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Comparative Study of Soft Tissue and Hard Tissue Variables Correlation between Two Different Racial groups: A Canonical study

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ABSTRACT

Aims: *The purpose of this study was to investigate the correlation between dental, skeletal, and soft tissue variables and compare the results with Saudi study and other previous studies.*

Material and Method: *The sample size consisted of 29 adult Sudanese patients (ages 18 to 25) seeking orthodontic treatment, and 19 variables were examined. The error of the method was assessed using Student's t-test, and canonical correlation analysis was used to analyze the correlation between soft and hard tissues.*

Results: *The study found that the Sudanese population had higher mean values in dental and soft tissue variables compared to the Saudi population, while similar mean values were found in the skeletal sagittal relationship, except for the vertical relationship, where the Saudi population had a higher tendency for an open basal configuration. The canonical analysis revealed that the upper and lower incisors' inclinations had a strong negative loading, while the nasolabial angle and lower lip thickness and position had moderate loading.*

Conclusion: *These findings show the impact of these variables which can help the clinician in diagnosis, prediction and assessment of post treatment changes. Additionally, the multivariate statistical analysis extracted a clinically significant association between soft tissue and hard tissue.*

Keyword

Skeletal, Dental, Soft tissue, Correlation, Canonical study.

Introduction and Literature Review

Orthodontic treatment is used to enhance the function and occlusion of the teeth as well as the aesthetics of the face. However, dentoskeletal tissue and underlying soft tissue are thought to be important for determining facial profile. The relative location of the maxilla and mandible, which were evaluated in the sagittal and vertical dimensions, respectively, is reflected in skeletal patterns, on the other hand [1].

Orthodontic treatment is not only aimed at improving the functional aspects and occlusion of the teeth, but also the appearance of the face. The determination of facial profile is influenced by both the dentoskeletal tissue and underlying soft tissue. The position of the maxilla and mandible in the sagittal and vertical dimensions, respectively, reflects the skeletal patterns that play a significant role in this determination [1].

Through the use of 2D pictures, cephalometric soft tissue evaluations of the face are helpful for diagnosing, planning therapy, and assessing potential changes in facial appearance brought on by orthodontic treatment. Instead of just using norm values for normal populations, it aids orthodontists in creating more customized treatment regimens for patients with diverse skeletal patterns [1].

Cephalometric soft tissue evaluations, based on 2D pictures, are valuable tools for diagnosing, planning orthodontic therapy, and predicting changes in facial appearance resulting from such treatment. These evaluations provide a more individualized approach to treatment planning by taking into account the unique skeletal patterns of each patient, rather than relying solely on norm values for general populations [1].

Numerous elements, including as the development of the facial skeleton, the size of the nose, and the inclination of the teeth, affect the soft tissue profile. Burstone [2] described in detail the lip posture and its role in orthodontics and proposed the use of the relaxed lip position for taking cephalograms and for treatment planning. In order to establish a ratio between posterior motions of the incisal edge of the anterior teeth, various studies were interested in the relationship between the retrusion of the maxillary and mandibular incisors and the upper and lower lips [2].

The appearance of the soft tissue profile is influenced by various factors, including facial skeletal development, nose size, and tooth inclination. Burstone [2] provided a comprehensive description of lip posture and its significance in orthodontics. He suggested using the relaxed lip position for taking cephalograms and treatment planning. Several studies have examined the correlation between the retrusion of the maxillary and mandibular incisors and the position of the upper and lower lips to establish a ratio for posterior movement of the anterior teeth [2].

The ratio between the movement of the upper lip and the retraction of the maxillary incisors was reported by Jacobs et al. [3] to be 0.7: 1, while the ratio between the movement of the lower lip and the retraction of the mandibular incisors was reported to be 1:1. The latter is noted to be less predictable than the former.

