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Research Article/Özgün Araştırma

Does vertical pattern affect lip strain in open-bite patients?: A cephalometric study

Açık kapanış hastalarında dik yön gelişimi dudak gerilimini etkiler mi?

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Abstract

Aim: To examine effect of skeletal pattern on lip strain in open-bite, in individuals with normal and increased vertical pattern.

Materials and Methods: 56 open bite patients with Normovergent (NG) and Hyperdivergent (HG) vertical patterns (Mean age: 16.57 years) underwent cephalometric analysis. Soft tissue labial, hard tissue, and dental inclinations were measured. Statistical analyses were performed using Kolmogorov Smirnov, Mann Whitney-U, and independent sample t-tests; Pearson and Spearman correlation analyses; and Linear regression analysis.

Results: In HG, each degree of SN-UOP increase caused 0.371 mm increase in lower lip strain. While in NG, upper lip strain was associated with IMPA and SNB (each degree caused 0.14 mm increase and 0.207 mm decrease respectively).

Conclusion: IMPA, SN-UOP and SNB were found to be the determinants of lip strain. Dental, vertical, and sagittal variables showed association with lower face.

Keywords: Open bite; Cephalometry; Vertical dimension.

Öz

Amaç: Bu çalışmada açık kapanışlı bireylerde dik yön paterninin dudak gerginliği üzerine etkisinin, normal ve artmış dik yön paternine sahip bireylerle karşılaştırmalı olarak incelenmesi amaçlanmıştır.

Gereç ve Yöntem: Normoverjan (NG) ve Hiperdiverjan (HG) dik yön paternlerine sahip (Ortalama yaş: 16,57 yıl) 56 açık kapanış hastasının lateral sefalometrik röntgenleri analiz edilmiş, hastaların yumuşak doku, sert doku ve dental eğimleri ölçülmüştür. İstatistiksel analizler Kolmogorov-Smirnov, Mann Whitney-U ve bağımsız örneklem t-testleri; Pearson ve Spearman korelasyon analizleri; ve doğrusal regresyon analizi kullanılarak gerçekleştirilmiştir.

Bulgular: HG'de her derece SN-UOP artışı alt dudak geriliminde 0,371 mm artışa neden olmuştur. NG'de ise üst dudak gerilimi IMPA ve SNB ile ilişkili bulunmuştur (Her bir derece artış, sırasıyla 0,14 mm artış ve 0,207 mm azalmaya neden olmuştur).

Sonuç: IMPA, SN-UOP ve SNB'nin dudak geriliminin belirleyicileri olduğu düşünülmektedir. Dental, vertikal ve sagital parametreler alt yüz ile ilişkili bulunmuştur.

Anahtar Kelimeler: Açık kapanış; Sefalometri; Dikey boyut.

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Introduction

Anterior open bite (AOB) malocclusion is commonly known for its need for the most complicated diagnostic steps and treatment process. High relapse tendency necessitates prolonged retention precautions. The multifactorial etiology and conflict amongst classifications frequently result in misdiagnosis.[1]

The etiology of increased vertical pattern by steepening of mandibular plane (MP) angle is disproportional growth in favor of vertical dimension. If antagonist dentition cannot compensate for the increasing interocclusal distance, a symmetrical AOB with posterior occlusal contacts is seen. Studies also report that trauma, inflammatory and autoimmune diseases, degenerative joint disease, functional factors, inheritance, and deleterious effects of bad habits may cause AOB.[2-4] Amongst functional factors, tongue posture or endogenous tongue thrust are the key etiologic factors in formation of functional AOB. However, confliction regarding lingual behavior, whether the tongue position is a contributor or a consequence, remains.[2, 5]

The contribution of MP angle as a causative component to AOB malocclusion was first suggested by Sassouni; who classified AOB as *dentoalveolar* or *skeletal*.[6] Today in clinical practice, MP is a strong indicative of vertical pattern.[7-9] However its relevance with AOB malocclusion is a matter of debate in literature.[10-12] Some authors claim that two conditions don't necessarily have to be seen together, while another group claims that skeletal origin of AOB can be distinguished from hyperdivergent cephalometric tracing results.[1, 13, 14]

Proclined anterior teeth and a normal vertical pattern usually indicate dental AOB.[14] Arat et al. classified AOB as *morphogenetic* or *functional* according to lower facial height and lip competency as diagnostic parameters.[1]

