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Comparative Study on the Impact of Vertical Growth on dental and Soft Tissue Profile

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ABSTRACT

Aim: *This study aimed to compare facial groups based on their vertical skeletal characteristics (hypodivergent, normodivergent, and hyperdivergent) and their associated soft tissue features, focusing on the lips and chin.*

Materials and Methods*: A total of 103 lateral cephalometric x-rays were obtained from patients sought orthodontic treatment. The samples were categorized into hypodivergent (Md/Mx <20°), normodivergent (Md/Mx between >20° and 28°), and hyperdivergent (Md/Mx >28°) facial types.*

Results*: In Class I group, normodivergent facial type was the most prevalent (55.2%), while hyperdivergent pattern dominated in Class II (54.5%) and Class III (40%) groups. The hypodivergent group exhibited the highest mean thickness for upper and lower lips (8.95 mm and 9.35 mm, respectively). Hyperdivergent individuals had the greatest mean upper lip height (11.3 mm), whereas hypodivergent individuals had the highest mean lower lip height (25.32 mm). Procumbency of upper (PUL) and lower lips (PLL) was most prominent in the hypodivergent group (2.08 mm and 0.87 mm, respectively). Hyperdivergent individuals showed the maximum mean chin thickness (7.84 mm). Statistically significant differences were observed only between Hypo vs Normo-divergent groups in upper lip thickness (ULT), and in PUL and PLL between Hypo vs Normodivergent and Hypo vs Hyperdivergent groups.*

Conclusion: *The study concluded that a correlation between the hard tissue (bones and teeth) and soft tissue (facial features) topography were found in Sudanese subjects. There was a significant correlation between the soft tissue variables including nasolabial angle, upper lip thickness, and length in the three different skeletal vertical dimensions, but this correlation was observed only in the lower jaw. Individuals with hypodivergent facial patterns tend to have greater thickness in the upper and lower lips, lower lip height, compared to normodivergent and hyperdivergent counterparts.*

Keywords
Lip thickness, Lip height, Chin thickness, Skeletal Vertical pattern.

Introduction and review of literature

The main goal of orthodontic treatment is to attain and sustain ideal functionality and aesthetics. When formulating an orthodontic diagnosis and treatment strategy, it is essential to take into account enhancements in both function and visual appeal. One crucial aspect to consider is the facial aesthetics, particularly when evaluating the soft tissues from a side view. Interestingly, there is a scarcity of research in the field of orthodontics prior to the 1950s that made efforts to establish a link between orthodontic treatment and the improvement of soft-tissue profiles [1].

Cephalometric evaluations of facial soft tissues are a crucial component in orthodontics, offering significant value in the areas of diagnosis, treatment planning, and evaluating potential changes in facial aesthetics resulting from orthodontic interventions utilizing 2D images. This methodology empowers orthodontists to develop personalized treatment strategies that cater to patients with diverse skeletal patterns, rather than depending exclusively on standardized norms applicable to the general population [2].

While cephalometric soft tissue analysis is undeniably valuable, it presents challenges in interpretation due to a multitude of factors that can impact the outcomes. These influencing factors encompass skeletal relationships, tooth positioning, soft tissue thickness, ethnicity, gender, and age. It's crucial to emphasize that achieving a harmonious facial structure is not solely contingent upon achieving a proper occlusion as determined by standard cephalometric assessments [2,3]. In one of the early investigations into the effects of orthodontic treatment on soft-tissue profiles, Riedel conducted a study involving thirty individuals and utilized lateral cephalograms. His research revealed that the alignment of the upper and lower jaw bases, the degree of convexity in the skeletal structure, and the positioning of the anterior teeth in relation to their respective jaw bases have a notable influence on the soft-tissue profile. Although orthodontic treatment frequently leads to alterations in facial profiles, it's essential to recognize that accurately predicting these changes can be a challenging endeavor [4].

The position of both the upper and lower incisors is a critical determinant in shaping the soft tissue profile, particularly in relation to how the lips interact with these incisors. Researchers have made efforts to establish a connection between the backward movement of the incisal edges of the front teeth and the retraction of the lips. For instance, Jacobs et al. identified a ratio of 0.7:1, indicating that there is a correlation between the movement of the upper lip and the retraction of the upper incisors. Additionally, they found a 1:1 ratio between the movement of the lower lip and the retraction of the lower incisors. However, they also observed that predicting how the lower lip responds to the retraction of the lower incisors is less precise when compared to the upper lip's response to the retraction of the upper incisors [5].

Flynn et al. [6] employed Legan and Burstone's [7] cephalometric analysis to derive standard measurements from cephalometric X-rays of 33 black American adults with well-aligned teeth. Their research revealed that black individuals, in comparison to white individuals, exhibited increased upper and lower lip lengths, as well as thicker soft tissue in their lips. Moreover, black individuals demonstrated sharper nasolabial angles. In contrast, the angle between the lower face and throat was found to be more pronounced in males, while the vertical height ratio was lower in males than in females. Additionally, males displayed longer lower lip lengths [6,7].

In their study, Jain and Kalra [8] utilized the Legan and Burstone analyses [7] to establish soft tissue cephalometric standards for a group of North Indian individuals consisting of sixty adults aged 18 to 25. Their research unveiled notable distinctions between North Indians and Caucasians. Specifically, North Indians displayed more pronounced convex facial features, protruding lips, and sharper nasolabial angles when compared to Caucasians. Moreover, within the North Indian group, males tended to exhibit more convex facial features and protruding lips than females, while females demonstrated a more balanced distribution of vertical facial proportions. These findings highlight significant variations from the typical characteristics observed in Caucasian populations [8].