Jacobs et al. [3] conducted a study to determine the ratio between the movement of the upper and lower lips and the retraction of the maxillary and mandibular incisors, respectively. They found that the ratio between the movement of the upper lip and the retraction of the maxillary incisors was 0.7:1, while the ratio between the movement of the lower lip and the retraction of the mandibular incisors was 1:1. However, the study noted that the ratio for the lower lip was less predictable than the ratio for the upper lip.

Additionally, Caplan and Shicapuja discovered that African Americans had posterior motions of the upper and lower lips that were 1.75:1 and 1.2:1, respectively. This was dependent on the lower and upper incisors retracting [4]. Furthermore, Yasutomi et al. [5] observed that these ratios were 1.85: 1 and 1.32: 1 in a study with Japanese subjects.

Caplan and Shicapuja [4] found that in African Americans, the ratio between the posterior movement of the upper lip and retraction of the upper incisors was 1.75:1, and the ratio between the posterior movement of the lower lip and retraction of the lower incisors was 1.2:1.

Yasutomi et al. conducted a similar study with Japanese subjects and found ratios of 1.85:1 and 1.32:1 for the upper and lower lips, respectively. These ratios were also dependent on the retraction of the corresponding incisors [5].

The significance of soft tissues in orthodontic treatment has been acknowledged by numerous researches. These researches made an effort to apply these ideas to clinical practice. Tweed [6] was one among those people who thought the mouth was crucial in portraying the beauty and personality of the face. He asserts that variations in the inclination of the mandibular incisors with respect to the basal bone are strongly related to changes in the occlusal relationships of the teeth, which have an impact on the shape and aesthetics of the lips. The Tweed triangle is used in clinical treatment based on this concept. Additionally, various researchers looked at the soft tissues of the face's aesthetics [7-10].

The role of soft tissue in orthodontic treatment has been recognized by several studies, and efforts have been made to apply these findings in clinical practice. Tweed, [6] for instance, believed that the mouth played a critical role in projecting the beauty and personality of the face. He suggested that changes in the occlusal relationships of the teeth resulting from variations in the inclination of the mandibular incisors relative to the basal bone could have an impact on the shape and aesthetics of the lips. The Tweed triangle, based on this principle, is commonly used in clinical treatment. Other researchers have also examined the aesthetics of the soft tissues of the face [7-10].

33 black American adults with perfect dentitions had cephalometric radiographs taken by Flynn et al., who used Legan and Burstone COGS to determine standard values. It was discovered that black people had longer upper and lower lips, as well as thicker soft tissue around the lips, than white people had. Additionally, black persons had sharper nasolabial angles. The vertical height ratio was lower in men than in women, in contrast to the lower face-throat angle, which was greater in men. The bottom lip of men was also longer [11].

Flynn et al. conducted a study on 33 African American adults with ideal dentitions, using Legan and Burstone cephalometric analysis to determine normative values. The study revealed that African Americans have longer upper and lower lips, as well as thicker soft tissue around the lips, compared to their white counterparts. Moreover, they had sharper nasolabial angles. In terms of gender differences, men had a lower vertical height ratio than women, but a greater lower face-throat angle. Additionally, men had longer lower lips [11].

Jain and Kalra created soft tissue cephalometric norms for a North Indian population group using Legan and Burstone analysis. We looked at sixty adults, ranging in age from 18 to 25. North Indians had more prominent lips, convex features, and sharp nasolabial angles than Caucasians had. Female faces were more vertically balanced, whereas masculine faces were more convex and featured prominent lips. The results showed a considerable departure from Caucasian averages [12].

Jain and Kalra conducted a study on a North Indian population group to establish soft tissue cephalometric norms using Legan and Burstone analysis. The study involved 60 adults aged between 18 to 25. Results indicated that North Indians had more prominent lips, convex features, and sharper nasolabial angles compared to Caucasians. Female faces were found to be more vertically balanced while masculine faces were more convex with prominent lips. The findings showed a significant deviation from the Caucasian averages [12].