The chief concern of AOB individuals is often esthetic or functional problems such as inability to bite and speech problems.[3, 15, 16] However, the scale has another pan that is only visible to the clinician's eye. Evaluation of lip competence, incisal exposure, and inclination of occlusal plane (OP) are also crucial components of the clinical examination.[14] For example, lip incompetence is a pathological condition characterized by difficulty or inability to seal the lips and is commonly accompanied by AOB malocclusion. Etiologic factors are either skeletal, dental, or labial originated. If treatment is delayed, unappealing facial esthetics, speech problems and periodontal tissue reactions caused by mouth breathing are inevitable.[17]

Previous studies investigated the behavior of perioral soft tissues in different malocclusions, or mouth breathing as an etiologic factor of AOB.[18, 19] To best of our knowledge, none studied how vertical divergence affected the lip competence in AOB. Whether the soft tissue conditions are the response or cause is an issue that should be further investigated. The current study hypothesized that the increase in MP angle is an indisputable fact in AOB malocclusion, resulting in soft tissue response. So, primary aim of this study was to investigate the soft tissue response of labial structures to increased vertical dimension in a sample that has AOB malocclusion. The secondary aim was to analyze other contributory skeletal and dental factors of soft tissue response in AOB in normovergent and hyperdivergent patients.

Materials and Methods

Signed informed consent forms were obtained from all subjects at the beginning of their treatment.

The sample consisted of 56 AOB patients who received extraction treatment. The demographic data are presented in Table 1. The initial lateral cephalograms underwent cephalometric analysis following linear calibration, head orientation according to Frankfort horizontal by the same examiner (EB) using NemoStudio NX-Pro v.10.4.2 (Nemotec, Madrid, Spain). According to the tracing results, the sample was classified into two as (1) Normovergent Group ("NG"; n:28, 26°<GoMe-SN<39°, Mean: 35.53°±3.57) and (2) Hyperdivergent Group ("HG"; n:28, GoMe-SN>40°, Mean: 45.28°±3.7).

Table 1. Demographic data of the sample

Variables		Hyperdivergent Group			Normovergent Group		
	Sex	**n**		**%**	**n**		**%**
Demographic data	**Female**	17		60.7	16		57.1
	Male	11		39.3	12		42.9
	Total	28		100	28		100
		Mean	**Median**	**SD**	**Mean**	**Median**	**SD**
Pretreatment Age (y)		17.06	16.53	3.04	16.08	16.18	2.76

The inclusion criteria were as follows:

- ANB between -2 and 4 degrees,
- Lateral cephalograms with high quality,
- No previous orthodontic treatment history,
- No syndromic disorders,
- Complete anterior dentition,
- Sealed lip postures were included in the sample.

The soft and hard tissue parameters that were used in cephalometric analysis and their descriptions are presented in Figure 1 and Table 2.

Type of the study

The study is retrospective.

The sample size of the study

A post-hoc power analysis was conducted using G*Power (Version 3.1.9.6, Heinrich-Heine-Universität, Düsseldorf, Germany) software. The calculation revealed that 28 participants for each group allowed preserving 94.7% power and an alpha of 0.05 to obtain an effect size of 0.99 with reference to SNA values of groups.