The assessment of facial soft tissue through cephalometric analysis plays a pivotal role in the field of orthognathic surgery. This analytical approach is indispensable in assisting orthodontists and surgeons in developing treatment strategies that encompass not only the skeletal aspects but also the expected modifications in soft tissue brought about by the surgical intervention. Therefore, it becomes imperative to take into account all relevant factors that could influence the results of cephalometric analysis when interpreting alterations in facial soft tissue [9].

Consequently, orthodontists and surgeons must prioritize considering the individual characteristics and features of each patient when devising a treatment plan, rather than relying solely on standardized values derived from a specific population. This personalized approach is essential to ensure the most effective and tailored outcome for each patient undergoing orthognathic surgery [10,11].

Extensive research has been conducted to investigate the influence of sagittal (side-to-side) and vertical (up-and-down) skeletal patterns on the appearance of soft tissues [12,13]. As an example, studies conducted on an Indonesian population demonstrated that individuals with Class III skeletal patterns exhibited a more prominent upper lip in comparison to those with Class II patterns. This research underscores the significant impact of sagittal skeletal variations on soft tissue characteristics [14].

Furthermore, the thickness of facial soft tissue, particularly in the chin area, displayed notable disparities among various vertical developmental patterns. Hyperdivergent patterns were found to have the thinnest soft tissue in this region. This highlights the importance of considering vertical skeletal patterns when assessing soft tissue attributes [15,16]. In the past, earlier studies made the assumption that soft tissue features were a direct reflection of the underlying hard tissue structures [17].

Achieving the ideal vertical facial profile represents a fundamental goal in orthodontic treatment due to its close association with attaining optimal facial aesthetics. Orthodontic literature classifies individuals into distinct facial types according to their vertical skeletal characteristics. These categories typically encompass hypodivergent individuals, who have reduced vertical dimensions, normodivergent individuals, who have average vertical dimensions, and hyperdivergent individuals, who exhibit increased vertical dimensions.

In orthodontics, various methods have been proposed for evaluating vertical relationships. Nonetheless, two commonly used measurements include the inclination of the mandibular plane relative to the anterior cranial base and the percentage of lower anterior face height in relation to the total anterior face height.[18]

In 2022, Abdulal and his research team conducted a study to investigate the facial soft tissue morphology of patients seeking orthodontic treatment at the Faculty of Dentistry's Orthodontic clinic at Beirut Arab University. The study categorized these patients into three equal groups based on their mandibular plane angle: Hypodivergent facial type (SN/MP <27°). Normodivergent facial type (SN/MP between 27° and 37°). Hyperdivergent facial type (SN/MP >37°).Their findings revealed that individuals with hypodivergent facial patterns exhibited greater thickness in both the upper and lower lips, an increased height of the lower lip, and more forward projection (procumbency) of both lips when compared to individuals with other facial types [19].

Upon a comprehensive review of the existing literature, it becomes apparent that there is a limited number of studies that comprehensively describe and compare facial soft tissue characteristics among different vertical skeletal groups. Most research in this field tends to focus predominantly on investigating how soft tissues respond to changes resulting from orthodontic treatment, as exemplified by the work of Ramos et al. [20].

The study conducted by Al-Mashhadany among Iraqi adults aimed to assess facial soft tissue thickness in individuals with different vertical discrepancies. The sample was categorized into three groups, each consisting of twenty participants, based on the SN-MP angle. The analysis involved evaluating gender differences using an independent sample t-test, as well as comparing soft tissue thickness among individuals with various vertical relationship. The findings of the study revealed that, in general, males exhibited thicker soft tissue compared to females. Additionally, within the vertical angle groups, those with low angles had thicker soft tissue in contrast to individuals with high and normal angle groups, particularly among males [21].

Toth et al. conducted a study examining the connections between soft tissue characteristics in a posed smile and vertical cephalometric skeletal measurements. The primary objectives were to measure the three-dimensional parameters of a posed smile and explore potential correlations with vertical cephalometric skeletal measurements. The research gathered pretreatment records from a group of 110 white girls aged 12 to 18 years. Through correlations and multiple linear regression analyses, the study aimed to identify associations and predictive links between cephalometric skeletal measurements and changes in soft tissue. The study's conclusions indicated moderate correlations, suggesting that as SN-GoGn and anterior facial height increased, the gap between the lips (interlabial gap) widened while the smile index decreased. Moreover, the research revealed significant relationships between specific hard tissue cephalometric measurements and the width of the smile, as well as movements of the lower lip [22].

In 2017, Subramaniam and colleagues conducted a study titled "Comparison of soft tissue chin prominence in various mandibular divergence patterns of the Tamil Nadu population." The study aimed to assess the prominence of the soft tissue chin (STC) in different mandibular divergence patterns. They selected a total of 90 lateral cephalograms from individuals above 19 years of age who were seeking orthodontic treatment (38 men and 52 women). The lateral cephalograms were categorized into three groups based on their mandibular divergence patterns. The study's conclusions revealed that the STC was thicker in individuals with hypodivergent patterns, while there was no significant difference in STC thickness between those with hyperdivergent and normodivergent patterns. Additionally, it was found that STC prominence was greater in males compared to females. Therefore, these findings suggest that these parameters can be valuable when planning advancement genioplasty procedures for Class II individuals [23].

Macari and Hanna conducted a study in which they compared soft tissue chin (STC) thickness among individuals with different mandibular divergence patterns. Their research revealed a noteworthy difference between hyperdivergent and hypodivergent individuals. Furthermore, they observed that an individual's growth pattern played a role in the amount of soft tissue growth in the chin area. In some cases, orthodontic treatment alone may not be sufficient, and orthognathic surgery may be necessary in combination with orthodontic care to achieve optimal results [16]. As stated by Kasai, the connection between the hard tissue (such as bones and teeth) and the soft tissue profile (like facial skin and muscles) can vary significantly. This variability arises from the fact that certain soft tissue structures are closely associated with the underlying hard tissue, while others are influenced by factors such as their length, thickness, and function. In essence, Kasai highlights that the relationship between hard and soft tissues in the face is complex and multifaceted, and it's important to consider these various factors when assessing and planning orthodontic or orthognathic treatments for optimal aesthetic outcomes [24].