The link between the incisor and lip inclinations was investigated by Sungdong Oh et al. using lateral cephalometric radiographs of 353 Korean subjects. They found significant negative correlations between the lower-nasolabial angle and the inclination of the upper incisors in all forms of skeletal malocclusion. The inclination of the lower incisors and the mentolabial angle also revealed a negative relationship, although class II malocclusion had a strong positive correlation. They came to the conclusion that the factors influencing lip inclination were identified and verified by this investigation [13].

Sungdong Oh et al. conducted a study on 353 Korean subjects to investigate the relationship between incisor and lip inclinations using lateral cephalometric radiographs. They found that there was a significant negative correlation between the inclination of the upper incisors and the lower-nasolabial angle in all forms of skeletal malocclusion. Similarly, there was also a negative relationship between the inclination of the lower incisors and the mentolabial angle, although class II malocclusion had a strong positive correlation. Based on their findings, they concluded that the factors influencing lip inclination were identified and validated through their study [13].

Soft tissue shape has been found to be significantly influenced by sagittal and vertical skeletal patterns [14,15]. According to a study of an Indonesian society, Class III, for instance, had an upper lip that was deeper than Class II [16]. Similar to this, distinct vertical developmental patterns differed in the thickness of soft tissue on the face, particularly under the chin, with hyperdivergent patterns having the thinnest thickness [17,18]. In the past, it was thought that the characteristics of soft tissue were identical to those of adhering hard tissue [19].

Studies have shown that the shape of soft tissues is significantly influenced by the sagittal and vertical skeletal patterns [15]. For instance, a study conducted on an Indonesian population [16] found that Class III individuals had a deeper upper lip compared to those with Class II. Similarly, vertical developmental patterns also have an impact on the thickness of soft tissue on the face, particularly under the chin, with hyperdivergent patterns having the thinnest thickness [17,18]. It is now known that the characteristics of soft tissue are not identical to those of the underlying hard tissue, contrary to previous beliefs [19].

Ahmed et al. conducted a study to ascertain which skeletal studies best match the parameter used to characterize the profile of the soft tissues of the face. Class I, II, and III sagittal groups were uniformly distributed among 198 patients (99 males and 99 females; mean age = 23.6 4.6 years) based on the soft tissue angle of convexity. The ANB angle, AB plane angle, Downs' angle of convexity, and Wits appraisal were all assessed on pretreatment lateral cephalograms. The association between several skeletal analyses and the angle of convexity in soft tissues was ascertained using Spearman's correlation. They demonstrated that reliable skeletal markers for evaluating the soft tissue profile of the face include the ANB angle and the Downs angle of convexity. The soft tissue profile of the face, which is more accurately related to the underlying facial pattern, can be measured using the ANB angle and the Downs angle of convexity, they demonstrated [20].

Ahmed et al. conducted a study to determine which skeletal measurements are best correlated with the soft tissue profile of the face. The study included 198 patients (99 males and 99 females; mean age = 23.6 4.6 years) with Class I, II, and III sagittal groups evenly distributed based on their soft tissue angle of convexity. The researchers evaluated four different skeletal parameters on lateral cephalograms, including the ANB angle, AB plane angle, Downs' angle of convexity, and Wits appraisal. They found that the ANB angle and Downs' angle of convexity were reliable indicators for evaluating the soft tissue profile of the face, which is more closely related to the underlying facial pattern. Spearman's correlation was used to determine the association between the skeletal measurements and the angle of convexity in soft tissues. In summary, Ahmed et al. demonstrated that the ANB angle and Downs' angle of convexity are reliable skeletal markers for evaluating the soft tissue profile of the face.

Additionally, there is a correlation between dental traits such crowding, occlusal relationship, and incisor location. Anterior-posterior upper incisor location was found to be significantly correlated with upper lip thickness [21,22]. The lip is the most important factor determining the lower area of the face's aesthetics since the upper lip receives the most attention and vertical lip width has been found to be the most influential variable in smiling esthetics [22].