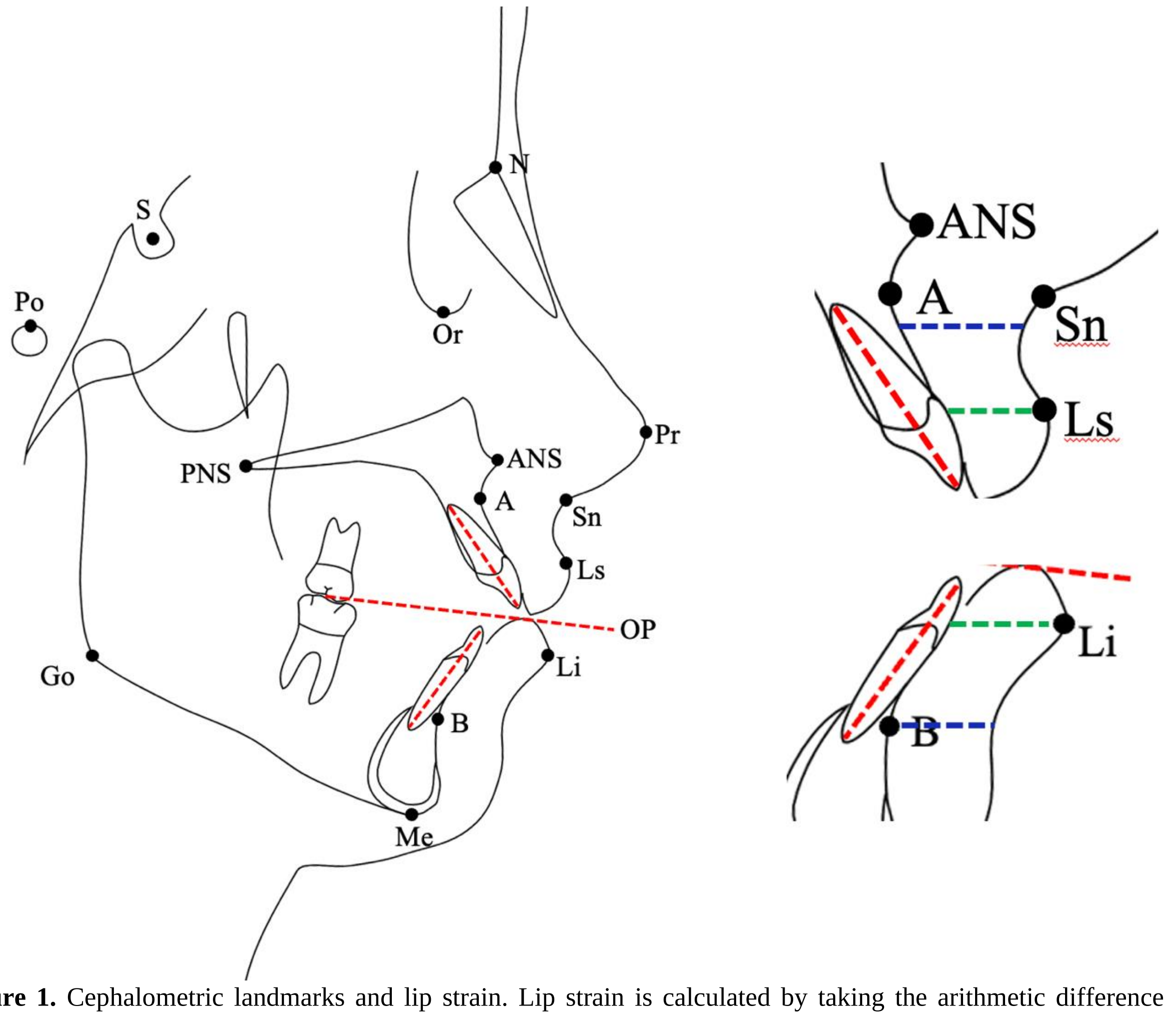

Figure 1. Cephalometric landmarks and lip strain. Lip strain is calculated by taking the arithmetic difference of lip thickness and basal lip thickness. Green dashed lines indicate lip thickness, blue dashed lines indicate basal lip thickness

Table 2. The cephalometric parameters that is used in the study, and their descriptions

Cephalometric Variables		Descriptions
Skeletal, Sagittal	**SNA (°)**	Angle formed between S, N and A point
	SNB (°)	Angle formed between S, N and B point
	ANB (°)	Arithmetic difference of SNA angle and SNB angle
	N⊥A (mm)	A true vertical line dropped from N and horizontal distance parallel to this true vertical line is measured from A point
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
	ANSMe/NMe	The ratio of lower facial height divided by total facial height (x100)
	Jarabak ratio	The ratio of posterior facial height divided by anterior facial height (x100)
	SN-PP (°)	Angle formed between S-N line and palatal plane
	SN-UOP (°)	Angle formed between S-N line and maxillary occlusal plane
Dental	**UI-SN (°)**	Angle formed between S-N line and and upper centrals axis
	UI-PP (°)	Angle formed between palatal plane and upper centrals axis
	IMPA (°)	Angle formed between lower centrals axis line and Go-Me line
	UI-OP (°)	Angle formed between upper centrals axis line and functional occlusal plane
	LI-OP (°)	Angle formed between lower centrals axis line and functional occlusal plane
	I̲-Ī (°)	Angle formed between upper and lower centrals axis lines
	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 (°)**	The angle formed by a line tangent to the base of the nose and a line tangent to the upper lip
	UL Thickness (mm)	Horizontal thickness of upper lip overlying the incisors at the level of vermilion border
	Basal UL Thickness (mm)	Lip thickness near the base of alveolar process, about 3 mm below A point
	UL Strain (mm)	Arithmetic difference between upper lip thickness and basal upper lip thickness. Values >1 mm show lip redundancy, negative values or 0 mm show lip strain.
	UL Length (mm)	Distance between subnasale (Sn) and stomion superius (Sts)
	LL Thickness (mm)	Horizontal thickness of lower lip overlying the incisors at the level of vermilion border
	Basal LL Thickness (mm)	Lip thickness near the base of alveolar process, at about B point
	LL Strain (mm)	Arithmetic difference between lower lip thickness and basal lower lip thickness. Values >1 mm show lip redundancy, negative values or 0 mm show lip strain.
	LL Length (mm)	Distance between stomion inferius (Sti) and menton (Me)

Data collection tools

Subjects were collected retrospectively from the archive of Orthodontics Department in Marmara University, Faculty of Dentistry. Data was collected using a cephalometric tracing software (NemoStudio NX-Pro v.10.4.2, Nemotec, Madrid, Spain).