Cephalometric dentoskeletal analysis, on its own, is insufficient for predicting the final soft tissue outcomes of orthodontic treatment. It's crucial to accurately determine the initial position of the lips to plan appropriate treatment. Moreover, comprehending the relationship between the hard tissues (bones and teeth) and soft tissues (such as the lips) before treatment is essential for predicting the potential changes that may occur as a result of orthodontic intervention. This holistic approach is necessary to achieve successful treatment planning and outcomes [25].

An analysis of a group of Saudi adults with normal occlusion revealed that the differences in upper lip length and lower lip position could be attributed to variations in the position of the upper incisors and the position and inclination of the lower incisors. Saxby and Freer observed a correlation between the horizontal position of both the upper and lower incisors and the angulation of the upper incisors in relation to lip position. They further emphasized that the positions of the upper and lower incisors, as well as the angulation of the upper incisors, play crucial roles in determining the characteristics of the associated soft tissues. In essence, the alignment and orientation of the incisors have a significant impact on the appearance of the lips and other surrounding facial features [3].

Racial and ethnic characteristics have been identified as additional factors that influence soft tissue configuration. Studies have shown that white Europeans tend to have thinner lips with minimal protrusion, whereas individuals of Middle Eastern origin often exhibit more lip protrusion. On the other hand, Orientals and Africans are more likely to have greater lip thickness and protrusion. These variations in lip characteristics are attributed to genetic and ethnic factors and contribute to the diversity in facial aesthetics among different racial and ethnic groups [26].

In 2019, Plaza et al. conducted a study examining the correlation between skeletal Class II and Class III malocclusions and vertical skeletal patterns. Their findings revealed that the normal vertical skeletal pattern was the most prevalent in both Class II and Class III malocclusion groups. Notably, the Class II malocclusion group exhibited a higher percentage of hyperdivergent patterns than hypodivergent patterns. In contrast, the Class III malocclusion group, as determined by ANB and Wits App-Bpp (mm) measurements, showed a greater prevalence of hypodivergent patterns compared to hyperdivergent patterns.

Given the current gap in research, this study was designed to address the need for a comprehensive examination and comparison of various facial groups distinguished by their vertical skeletal traits. These groups were categorized as hypodivergent, normodivergent, or hyperdivergent. The primary aim of the study is to evaluate the soft tissue characteristics associated with these different facial groups, with a specific focus on the lips and chin regions since we have not found any published study making these types of measurements in Sudanese patients who had also undergone orthodontic treatment.

Material and Method

The study involved 103 Sudanese individuals aged 18 to 25. Those with prior orthodontic or orthognathic treatment, craniofacial anomalies, facial trauma, or identified asymmetries were not included in the study.

Pretreatment lateral cephalometric radiographs were taken and traced digitally using the Web Ceph program. The measurements obtained from the cephalometric radiographs were analyzed. The sample was then classified into three skeletal classes based on the maxillary mandibular plane angle into hyodiversion group.

All lateral cephalometric x-rays were taken by the same operator using the same device.

The cephalometric landmarks in upper jaw as follows (Figure 1):

- Porion (Po): the midpoint of the upper contour of the external auditory canal. • Orbitale (Or): the lowest point on the inferior margin of the orbit.
- Nasion (N): the most anterior point on midline of fronto-nasal suture.
- Soft tissue Nasion (n): The point of maximum convexity between the nose and forehead
- Columella (Cm): The most prominent point on the borderline between lower part of the nose contour and nasal tip.
- Subnasale (Sn): the deepest point on the curvature between the anterior nasal spine (ANS) and the prosthion on the anterior surface of the maxilla.
- Sub-spinale (point A): the innermost point on the contour of the pre-maxilla between ANS and the incisor tooth. (A'): Soft tissue A point.
- Anterior nasal spine (ANS): The tip of the bony anterior nasal spine in the median plane.
- Posterior nasal spine (PNS): The posterior spine of the palatine bone constituting the hard palate coincides with the lowest point of the pterygomaxillary fissure.
- Labrale superius (UL): the most anterior and convex point of upper lip vermilion.
- Stomion superius (Stms): the lowest point of the margin of upper lip vermilion.
- Root apex of upper incisor (Ur)
- Incisor superius (Is)
- The cephalometric landmarks in lower jaw were as follows (Fig 1):
- Supramental (point B): the innermost point on the contour of the mandible between the incisor tooth and the bony chin. (B'): Soft tissue B point.
- (Pog): Most anterior point in mandibular symphysis.
- Incisor inferius (Ii)
- Root apex of lower incisor (Lr)
- Labrale inferius (Li): The most anterior point on the convexity of the lower lip
- Sulcus inferius (Si): The point of greatest concavity in the midline
- Soft tissue pogonion (Pg'): The most anterior point of the soft-tissue profile over the mandibular symphysis.

- Menton (Me): The most caudal point in the outline of the symphysis, it is regarded as the lowest point of the mandible
- Gonion (Go): The most inferior and posterior point at the angle of the mandible, formed by the junction of the tangent to the posterior border of the ramus and inferior border of the mandible meets the mandibular outline.

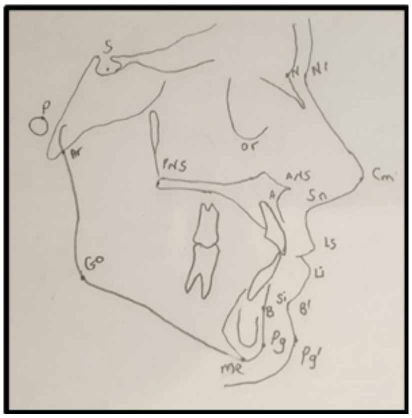

Figure 1: The cephalometric landmarks in upper and lower jaw.