Moreover, dental factors such as crowding, occlusal relationship, and incisor position have been found to be correlated with the soft tissue profile of the face. Specifically, the position of the upper incisors in the anterior-posterior direction was significantly associated with the thickness of the upper lip [21]. The lip is a crucial factor in determining the aesthetic appearance of the lower face, as the upper lip receives the most attention. In smiling aesthetics, the vertical width of the lip has been identified as the most influential variable. These findings were reported in previous studies [22].

Park and Burstone tested the effectiveness of using a cephalometric dentoskeletal standard as a clinical tool to create predictable and desirable facial esthetics on thirty adolescent patients. A typical sample of attractive faces (Indiana sample) was used as a benchmark. Hard and soft tissue profiles were measured. There was noticeable variation in facial characteristics even in cases that were successfully treated to a cephalometric dentoskeletal norm. They came to the conclusion that any one dentoskeletal criterion was unlikely to produce acceptable esthetics or reproducible profiles after treatment since lip protrusion from the subnasale pogonion plane varied by 5 mm (2 standard deviations), for a total of 10 mm [23].

Park and Burstone conducted a study on thirty adolescent patients to investigate the effectiveness of using a cephalometric dentoskeletal standard as a clinical tool to achieve predictable and desirable facial esthetics. The study utilized the Indiana sample, which is a typical sample of attractive faces, as a benchmark. They measured both hard and soft tissue profiles and found that there was noticeable variation in facial characteristics even in cases that were successfully treated to a cephalometric dentoskeletal norm. They concluded that relying solely on a single dentoskeletal criterion was unlikely to produce acceptable esthetics or reproducible profiles after treatment. This is because the protrusion of the lip from the subnasale pogonion plane varied by 5 mm (2 standard deviations), resulting in a total variation of 10 mm.

Maddalone et al. investigate the relationship between profile and soft tissue thickness and incisor inclination. They examine the relative importance of each of these two criteria and how various inclinations and thicknesses might produce various face patterns. They came to the conclusion that soft tissue thickness significantly affected the profile with respect to the location of the incisors, and that the numerous aesthetic cephalometric factors evaluated in their study had strong statistical relationships with lip position. To have the best esthetic outcomes, they advised that this parameter be considered each time before starting orthodontic treatment [24].

Maddalone et al. conducted a study to explore the relationship between the soft tissue profile and thickness, as well as the inclination of the incisors. They investigated the relative importance of each of these criteria and how different inclinations and thicknesses might produce various facial patterns. The authors found that soft tissue thickness played a significant role in determining the profile with respect to the location of the incisors. Furthermore, they found that numerous aesthetic cephalometric factors evaluated in their study had strong statistical relationships with lip position. Based on their findings, they recommended that this parameter be considered before starting orthodontic treatment to achieve the best aesthetic outcomes. These results were reported in their study [24].

Yan et al. looked examined the association between the morphological characteristics of the upper lip and the sagittal and vertical skeletal patterns in a cross-sectional investigation. Sagittal and vertical groups were created from a total of 2079 patients from Western China. The ANB angle was used to establish classes I, II, and III, while the face height index was used to determine normodivergent, hyperdivergent, and hypodivergent. After adjusting for variables, they found that superior sulcus depth was inversely related to Class II and positively connected to Class III and the hypodivergent pattern. They came to the conclusion that the superior sulcus depth is the sole aspect of the upper lip that can be considerably altered by skeletal development intervention [25].

Yan et al. conducted a cross-sectional study to investigate the association between the morphological characteristics of the upper lip and the sagittal and vertical skeletal patterns. The study involved 2079 patients from Western China who were divided into sagittal and vertical groups based on the ANB angle and face height index, respectively. The researchers found that the depth of the superior sulcus, a groove between the upper lip and the nose, was inversely related to Class II (retrognathic) and positively connected to Class III (prognathic) and the hypodivergent pattern. They adjusted for variables to ensure the validity of their findings. Yan et al. concluded that the superior sulcus depth is the only aspect of the upper lip that can be significantly altered by skeletal development intervention. This finding is significant because it suggests that orthodontic treatment and other skeletal development interventions may have a limited effect on the overall appearance of the upper lip, except for the superior sulcus depth [25].