Data analysis

Statistical analyses were performed using SPSS software (Version 25.0, IBM Corp, Armonk, NY, USA). The conformity of the variables to the normal distribution was assessed using Kolmogorov-Smirnov test. Intergroup differences of variables were analyzed with Mann Whitney-U and independent sample t-tests. Significantly different hard tissue variables in HG and NG were analyzed using Pearson and Spearman correlation analyses. Then linear regression analysis was performed on the significantly correlated pairs to interpret and formulize the relationship between soft and hard tissue variables. Statistical significance was set at p=0.05.

Ethics committee approval

Ethics committee approval was obtained from Medical School Ethical Committee of Clinical Studies of the Marmara University (Protocol no 09.2023.1253; 08/02/2024). The study conformed to the principles of Helsinki Declaration.

Results

All variables were measured twice at one-month intervals by a second researcher (YBA).

Intraclass coefficient ranging between 0.893 to 1.000 revealed that measurements had high reliability. The intergroup differences are presented in Table 3. Regarding dentoskeletal structures, FMA, GoMe-SN, Jarabak, SNA, SNB, NperA, SN-UOP, IMPA showed significant differences between HG and NG. The significant variables were then subjected to correlation analyses with soft tissue parameters. There were no significant intergroup differences between the soft tissue values in HG and NG.

Table 3. Evaluation of intergroup differences

Variables		Hyperdivergent Group			Normovergent Group			
		Mean	Median	SD	Mean	Median	SD	*p*
Skeletal, Sagittal	SNA (°)	76.75	77	2.99	80.07	80	3.63	0.000*a
	SNB (°)	74.57	74.50	3.12	78.32	78.50	3.74	0.000*a
	ANB (°)	2.18	2.50	0.14	1.75	2	0.11	0.278b
	N⊥A (mm)	-4.05	-4.90	3.82	-1.97	-1.15	3.63	0.042*a
Skeletal, Vertical	GoMe-SN (°)	45.28	44.5	3.70	35.53	36.50	3.57	0.000*a
	FMA (°)	36.25	37	4.03	27.14	28	3.96	0.000*a
	ANSMe/NMe	56.70	56.80	1.94	55.76	56.35	4.65	0.533b
	Jarabak ratio	61.86	61.55	3.31	66.60	66.45	3.37	0.000*a
	SN-PP (°)	10.03	9.50	3.75	8.32	8	3.50	0.082a
	SN-UOP (°)	18.61	19	4.68	14.96	15	3.57	0.002*a
Dental	UI-SN (°)	113.15	112	6.95	115.03	115.5	6.34	0.293a
	UI-PP (°)	114.93	115	8.79	116.14	116.5	6.71	0.564a
	IMPA (°)	87	88	5.82	93.25	91.50	6.53	0.0003*a
	UI-OP (°)	55.03	56	4.86	57.61	57.61	5.49	0.069a
	LI-OP (°)	68.39	68.5	5.65	66.78	67.50	5.70	0.294a
	I̲-Ī (°)	121.71	123.5	9.74	123.21	122.5	8.78	0.548a
	Overjet (mm)	3.44	3.10	2.06	2.96	2.40	2.35	0.418a
	Overbite (mm)	-1.24	-0.80	1.58	-0.63	-0.50	1.56	0.081b
Soft tissue	Nasolabial Angle (°)	108.07	110	11.93	107.10	107	10.36	0.748a
	UL Thickness (mm)	12.40	12.33	2.24	12.53	12.51	1.97	0.814a
	Basal UL Thickness (mm)	16.06	16.45	2.41	15.33	15.27	2.28	0.247a
	UL Strain (mm)	-3,67	-3.69	2.20	-2,80	-2.15	2.13	0.140a
	UL Length (mm)	21.34	21.28	2.68	22.05	21.95	3.23	0.376a
	LL Thickness (mm)	14.83	14.44	2.62	16.23	14.31	9.06	0.954b
	Basal LL Thickness (mm)	13.29	13.69	2.00	13.04	13.04	1.51	0.594a
	LL Strain (mm)	1.53	1.36	2.47	4.27	1.80	10.33	0.583b
	LL Length (mm)	49.01	55.30	4.49	49.41	52.96	4.43	0.733a

a: Independent sample t-test, b: Mann Whitney-U test; UL: Upper lip, LL: Lower lip; $*p<0.05$