Cephalometric Planes include the following:

1– Maxillary plane (MXP): Formed by a line extend from anterior nasal spine to posterior nasal spine

2– Mandibular plane (MP): Formed by a line tangent to the lower border of the mandible extends from Gonion to Menton.

3– Anterior cranial base plane. Formed by a line extend from point Sella Tursica to Nasion

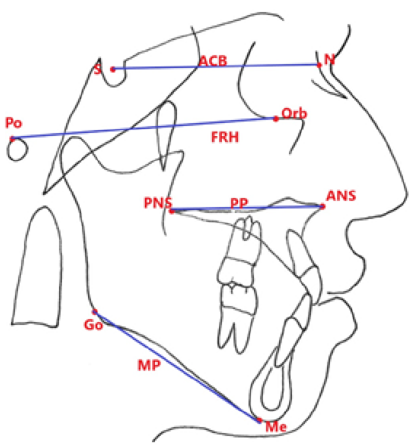

Figure 2: Cephalometric Planes.

The angular measurements include the following:

A. Dental angular measurements (Figure 3):

1–U1–NA angle: The angle formed between the long axis of upper central incisor and the NA plane.

2–U1–SN angle: The angle formed between the long axis of upper central incisor and the SN plane.

3–L1–MP (IMPA) angle: The angle formed between the long axis of lower central incisor and the mandibular plane.

4–L1–NB angle: The angle formed between the long axis of lower central incisor and NB line

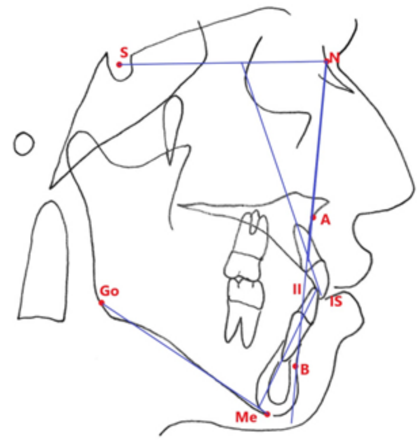

Figure 3: Dental angular measurements.

1. U1–SN angle, 2. UI- NA angle, 3. IMPA angle, 4. L1–NB angle

B. Skeletal angular measurements (Figure= 4):

The skeletal angular measurements include the following:

1- Chin angle N- angle. (Nordalval angle.). Formed between the mandibular plane and Tangent connecting Pog to B points.

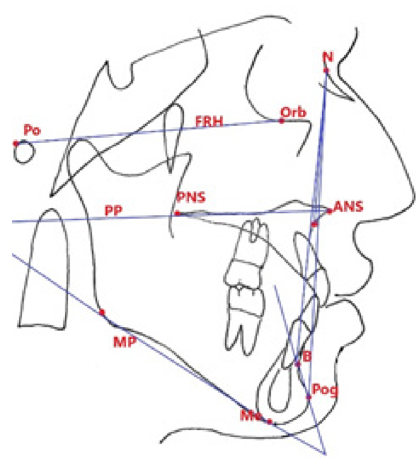

Figure 4: Skeletal angular measurements.

S to Na, Na to Point A, Na to Pog, ANB angle, FMA angle, Hard tissue chin angle (N- angle.),

ML- NL: (Inter-jaw angle)

C. Soft tissue angular measurements (Figure 5):

The soft tissue angular measurements include the following:

1–Nasolabial angle (NLA): The angle formed med by a line tangent to the lower border of the nose from subnasal point (Sn) with the line from Laberale superius (ls) to subnasal point (Sn).

2– Mentolabial angle (MLA): The angle formed by a line tangent to the chin from soft tissue Pogonion point (Pog') to submental point (B and from tangent extended from Laberale inferius (li) to submental point (B'). This angle represents the depths of the mental fold.

3– Soft tissue chin angle (Tangent B'-Pog' to Mandibular line).

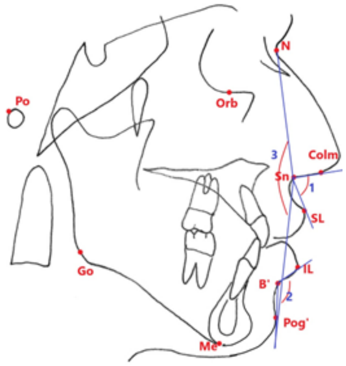

Figure 5: Landmarks and Soft tissue angular measurements.

Nasolabial angle (NLA), Mentolabial angle (MLA), Soft tissue facial convexity angle (N'– sn–Pog'):

iii) Linear measurement of soft tissue features

α) Upper lip characteristics and skeletal patterns.

Upper lip characteristics were described using the following indices:

1. Upper lip length is the vertical distance between Sn and Stms
2. Upper lip thickness is the distance from the labial surface of upper incisor to UL
3. Basic upper lip thickness is the distance from the point 3 mm below point A to Sn.

β) Lower lip characteristics and skeletal patterns.

Lower lip characteristics were described using the following indices:

1. Lower lip length is the vertical distance between Stm and Si
2. Lower lip thickness is the distance from B point to Si
3. Basic lower lip thickness is the distance from Si to point B.

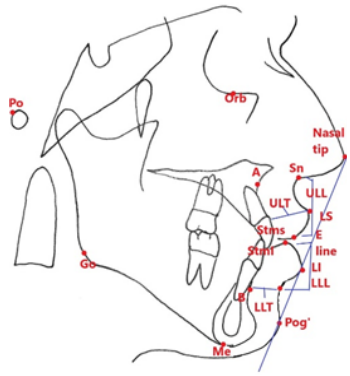

Figure 6: Land marks and linear measurement of soft tissue features Upper lip length, Upper lip thickness and Upper lip to Esthetic line, Lower lip length, Lower lip thickness and Lower lip to Esthetic line

Statistical Analysis

The Statistical Package for the Social Sciences (SPSS) version 22.0 was used for data analysis. The data were analyzed using two statistical methods: analysis of variance (ANOVA) and unpaired t-test as well as Pearson's correlation test. The level of significance was set at P<0.05.

