GoMe and UI-SN angles are the hard tissue values that need the utmost attention. Overbite is also the parameter the most correlated with soft tissue parameters (Ul-E Line, H angle, Nasolabial angle, G-Sn-Pog′, Pog′-TVL). However, it should be considered that it affected only 2 soft tissues with strong correlation values.

In the further analyses in our study, it was revealed that a 1° increase in the SN-GoMe angle reduced the UL Thickness by 50%. This finding showed us how important vertical control is in this patient group, for whom it is necessary to preserve and perhaps even improve the upper lip profile. It was also observed that a 1° increase in the UI-SN angle made the lower lip more protruded by nearly 20%. Although it has been reported in the literature that the upper incisor angle and overjet affect the lower lip, this strong relationship should not be ignored clinically (32). Due to the nature of camouflage treatment in Class III malocclusion cases, the maxillary incisor angle is increased to improve the upper lip profile. In individuals whose lower lip is more prominent due to underlying skeletal problems, treatment planning should be made by keeping this in mind while ensuring balance between the lips. The results of the linear regression analysis in this study showed that the overbite value was highly compatible with two different soft tissue parameters. The common point of both soft tissue parameters was the Pogonion point. In this context, it should not be forgotten that an increase in overbite during treatment will bring the Pogonion forward, and therefore, worsen the soft tissue profile which is already compromised.

Even though the most commonly used analyses were preferred in cephalometric evaluations, 3D measurements may have superiority over 2D imaging while facilitating the understanding of different aspects of hard and soft tissue interactions in future studies.

Conclusion

Due to their close associations with soft tissues, SN-GoMe angle, UI-SN angle, and overbite are among the cephalometric criteria of utmost importance in Class III camouflage treatment planning. It would be advantageous for clinicians to select the biomechanics they will employ by considering these cephalometric characteristics if they aim to improve the lip profile and obtain better cosmetic outcomes.

Declaration

Funding

Not applicable.

Conflicts of interest / Competing interest

Not applicable.

Ethical approval

………… University Faculty of Medicine Clinical Research Ethics Committee (30.05.2023, 09.2022.1465)

Availability of data and material

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Authors' contributions

Concept: EB, GY; Design: EB, EOO; Data Collection: GY, BT; Analysis: EB, EOO; Literature: EOO, BT; Writing: EB, GY, BT.

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