In upper lip region, upper lip thickness and upper lip length had no association in NG, however, they had a moderate positive correlation with SNA *(r*=0.474 and *r*=0.449 respectively) in HG. Upper lip strain had also moderate positive correlation with SNA and SNB of HG (*r*=0.521 and *r*=0.502 respectively), and moderate negative with GoMe-SN (*r*=-0.482) in HG, while dental variables had no significant relation. In NG; IMPA had moderate negative (*r*=-0.485), and SNB had positive moderate correlations (*r*=0.430*)*, and vertical dimension of the jaws had no significant effect on upper lip strain. Moreover, nasolabial angle of HG had moderate and strong positive correlations with SNA (*r*=-0.547) and SNB (*r*=-0.664) respectively. In NG, nasolabial angle had moderate negative with SNA (*r*=-0.491), moderate positive with SNB (*r*=0.451) and NperA (*r*=0.414), moderate negative with SN-OP (*r*=-0.571) and strong negative with SN-UOP (*r*=-0.630). (Table 4)

Regarding lower lip region; lower lip thickness of HG was found to have weak positive correlation with IMPA (*r*=0.382) and moderate negative correlation with SN-UOP (*r*=-0.458). NG, on the other hand, had moderate negative correlation with SN-OP (*r*=-0.583). Lower lip length of HG was seen to be affected with moderate positive correlation by SNA (*r*=0.429) and weak negative correlation by SN-UOP (*r*=-0.376). However, in NG, the length interacted with

SNB and NperA with weak negative correlations (*r*=-0.390, *r*=-0.378, respectively). In terms of lower lip strain, moderate negative correlations were found with SN-UOP (*r*=-0.583 in HG, *r*=-0.420 in NG) and SN-OP in both groups. (*r*=-0.488 in HG, *r*=-0.554 in NG). (Table 4)

Table 4. Correlation between soft and hard tissue variables in Hyperdivergent and Normovergent Groups

Variables			Upper lip thickness		Upper lip length		Upper lip strain		Nasolabial angle		Lower lip thickness		Lower lip length		Lower lip strain	
			HG	NG	HG	NG	HG	NG	HG	NG	HG	NG	HG	NG	HG	NG
Vertical	FMA (°)	r	-0.099	-0.135	0.058	-0.005	-0.172	-0.021	-0.064	0.163	0.143	0.286	0.081	-0.269	-0.072	0.196
		p	0.616a	0.493a	0.768a	0.980a	0.380a	0.914a	0.745a	0.408a	0.467b	0.139b	0.683a	0.166a	0.715b	0.319b
	GoMe-SN (°)	r	-0.099	-0.168	0.067	-0.064	-0.482	-0.064	0.221	0.020	0.016	0.031	0.031	0.320	-0.253	-0.121
		p	0.616a	0.393a	0.737a	0.745a	0.009*a	0.747a	0.258a	0.918a	0.937b	0.876b	0.875a	0.097a	0.195b	0.539b
	Jarabak ratio	r	-0.099	-0.035	0.103	-0.165	0.037	-0.233	0.013	0.150	0.032	0.229	-0.029	0.136	0.209	0.127
		p	0.616a	0.861a	0.603a	0.401a	0.851a	0.233a	0.950a	0.445a	0.873b	0.242b	0.884a	0.490a	0.285b	0.518b
	SN-UOP (°)	r	-0.233	-0.141	-0.140	-0.008	-0.162	-0.362	0.349	-0.630	-0.458	-0.346	-0.376	0.014	-0.583	-0.420
		p	0.233a	0.474a	0.476a	0.967a	0.412a	0.059a	0.069a	<0.001*a	0.014*b	0.072b	0.049*a	0.944a	0.001*b	0.026*b
Dental	IMPA (°)	r	0.357	-0.083	0.290	0.109	0.080	-0.485	0.186	0.127	0.382	0.117	0.326	-0.192	0.056	0.127
		p	0.063a	0.676a	0.135a	0.580a	0.684a	0.009*a	0.343a	0.521a	0.045*b	0.553b	0.090a	0.327a	0.776b	0.518b
Sagittal	SNA (°)	r	0.474	-0.082	0.449	-0.077	0.521	0.292	-0.547	-0.491	0.347	-0.201	0.429	-0.246	0.209	-0.170
		p	0.011*a	0.677a	0.017*a	0.699a	0.004*a	0.132a	0.003*a	0.008*a	0.071b	0.305b	0.023*a	0.207a	0.285b	0.387b
	SNB (°)	r	0.310	-0.220	0.172	0.073	0.502	0.430	-0.664	0.451	0.056	0.019	0.167	-0.390	0.213	0.163
		p	0.108a	0.260a	0.381a	0.710a	0.006*a	0.023*a	<0.001*a	0.016*a	0.778b	0.922b	0.395a	0.040*a	0.277b	0.407b
	NPerA (mm)	r	0.187	-0.195	0.278	0.085	0.231	0.200	-0.276	0.414	0.013	0.114	0.183	-0.378	-0.138	0.291
		p	0.341a	0.321a	0.152a	0.666a	0.237a	0.308a	0.155a	0.028*a	0.948b	0.563b	0.351a	0.048*a	0.484b	0.133b