Result

Table 1: Distribution of vertical dimension in class I class II and class III Malocclusion groups (MMPS CLS Cross – tabulation).

Angle Classification		MMPS CLS			
		Hypo	Normo	Hyper	Total
class 1	% within angle class	17.2%	55.2%	27.6%	100.0%
class 2	% within angle class	9.1%	36.4%	54.5%	100.0%
class 3	% within angle class	23.3%	36.7%	40.0%	100.0%

Hypo: Hypo diversion, Normo: Normo diversion, Hyper: Hyper diversion

Table 1 exhibited that in class 1 group; the highest percentage (55.2%) was found in norm diversion whereas hyper diversion pattern was in the second rank (27%). On the other hand, Hyper diversion pattern was the highest (54.5%) in class II group whereas the norm diversion was in the second rank (36.4%). Moreover, hyper diversion pattern was found to be the highest (40%) in class III group whereas class II was in the second rank.

Table 2 showed that there were statistical significance differences between the dental and soft tissue variable of upper lip thickness (class I VS class III) and upper lip to E-plane in upper jaw (class II vs class III). In the lower jaw statistically, significant differences were noted in the lower incisor to mandibular plane angle only between class II and class III.

Table 3 demonstrated comparison between the norm diversion mean values and the dental and soft tissue variables in upper and lower jaw. The result showed there were statistically significant differences between the dental and soft tissue variables of the upper lip to E-plane in upper jaw only between class I and class II. In the lower jaw statistically, significant differences were noted in the lower incisor to NB in mm between class I and Class II, and inclination of the lower incisor to NB angle between class II and Class III. Also, found in lower incisor inclination to mandibular plane (angle) between class II and Class 11I at P <0.001 and between Class I and Class II at P < 0.02.

Table 4 exhibited the comparison between class I, II, III hyper diversion groups and the dental and soft tissue variables in upper and lower jaw. The result indicated that there were statistically significant differences between the dental and soft tissue variables of the upper lip to E-plane in upper jaw only between class II and class III at P< 0001. In the lower jaw statistically significant differences were noted in the lower incisor to NB mm between class II and Class III at P< 0.009 and lower incisor to NB angle between class II and Class III at P < 0.014 and also in lower incisor

Table 2: Comparison between the dental as well as soft tissue and vertical hypo--diversion groups in class I, 11, III malocclusion groups.

Variables	Hypo diversion MX_MN angle < 20 degrees Class I malocclusion		Hypo diversion MX_MN angle < 20 degrees Class II malocclusion		Hypo diversion MX_MN angle < 20 degrees Class III malocclusion		Statistical Analysis (ANOVA TEST)
Upper Jaw	**Mean**	**Sd**	**Mean**	**Sd**	**mean**	**Sd**	**P-Value**
UI to NA mm	7.2680	2.81048	6.2375	2.9244	7.3057	1.8306	0.761 NS
UI to NA	29.9080	7.08666	28.7225	8.5421	32.4286	6.6175	0.693 NS
UI to SN	115.282	13.88829	114.8650	9.4347	124.3386	6.3703	.220 NS
Nasolabial angle	83.2420	16.20985	89.5050	9.2865	87.2273	13.021	0.058 NS
ULT mm	12.5620	1.77909	13.1775	1.6123	16.1229	2.2589	0.02 S* C1 vs Cl III
ULL mm	21.2000	2.17213	20.8300	2.7239	19.8371	4.2366	0.775 NS
Upper lip to E-plane	-.3780	1.43048	.0625	2.5087	-3.3529	2.1149	0.027 S* Cl II vs Cl III
Lower Jaw	Mean	Sd	Mean	Sd	Mean	Sd	P-Value
LI to NB mm	6.5140	4.85088	8.6800	2.5176	7.7400	2.3167	0.630 NS
LI to NB	29.3540	12.67819	31.6375	6.6291	28.6743	3.2417	0.839 NS
IMPA	102.614	10.18247	107.9975	2.6110	93.8900	3.1338	0.008 S* Cl II vs Cl III
Mentolabial angle	116.924	12.54598	108.4000	23.431	114.1643	45.298	0.929 NS
LLT mm	14.0420	3.04951	14.0900	1.5599	16.5929	2.5324	0.178 NS
LLL mm	17.8680	1.63358	17.4025	2.3297	19.5829	2.0208	0.189 NS
Lower lip to E-plane	1.5660	2.69166	1.8700	1.4902	4.2243	3.3201	0.237 NS

P< 0.05= *, P< 0.01=**, P<0.001=***, NS = Not significant

Table 3: Comparison between the dental as well as soft tissue and vertical hyper-diversion groups in class I ,11, III malocclusion groups.