Recently, Evangelista et al. in (2021) used 195 lateral cephalometric radiographs from untreated adults in a cross-sectional research to analyze the morphology of the symphysis and soft tissue chin in relation to sex, age, and sagittal/vertical skeletal patterns. Their conclusion was that sex, age, and sagittal and vertical patterns influence the symphysis and surrounding tissues, operating differently on the alveolar, basal, and soft tissue region. Sagittal and vertical skeletal patterns have the greatest influence on alveolar symphysis inclination, but sex and age have had an impact on the position of the vertical symphysis and the thickness of the soft tissues [26].

Previous studies have discovered a relationship between the soft tissue profile of the face and age, as well as how it interacts with the inclination of the incisors after orthodontic treatment. Few studies, and even fewer studies on Sudanese people, have examined the interaction between soft and hard tissues in patients who have not received orthodontic treatment.

Aim

Hence, it is the objective of this study is to establish the mean values of upper and lower lip characteristics of adult Sudanese; and to explore the association between skeleto-dental characteristics and corresponding soft tissue. Further, to compare the findings with other previous researches results in different population.

The objective of this study is to investigate the relationship between the soft and hard tissues of the face in adult Sudanese individuals who have not undergone orthodontic treatment. Specifically, the study aims to determine the average values for upper and lower lip characteristics in this population and to explore how these characteristics are associated with skeleto-dental characteristics

Material and Method

The sample size consisted of Twenty nine (29) pretreatment lateral cephalographs of adult Sudanese patients with age range 18 to 25 years old seeking orthodontic treatment at the orthodontic department clinic. The selection was based on the following criteria:

1- Patients between the ages of 18 and 25 years old.
2- Having skeletal and dental Class 1 prior to treatment.
3- The availability of pretreatment lateral cephalographs of high quality taken by the same cephalostat with the lips relaxed and the teeth in occlusion.
4- There were no congenital abnormalities, jaw injuries, fractures, or major facial asymmetry in any of the instances.

The study was approved by the orthodontic department of the college of dentistry at Khartoum University, indicating that ethical considerations were taken into account. Additionally, each participant signed a written informed consent form, demonstrating that they were aware of the study's purpose and had agreed to participate voluntarily.

The Cephalometric Landmarks in Upper Jaw as Follows: (Figure 1)

¬ Nasion (N): the most anterior point on midline of frontonasal 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.

¬ Subspinale (point A): the innermost point on the contour of the premaxilla 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)

¬ Stomion superius (Stms): the lowest point of the margin of upper lip vermilion.

The cephalometric landmarks in lower jaw were as follows:

¬ 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

¬ Pog': Soft tissue pogonion: 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

¬ Go: (Gonion): 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.

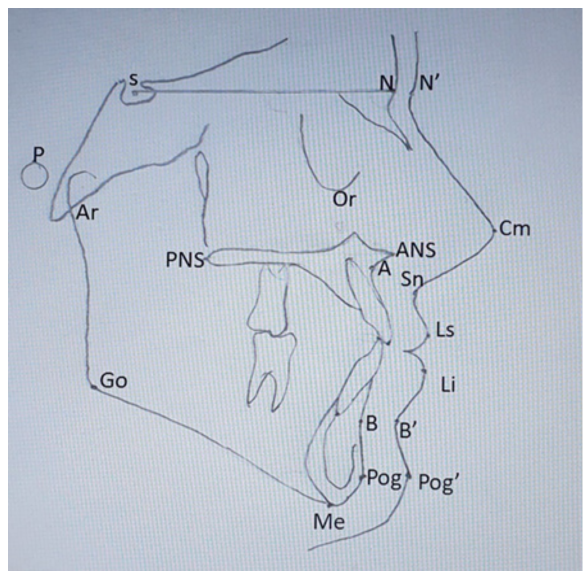

Figure 1: Cephalometric landmarks.