a: Pearson correlation analysis, b: Spearman correlation analysis; HG: Hyperdivergent group, NG: Normovergent group; *$p<0.05$

In the last step of statistical analyses, significantly correlated pairs were investigated by linear regression analysis. (Table 5) When evaluating the components of upper lip region, it was found that one unit increase in SNA leads 0.355 unit increase in upper lip thickness (*p*=0.011, R^2=0.224) and 0.403 unit increase in upper lip length (*p*=0.017, R^2=0.201) in HG. However, in NG, there was no further significance. When upper lip strain of HG was investigated, there was no statistical significance. In NG; in case of one unit increase (1) in IMPA: strain increases 0.140 unit, (2) in SNB: strain decreases 0.207 unit (*p*=0.004, Adjusted R^2=0.312). For nasolabial angle of HG, each unit increase in SNB was found to cause 2.954-unit decrease in the angle (*p*=0.001, Adjusted R^2=0.400), while in pairwise comparisons of NG no statistical significance was found (*p*=0.015, Adjusted R^2=0.328).

In the lower lip region of HG; the increase in each unit of IMPA caused 0.208 unit of lower lip thickness increase, while SN-UOP caused 0.286 decrease (*p*=0.0002, Adjusted R^2=0.449). In NG, there was no significant relationship (*p*=0.086). Even if the regression model of lower lip length in HG is significant, no significant equation was obtained in either group. As the variable of the groups; lower lip strain of HG increased 0.371 unit, as a result of a unit increase of SN-UOP (*p*=0.002, Adjusted R^2=0.350), however in NG, there was no hard tissue interaction that could be related with lip strain.

Table 5. Linear regression analyses of hard and soft tissues

		Hyperdivergent group							
Dependent variables	**Independent variables**	**β₀**	**%95 Confidence Interval Lower bound**	**Upper bound**	**Std. Error**	**t**	**p**	**R^2**	**Adjusted R^2**
UL Thickness	**(Constant)**	-14.853	-35.295	5.589	9.945	-1.493	0.147	0.224	0.195
	SNA	0.355	0.089	0.621	0.129	2.742	0.011*		
UL Length	**(Constant)**	-9.589	-34.439	15.261	12.089	-0.793	0.435	0.201	0.171
	SNA	0.403	0.079	0.726	0.157	2.560	0.016*		
ULStrain	**(Constant)**	-13.829	-44.401	16.743	14.813	-0.933	0.360	0.361	0.282
	GoMe-SN	-0.221	-0.483	0.041	0.127	-1.737	0.095		
	SNA	0.377	-0.146	0.902	0.254	1.486	0.150		
	SNB	-0.118	-0.692	0.455	0.278	-0.425	0.674		
Nasolabial angle	**(Constant)**	290.042	195.275	384.809	46.013	6.303	0.000001	0.445	0.400
	SNA	0.499	-1.982	2.979	1.204	0.414	0.682		
	SNB	-2.954	-5.33	-0.577	1.154	-2.559	0.017*		
LL Thickness	**(Constant)**	2.085	-9.950	14.120	5.844	0.357	0.724	0.490	0.449
	IMPA	0.208	0.075	0.340	0.064	3.229	0.003*		
	SN-UOP	-0.286	-0.451	-0.121	0.080	-3.583	0.001*		
LL Length	**(Constant)**	3.068	-71.996	78.134	36.447	0.084	0.933	0.231	0.170
	SNA	0.756	-0.154	1.666	0.442	1.711	0.099		
	SN-UOP	-0.348	-0.929	0.233	0.282	-1.234	0.228		
LL Strain	**(Constant)**	7.389	3.487	11.291	1.894	3.900	0.001	0.398	0.350
	SN-UOP	-0.371	-0.683	-0.058	0.152	-2.443	0.022*		
		Normovergent group							
Dependent variables	**Independent variables**	**β₀**	**%95 Confidence Interval Lower bound**	**Upper bound**	**Std. Error**	**t**	**p**	**R^2**	**Adjusted R^2**
UL Thickness					***NS***				
UL Length					***NS***				
ULStrain	**(Constant)**	-5.955	-25.242	13.332	9.365	-0.636	0.531	0.363	0.312
	IMPA	-0.140	-0.249	-0.031	0.053	-2.649	0.014*		
	SNB	0.207	0.017	0,397	0.092	2.245	0.034*		
Nasolabial angle	**(Constant)**	216.623	81.621	351.625	65.096	3.328	0.003	0.452	0.328
	SNA	-1.107	-3.760	1.545	1.279	-0.865	0.396		
	SNB	-0.335	-2.836	2.165	1.206	-0.278	0.783		
	NPerA	-0.265	-1.613	1.084	0.650	-0.407	0.688		
	SN-UOP	1.290	-1.180	3.760	1.191	1.083	0.290		
LL Thickness	**(Constant)**					***NS***			
	SNB								