Variables	Normo diversion MX_MN angle >20-<28 degrees Class I malocclusion		Normo diversion MX_MN angle >20-<28 degrees Class II malocclusion		Normo diversion MX_MN angle >20-<28 degrees Class III malocclusion		Statistical Analysis (ANOVA TEST)
Upper Jaw	**Mean**	**Sd**	**Mean**	**Sd**	**mean**	**Sd**	**P-Value**
UI to NA mm	7.3163	3.68060	7.4200	3.4817	7.5764	2.6130	0.981 NS
UI to NA	28.3006	8.57526	27.6519	8.1085	31.2200	6.9230	0.504 NS
UI to SN	111.261	8.71965	112.1713	8.7845	116.6855	8.1183	0.256 NS
Nasolabial angle	90.7813	17.26642	86.9462	15.204	87.2273	13.021	0.750 NS
ULT mm	13.9538	1.88209	13.5894	2.2034	14.1782	1.6134	0.730 NS
ULL mm	22.8175	2.39285	22.0963	2.9767	22.4855	1.9653	0.725 NS
Upper lip to E-plane	.3213	2.83258	1.5894	2.6148	-2.3436	2.4699	0.002 S* C1 vs C II
Lower Jaw	Mean	Sd	Mean	Sd	mean	Sd	P-Value
LI to NB mm	7.2056	2.61037	10.1469	3.3802	7.4136	2.8995	0.016 S* Cl I vs CII
LI to NB	28.8031	6.86531	34.2513	8.48251	26.7233	4.45697	0.020 S* Cl II vs III
IMPA	96.5681	6.57577	103.2350	7.9751	90.7645	5.5567	<0.001S** Cl II vs Cl III 0.025 S* Cl I vs Cl II
Mentolabial angle	119.695	17.09439	110.1975	23.958	125.9627	18.325	0.136 NS
LLT mm	16.7875	2.14168	15.6931	2.9105	15.6991	2.0032	0.371 NS
LLL mm	19.3831	2.48053	17.4850	2.7818	19.2309	2.7629	0.105 NS
Lower lip to E-plane	2.8919	3.25380	4.0450	3.3466	2.3864	1.9091	0.338 NS

P< 0.05= *, P< 0.01=**, P<0.001=***, NS = Not significant

to mandibular plane angle between class II and class 11I at P <0.001 and between class I and class II at P < 0.04.

Table 5 presented findings indicating that there were no significant correlations observed between all soft tissue variables in the upper jaw and the three different skeletal vertical relationships (p > 0.05).

Table 6 showed that three of the soft tissue variables in the lower jaw exhibited significant statistical correlations, both at the 5% and 1% significance levels. These correlations were as follows:

Normodivergent individuals: Two variables showed significant correlations - Lower lip length (P < 0.01) and soft tissue chin (P < 0.05).

Table 4: Comparison between the dental as well as soft tissue and vertical hyper-diversion groups in class I, 11, III malocclusion groups.

Variables	Hyper diversion MX_MN angle >28 degrees Class I malocclusion		Hyper diversion MX_MN angle >28 degrees Class II malocclusion		Hyper diversion MX_MN angle >28 degrees Class III malocclusion		Statistical Analysis (ANOVA TEST)
Upper Jaw	**mean**	**Sd**	**Mean**	**Sd**	**mean**	**Sd**	**P-Value**
UI to NA mm	7.5963	4.27254	6.8758	3.0044	7.6783	2.8784	0.734 NS
UI to NA	28.6850	7.95952	25.3163	7.1754	30.3900	6.2391	0.120 NS
UI to SN	108.312	9.14838	109.3529	7.9423	112.0417	7.0020	0.524
Nasolabial angle	92.4625	10.26683	84.8225	18.128	78.4417	12.823	0.158 NS
ULT mm	13.4688	1.61570	13.5242	1.5574	14.1500	1.4755	0.478 NS
ULL mm	23.7788	2.46719	24.2800	3.0134	22.0900	3.1607	0.124 NS
Upper lip to E-plane	-1.7087	3.70197	1.5075	2.2166	-3.9133	3.6882	<0.001 S**, Cl II vs Cl III,0.029 S* Cl I vs II
Lower Jaw	mean	Sd	Mean	Sd	Mean	Sd	P-Value
LI to NB mm	7.7850	4.10915	11.2325	3.7894	7.5333	2.9124	0.009 S** Cl II vs Cl III
LI to NB	27.8188	6.45423	33.0775	8.1742	25.1092	7.0819	0.014 S* Cl II vs Cl III
IMPA	90.4487	7.22441	94.0179	8.1432	81.4733	7.3158	<0.001 S**, Cl II vs Cl III,0.040, Cl I vs Cl III
Mentolabial angle	128.115	14.94564	123.9938	13.469	136.8875	16.723	0.056
LLT mm	16.3425	2.01369	16.9325	3.0144	17.3658	2.4210	0.712 NS
LLL mm	19.8750	2.22395	20.2958	2.4837	21.3117	2.5160	0.376 NS
Lower lip to E-plane	1.7175	3.26872	5.1579	2.9775	1.8508	3.7005	0.006 S**0.017 S* Cl I1 Vs Cl III 0.033 S* Cl I Vs Cl II

P< 0.05= *, P< 0.01=**, P<0.001=***, NS = Not significant.

Table 5: Comparison of correlation between the inclinations of the upper incisors as well as the lips and the three skeletal vertical relationship groups.

Variables	Hypo diversion MX_MN angle < 20 degrees (n =16)		Normo diversion MX_MN angle > 20 < 28 (n =43)		Hyper diversion MX_MN angle >28 (n =44)		
Upper Jaw	**r**	**P**	**r**	**p**	**r**	**p**	**Comment**
UI to NA	-0.121	0.656	0.147	0.347	0.109	0.482	No sig. Cor
UI to SN	-0.200	0.458	0.177	0.256	-0.117	0.448	No sig. Cor
Nasolabial angle	0.138	0.610	0.071	0.651	0.212	0.166	No sig. Cor
ULT	-0.418	0.107	0.293	0.057	0.052	0.737	No sig. Cor
ULL mm	0.353	0.180	0.235	0.130	0.263	0.085	No sig. Cor

HPO=Hypo diversion, ND= Norm diversion. HP= Hyper diversion,
P< 0.05= *, P< 0.01=**, P<0.001=***, No Sig. Cor. = No significant Correlation

Table 6: Comparison of correlation between the inclinations of the lower incisors as well as the lips and the three skeletal vertical relationship groups.