A. Skeletal angular measurements (Figure2):

The skeletal angular measurements include the following:

1. SNA: represent the position of maxilla in relation to anterior cranial base
2. SNB: represent the position of mandible in relation to anterior cranial base
3. Inclination of maxillary plane to anterior cranial base.
4. Maxillary mandibular plane angle (Inter-jaw angle)
5. Inclination of mandibular plane to anterior cranial base.
6. Chin angle N- angle. (Nordalval angle.). Formed between the mandibular plane and Tangent connecting Pog to B points. Represent the degree of chin prominence.

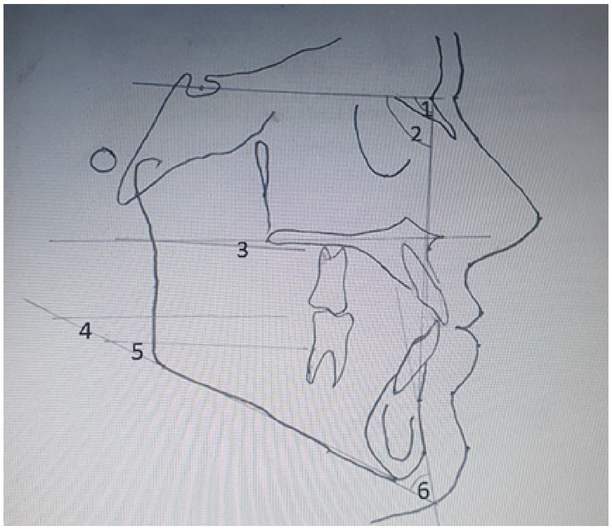

Figure 2: Skeletal angular measurements.

B. Dental angular measurements (Figure 3):

1. U1–SN plane angle: The angle formed between the long axis of upper central incisor and the SN plane.
2. U1–Maxillary plane angle: The angle formed between the long axis of upper central incisor and the maxillary plane.
3. UI TO LI: Interincisal angle.
4. 4- L1–MP angle: The angle formed between the long axis of lower central incisor and the mandibular plane.
5. L1–NB angle: The angle formed between the long axis of lower central incisor and NB line
6. UI TO NA Line angle
7. Li to NB Line angle
8. UI to E- Line mm.
9. Li to E-Line mm.

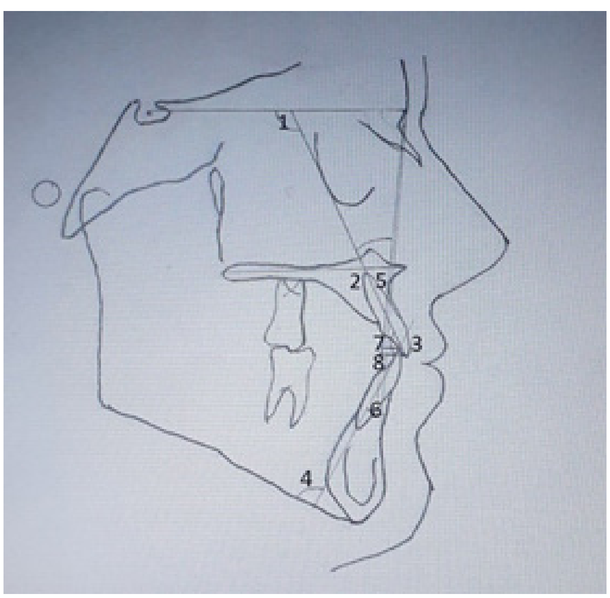

Figure 3: Dental angular measurements.

C. Linear and Angular Measurement of Soft Tissue Features Figure 4

The soft tissue angular measurements include the following:

1. Soft tissue facial convexity angle (N'– Sn–Pog'): The angle formed between soft tissue Nasion (N'), subnasale (Sn) and soft tissue pogonion (Pog').