LL Length	**(Constant)** **SN-UOP**	***NS***
LL Strain	**(Constant)** **SNA** **SNB**	***NS***

Linear regression analysis; UL: Upper lip, LL: Lower lip; *$p<0.05$

Discussion

Soft tissue profile started to take more place in contemporary orthodontic diagnosis and treatment planning. Many studies have examined AOB malocclusion and its relationship with soft tissues.[1, 5, 20] However none focused on the effects of vertical dimension over labial structures in an AOB sample. Thus, the current study aimed to investigate the interaction between dental, skeletal, and soft tissue variables.

The vertical pattern of the sample comprised normovergent and hyperdivergent individuals since the etiologic nature of AOB malocclusion usually manifests in vertical direction.[1] The severity of AOB malocclusion in the present sample can be considered moderate. Cephalograms were preferred in this study since the technique provides the evaluation of both soft and hard structures, as well as its ease and availability in clinical routine.[21] Sealed lip posture was preferred to be able to evaluate lip strain which is the prominent goal of the current study.

During sample selection, GoMe-SN was used as the primary criterion to describe the vertical relationship. ANB angle was standardized to achieve similar anteroposterior relationship of the jaws relative to each other. Moreover, upper incisor inclination which is a robust determinant of both upper and lower lip support, was similar between two groups. Thus, these interfering factors were eliminated so that expression of soft tissue parameters due to vertical differences could be understood better. The significantly differing variables such as sagittal (HG<NG) and vertical (NG<HG) skeletal parameters, OP (NG<HG) and lower incisor inclinations (HG<NG) could undergo rather unbiased evaluation. However, in contrast to the expected outcome, soft tissue characteristics of both groups were found to be similar, and the study hypothesis was rejected. Although there was a numerical difference in lip strain parameters between the two samples, they were statistically insignificant.

During interpretation of the statistical analysis results, the similarities and differences between structural natures of groups were examined (Table 3) to explain this outcome. The two groups were found to be similar in terms of some vertical parameters such as ANSMe/NMe, SN-PP, and negative overbite. This can be the reason for insignificant soft tissue differences between groups, preventing significant soft tissue expression of vertical variation. These findings conformed to a previous study, defining the characteristics of skeletal AOB.[22] Previous studies compared open and normal bite individuals in two groups and found no difference in SN-UOP value.[5, 23] Several studies also found similar results to the present study, suggesting that NG has increased IMPA and GoMe-SN values in comparison with normal bite individuals.[5, 24] In the same studies, upper incisor inclination of AOB group was higher than normal bite group. However, in our study, both NG and HG had no significant difference in terms of upper incisors.[5]

Another notable point is the significant difference in sagittal positions of the jaws (SNA, SNB; HG<NG). This raises the question whether the vertical excess restricts the sagittal growth. This may be a question to be further investigated. In comparison of normal bite and AOB patients with both normovergent patterns, Shenoy and colleagues found similar SNA and SNB values in both groups, while Hassan et al. suggested that the individuals who show lip incompetence have shorter anterior cranial

base, thus exhibiting more retrognathism.[25] This latter complies with the present results.

Even though the increasing vertical dimension was hypothesized to affect the soft tissue conditions in the first place, a few vertical parameters could reach out significance until linear regression analysis. Only upper lip strain had significant relationship with FMA and GoMe-SN. For other parameters, SNA, SNB, IMPA, and SN-UOP parameters were concluded as the fundamental determinants of lip structures.