Variables	Hypo diversion MX_MN angle < 20 degrees (n =16)		Normo diversion MX_MN angle > 20 < 28 (n =43)		Hyper diversion MX_MN angle >28 (n =44)		
Lower Jaw	**r**	**P**	**r**	**P**	**r**	**p**	**Comment**
LI to NB	0.615*	0.011	0.251	0.104	0.161	0.298	*HPO
IMPA	0.188	0.485	-0.144	0.356	-0.188	0.223	No sig. Cor.
Mentolabial angle	0 .229	0. 393	0.271	0.079	-.060	0.699	No sig. Cor
LLT mm	0.188	0.485	0.258	0.094	0.117	0.450	No sig. Cor
LLL mm	0.349	0.185	0.422**	0.005	0.065	0.675	** ND
Soft tissue chin angle	0. 291	0.274	0.306*	0.046	0.487**	<.001	*ND **HP

HPO=Hypo diversion, ND= Normo diversion. HP= Hyper diversion,
P< 0.05= *, P< 0.01=**, P<0.001=***, No Sig. Cor. = No significant Correlation.

Hypodivergent individuals: One variable demonstrated a significant correlation - LI to NB ($P < 0.05$).

Hyperdivergent individuals: One variable displayed a significant correlation - Soft tissue chin ($P < 0.01$).

These findings suggest that there was a significant correlation between the soft tissue variables and the three different skeletal vertical dimensions, but this correlation was observed only in the lower jaw.

Discussion

Orthodontic treatment has a dual purpose: it works to enhance both bite functionality and facial appearance. It's important to recognize that the aesthetics of the face are closely tied to the positioning of teeth and jawbones beneath the skin. Consequently, many patients pursue orthodontic treatment primarily for cosmetic reasons. Establishing a personalized standard for facial profile beauty is crucial, along with identifying the factors that play a role in achieving it [27]. This is because it's widely believed that the appearance of soft tissues, such as the face, closely mirrors the underlying patterns of the hard tissues, like the bones and teeth [17,28].

Several studies highlight the importance of considering vertical growth in conjunction with anteroposterior growth to attain proper skeletal facial proportions [29-31]. Additionally, Ghafari and Macari suggested that problems in the vertical dimension could either enhance or mask misalignments in the sagittal plane [32]. Furthermore, Bergman; in assessing skeletal patterns, provided valuable insights into the interplay of the maxilla and mandible considering both the horizontal and vertical dimensions [2]. Further, the Orthodontists use the evaluation of the lip, chin, and nose, the three important area, to help determine the aesthetics of a person's profile when planning orthodontic and orthognathic treatment. This means understanding how the soft tissues connect with the shape and structure of nearby bones and teeth. This knowledge is crucial for making accurate diagnoses and setting precise goals after treatment [33].

In the present study, we explored the relationship between dental and soft tissue profiles and various vertical skeletal relationships. The results indicate that no significant correlations were observed between all soft tissue variables in the upper jaw and the three distinct skeletal vertical relationships ($p > 0.05$). However, in the lower jaw, statistically significant correlations were found at the 5% and 1% significance levels. Among Normodivergent individuals, two variables exhibited significant correlations – Lower lip length ($P < 0.01$) and soft tissue chin ($P < 0.05$). For Hypodivergent individuals, one variable demonstrated a significant correlation – LI to NB ($P < 0.05$).Further, in Hyperdivergent individuals, one variable displayed a significant correlation – Soft tissue chin ($P < 0.01$) which was partially agreed with other studies reported significant variations in the chin and nose among different skeletal patterns. However, there have been relatively fewer studies specifically focused on the lips [34,35]. The existing evidence highlights the substantial importance of the lips in facial aesthetics, whether the face is at rest or in motion. Lips are often a central focal point that quickly draws people's attention during their everyday communication and interactions [36,37].

In the current investigation, a notable discrepancy in the thickness of soft tissue in the chin (STC) was observed among individuals with varying mandibular divergence patterns. Specifically, those with hyperdivergent profiles exhibited a significant correlation ($r = 0.48$, $p < 0.001$) with an increased soft tissue thickness in the chin compared to individuals with hypodivergent or normodivergent profiles. These findings suggest distinct growth rates in the thickness of the soft tissue overlaying the underlying hard tissue and align, in part, with the observations made by Foley and Duncan, who identified diverse facial growth patterns from the Nasion (Na) to the pogonion (Pog) in late adolescent males. Furthermore, Subtelny's observations noted that regardless of mandibular divergence pattern, men generally displayed greater thickness of soft tissue in the chin (STC), particularly at the Pog and Me levels, compared to women. This gender-based difference in STC thickness is in line with findings from a study by Nanda et al., which reported similar trends [38-40]. It is important to note that comparing the results of the present study with those of the aforementioned studies is challenging due to differences in methodology and gender classification. However, gender classification was not included in the present study.

It's noteworthy that our study revealed a notably higher and statistically significant correlation in soft tissue chin thickness in the hyperdivergent group ($P < 0.001$), while a significant correlation at 5% level was observed in the normodivergent group. This outcome is consistent with the findings reported by Nanda et al., who also observed a difference in soft tissue chin (STC) thickness between these two groups [40].

However, the disparities observed in soft tissue chin (STC) thickness could potentially be linked to ethnic variations, as noted by Uysal et al. This agrees with the finding of Uysal et al. who stated that differences in research methodologies, including the use of different distinct vertical angle measurements, could also contribute to the variations in findings across these studies [41]. It's important to acknowledge that making direct comparisons between our current study and the previous mentioned studies may not be straightforward due to the lack of gender distribution information and different statistical method.