1. Nasolabial angle (NLA): The angle formed by a line tangent to the lower border of the nose from subnasale point (Sn) with the line from Labrale superius (ls) to subnasale 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 Labrale inferius (li) to submental point (B'). This angle represents the depth of the mental fold.
3. Soft tissue chin.
4. Upper lip thickness is the distance from the labial surface of upper incisor to (Is).
5. Lower lip thickness is the distance from labial surface of lower incisor to (Li).
6. Upper lip length is the vertical distance between (Sn) and Stms.
7. Lower lip length is the vertical distance between Stm and (Si).
8. Upper lip to E. line.
9. Lower lip to E- line

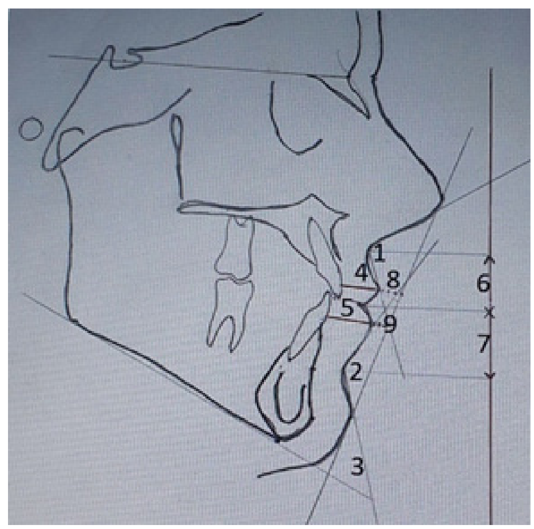

Figure 4: Linear and Angular Measurements of Soft Tissue.

Method Error

An error analysis was performed using five cephalographs. Five Lateral cephalographs were traced and retraced with one-week interval by one operator (I.K) using *web Ceph* program.

In this study, an error analysis was performed using five lateral cephalographs to assess the reliability of the measurements made by the operator using web Ceph program.

The five cephalographs were traced and retraced by the same operator (I.K) using web Ceph program, with a one-week interval between the tracing and retracing.

Statistical Analysis

Canonical correlation analysis was used to assess relationships between two sets of variables (Hard tissue variables versus Soft tissue variables). Significant level was set at P < 0.05.

Canonical correlation analysis is a statistical method that is used to explore the relationship between two sets of variables. In this study, it was used to examine the relationship between hard tissue variables and soft tissue variables in the face.

Results

A. Error of the method

By comparing the measurements made between the first tracing and second retracing, the results of the analysis revealed that there were no significant differences between the two readings.

Table 1: Means and standard deviations of the skeletal, dental, and soft tissue variables studied in Sudanese.

Skeletal variables	Sudanese	
	Mean	**SD**
SNA	82.46	4.63
SNB	80.02	4.48
ANB	2.44	1.07
SN ML	32.68	4.38
SN MX Line	7.05	3.05
MX-ML	25.63	5.67
Dental variables		
U1-L1	120.26	14.09
U1-SN	111.14	9.72
U1-PP	118.19	8.31
U1-NA	28.68	7.92
U1-NA (mm)	7.39	3.6
L1-NB	28.63	7.68
L1-NB (mm)	7.25	3.38
L1-MP	95.92	8.24
Soft tissue variables		
UL-E line (mm)	-0.44	2.29
LL-E line (mm)	2.33	3.13
NLA	89.95	15.29
UL thickness (mm)	13.58	1.81
LL thickness (mm)	16.19	2.42

Table 1 revealed the mean, standard deviation of the skeletal, dental and soft tissue features in Sudanese. The sagittal relationship showed an orthognathic maxilla (SNA 82.96) and mandible (SNB 80.02) with skeletal Class I relationship (ANB 2.44). The SN Pog (80.16) indicates slightly prominent chin. The vertical relationship revealed that; the maxilla was normally inclining anteriorly MX L-SNL (7.05) and the mandible (ML-SNL 32.68) was posteriorly inclined in relation to anterior cranial base with slight open basal configuration (MXL-ML 25.63). Dentally, the upper and lower incisors were proclined and protruded leading to reduced interincisal angle. The soft tissue showed that, the upper lip and lower lip were slightly protruded, and the nasolabial angle was less obtuse.