Regarding upper lip length, each degree of increase in SNA of HG was found to cause 0.403 mm of upper lip length increase. Forward position of maxillary bone may be deemed to force the upper lip to extend to reach lip closure.

All negative strain values were interpreted as "increased lip strain" since values >1 mm show lip redundancy, and negative values or 0 mm show lip strain. (Table 2) E.g., in NG, the negative regression equation between IMPA and upper lip strain was reported as each degree of increase in IMPA, caused a 0.140 mm increase in upper lip strain. Vice versa, a degree of increase in SNB caused 0.207 mm lip redundancy. However, the noteworthy emphasis is significantly higher mean values of IMPA and SNB in NG may reinforce their regression significance on upper lip strain; unlike HG, which has a significant regression model, however, has no interaction with independent variables. Dixit and Shetty studied a sample consisting of children with tongue thrust.[20] They concluded half of the thrusters had also AOB, and none without thrust had AOB, while many of the thrusters also showed lip incompetency. Even so, whether tongue or lips are responsible for the imbalance remained unknown. Moreover, Hassan et al. reported that interincisal angle is the most prominent dental determinant, and MP angle is the vertical determinant of lip incompetence.[25] Our findings offered no significant intergroup difference of interincisal angle, however, the results about MP are concurrent with those, suggesting moderate negative correlation.

Nasolabial angle of HG is the second highest (40%) explained regression model of the study. In this model, each degree of SNB decreases nasolabial angle by 2.954 degrees. This interaction may be thought of as the mandible moves forward; the reducing tonus of perioral muscles will decrease nasolabial angle. In NG, skeletal values were in an acceptable range, so, even if significant correlations were observed, no significance was found in regression model.

Lower lip thickness of HG had the highest percentage of explanation by its regression model (44.9%) in current study. IMPA showed a synergetic relation such that each degree of this variable will cause 0.208 mm of lower lip thickness increase. The same interaction was also observed in upper lip thickness, increasing 0.355 unit for each unit of SNA. In normal conditions, increasing hard tissue support ends up with toned perioral musculature to be able to seal the lips. This contrary result can be explained by interindividual anatomic variability.

Increase in the SN-UOP caused 0.286 unit of lower lip thickness decrease in HG, which is an expected consequence. Increased tension of lip closure is anticipated when OP rotates clockwise. This result approves the regression model of lower lip strain which involves SN-UOP interaction as well, and each unit increase of the angle was found to lead to 0.371 units of strain in lower lip. Strain in the lower lip - which is also the primary study objective- was the third most explainable parameter (35%) by its regression model in HG. On the other hand, in NG, OP inclination was significantly lower than HG. This may be the reason that lower lip strain is not significantly interfering with a flatter OP of NG.

Regarding lower lip length, no interactions were observed both in NG and HG even if the regression model of HG had significance.

Limitations

The shortcomings of the study are, although cephalograms are practical in daily routine, the functional examination of soft tissues may be overlooked. On the present closed lip cephalograms, the lip length and thickness parameters were found similar in two groups.

However, we cannot compare and comment on soft tissue characteristics of the patients with lips in repose. Unfortunately, this comparison could not be done in the retrospective nature of the study. Therefore, the parameters related to soft tissue function and phenotype could not be discussed.

Conclusion

The inevitability of involvement of several etiologic factors puts AOB malocclusion in the hot spot. Lip strain may usually be deemed as a result of dentoalveolar protrusion, related to IMPA parameter by our findings as well. Before preferring an extraction treatment plan, the clinician should pay attention to the whole, considering whether a short upper lip, an increased lower facial height, or severe sagittal discrepancies might be the cause.[26] If the main goal is to achieve a neutral lip closure, the parameters that need to be taken into consideration and relevant treatment mechanics should be well planned for more stable treatment outcomes. Recommendations for future studies can be listed as examining similar correlations in individuals with more severe open bite malocclusions that may necessitate surgical correction and investigating the disagreements between diagnostic and treatment approaches.

Ethics Committee Approval

Marmara University Faculty of Medicine, Ethics Committee approved this study. (Protocol number: 09.2023.1253; dated 08/02/2024) This study conformed to the principles of Helsinki Declaration.

Informed Consent

Informed consent was obtained from the individuals participating in the study.

Author Contributions

Conceptualization: EB, YBA; Design: EB, YBA; Auditing: EB; Resources: EB, YBA, BE; Data collection: EB, BE; Data analysis and interpretation: EB, YBA; Literature review: EB; Writers: EB, YBA, BE; The final version of this article was read and approved by all authors.

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Conflict of Interest

The authors declare that there is no conflict of interest for this article.

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Statements

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