When investigated the malocclusion association between sagittal and vertical skeletal patterns and possibility of developing skeletal Class II or Class III. Our study is partially in line with Plaza et al. findings in Class II group, hyperdiverted patterns were more prevalent (54.5%), nevertheless, disparities were found in our results when compared to the Class III group, where hyperdiverted patterns prevailed (40%). This contrasts with Plaza et al.'s observations, which indicated a higher incidence of hypodivergence in Class III malocclusion based on ANB and App-Bpp measurements whereas in our study it is based only on ANB angle [42].

Many studies have looked at how upper teeth affect the position of the upper lip. This study adds that both upper and lower teeth influence the position of the lower lip, showing the complex relationship between dental and facial structures in shaping overall facial aesthetics. However, just following standard criteria for placing teeth doesn't guarantee that the surrounding soft tissue will match well, as shown in Oliver's study on lip thickness and strain [43]. This finding was confirmed by Subtelny's extensive study on facial structures [44], This is due to considerable variations in the soft tissue covering the teeth and bones. Consequently, relying solely on the dentoskeletal pattern might not be enough to assess facial harmony, as discussed by Arnett and Bergman [45].

The findings of the present study suggest that there was a significant correlation between the soft tissue variables including nasolabial angle, upper lip thickness, and length and the three different skeletal vertical dimensions, but this correlation was observed only in the lower jaw. Further, the nasolabial angle and mentolabial angle showed that no significant differences were found between the three vertical patterns as well as no significant correlation. However, previous studies have explored the relationship between nasolabial angle, upper lip thickness, and length with skeletal patterns. However, these studies have yielded controversial perspectives and they often lacked an adequate sample size while failing to account for other potentially influencing factors or confusing variables [35,46].

Multiple studies have pointed out a tendency for bimaxillary protrusion among the Saudi population, characterized by both upper and lower jaw protrusion, resulting in more lip protrusion compared to individuals of Caucasian descent. This was confirmed by Kasai et al. who identified a connection between the position of the lower incisors and the thickness of the upper lip. In the present study the result exhibited bimaxillary protrusion of the upper and lower incisors without investigating the effect in lip protrusion. The findings of the above studies highlight the intricate relationship between the alignment of the teeth, particularly the lower incisors, and the characteristics of the overlying soft tissues, such as the upper lip. Further, changes in the position of the lower incisors can influence the appearance and thickness of the upper lip, which is a critical consideration in orthodontic and facial aesthetic assessments [24].

Both upper and lower lip thicknesses were highest for Class III followed by Class I and Class II, respectively. Lip lengths also were found to be highest for Class III skeletal relation The Nasolabial angle was larger in Class II malocclusion when compared to Class I and Class III. This result in agreement with Chaudhary et al. in their study of Subjects visited to Department of Orthodontics BPKIHS [47]. Our study in Sudanese population sample highlights the importance of considering ethnic and racial factors in orthodontic and facial aesthetic evaluations. Recognizing that different populations have distinct dental and facial traits highlights the necessity for a thoughtful and culturally aware approach in orthodontic assessments and treatment planning [48-52]. Hence, it's important to note that changes in the soft tissue facial profile resulting from tooth movement have unique characteristics that can't be easily calculated using simple ratios or formulas. While there is wide variability among individuals, it is still possible to make predictions about Posttreatment profile changes. To do this, it's essential to evaluate the pretreatment facial soft tissue profile on an individual basis. Studying the relaxed lip posture, as described by Burstone, is crucial for accurately determining the Posttreatment posture [53]. Thus, future studies incorporating three-dimensional evaluation methods are composed to provide a more precise and comprehensive measurement of facial soft tissues.

The utilization of three-dimensional assessments can capture the details of facial structures, offering a more accurate representation of facial soft tissue characteristics and their interplay with underlying skeletal features. These methodological advancements hold the potential to significantly enhance our comprehension of facial aesthetics and contribute to more effective treatment planning in the fields of orthodontics and orthognathic surgery.

The limitations of our study agree with Chaudhary et al. who acknowledged. Firstly, the racial variation in soft tissue thickness, as highlighted in existing literature, may affect the generalizability of our findings, given that our study was conducted among localized Sudanese population. Additionally, we did not conduct a gender-based analysis of soft tissue thickness due to an uneven distribution of male and female participants in our sample. Moreover, the use of lateral cephalogram for measurements limited our ability to assess both sides of the face. This is noteworthy, as previous research has demonstrated unequal soft tissue thickness between the right and left sides of the face. The utilization of three-dimensional radiographs for soft tissue evaluation would have provided a more comprehensive and accurate assessment [47].

Conclusion

The findings of the present study include the following:

1) A correlation between the hard tissue (bones and teeth) and soft tissue (facial features) topography were found in Sudanese subjects.
2) No significant correlations were observed between all soft tissue variables in the upper jaw and the three distinct skeletal vertical relationships ($p > 0.05$). In the lower jaw, statistically significant correlations were found at the 5% and 1% significance levels.
3) Among Normodivergent individuals, two variables exhibited significant correlations – Lower lip length ($P < 0.01$) and soft tissue chin ($P < 0.05$) whereas, in Hypodivergent individuals, one variable demonstrated a significant correlation – LI to NB ($P < 0.05$). In the other hand in Hyperdivergent individuals, one variable displayed a significant correlation – Soft tissue chin ($P < 0.01$).
4) Individuals with hypodivergent facial patterns tend to have

greater thickness in the upper and lower lips, lower lip height compared to normodivergent and hyperdivergent counterparts.

5) Both upper and lower teeth influence the position of the lower lip, showing the complex relationship between dental and facial structures in shaping overall facial aesthetics. However, just following standard criteria for placing teeth doesn't guarantee that the surrounding soft tissue will match well,
6) There was a significant correlation between the soft tissue variables including nasolabial angle, upper lip thickness, and length in the three different skeletal vertical dimensions, but this correlation was observed only in the lower jaw.
7) The utilization of three-dimensional radiographs for soft tissue evaluation would have provided a more comprehensive and accurate assessment.

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