Table 2: Comparison of means and standard deviations of the skeletal, dental, and soft tissue variables between Sudanese and Saudis.

Variables	**Sudanese Present Study**	**N=29**	**Saudis Shamlan & Al Drees [27]**	**N=60**
Skeletal variables	**Mean**	**SD**	**Mean**	**SD**
SNA	82.46	4.63	82.21 NS	4.21
SNB	80.02	4.48	79.49 NS	3.77
ANB	2.44	1.07	2.72 NS	1.24
SN –ML	32.68	4.38	35.41 *	5.82
Dental variables				
UI-LI	120.26	14.09	128.72 ****	3.53
UI-SN	111.14	9.72	104.13 ****	4.79
UI- PP	118.19	8.31	111.88 ****	4.21
UI-NA Degree	28.68	7.92	21.8 2 ****	4.74
UI-NA mm	7.39	3.60	4.44 ****	1.66
LI –NB Degree	28.63	7;68	26.03 *	3.74
LI – NB mm.	7.25	3.38	5.33 ****	1.63
Li – MP	95.92	8.24	90.85 ****	4.42
Soft tissue variables				
UL- EL mm	-0.44	2,97	- 4.18 ****	2.16
LL –EL mm	2.33	3.08	-1.84 ****	2.14
NLA	90.96	14.55	105.49 ****	10.27
UL Thickness mm	13.67	1.78	11.17 ****	2.23
LL Thickness mm	16.18	2.46	11.30 ****	1.71

NS: Not Significant. P< 0.05 *, P<0.0001 ****

Table 2 reveals the comparison between the present Sudanese sample and the result reported by Shamlan and Aldrees (2015). The statistical analysis shows that seven of the dental variables were extremely significant (P =0.000) whereas only the inclination of the Lower incisor to NB line (LI- NB Degree) was significant at 5% level. On the other hand, all soft tissue variables were extremely significant (P =0.000). Moreover, there was no statistically significant difference in all skeletal variables except for the inclination of the mandibular plane to the anterior cranial base (SN -ML) at 5% level.

Table 3: Canonical correlations and test of significance level in the upper jaw.

	correlation	**Eigenvalue**	**Wilks Statistic**	**F**	**Number of D. F**	**Significance**
1	**.437**	.236	.784	2.764	236.223	**.004**
2	.168	.029	.968	.794	196.000	.530
3	.060	.004	.996	.357	99.000	.551

The canonical correlation values for the upper jaw ranged from 0.437 to 0.060, (table 3). It was determined that just the first correlation was significant. The first canonical variates percentage of squared value was discovered to be 19.1%.

Tables (3a and 3b) loading and standardized canonical coefficients between hard tissue (set 1) and soft tissue (set 2) variables for the canonical variates in upper jaw.

Table 3a: Hard tissue Set 1 canonical Loadings in upper jaw.

Hard tissue Variables	Loading 1	Std. CCC
UI TO SN line	**-.935**	0.003
UI TO maxillary line	**-.996**	-.867
UI TO NA line	**-.886**	-.157

Std. CCC: standardized canonical correlation coefficient

Table 3b: Soft tissue Set 2 canonical Loadings in upper jaw.

Soft tissue variables	Loading 1	Std. CCC
UL TO EL	.100	-.076
NLA	**.874**	1.048
UL Thickness	-.178	-.516

NLA= Nasolabial angle. UL= Upper Lip. EL= Esthetic line.

Upper jaw

The loading and standardized canonical correlation coefficient values between set 1 (hard tissue variables) and set 2 (soft tissue variables) for the canonical variates in upper jaw was presented in tables (3a) and (3 b). The first canonical variates for hard tissue variables had a heavy negative loading with UI to maxillary line (-0.996), UI to SN line (-0.935) and UI to NA line (-0.886). The first canonical variates for soft tissue variables had a heavy positive loading with Nasolabial angle (0.874).

Table 4: Canonical correlations and test of significance level in the lower jaw.

	correlation	Eigenvalue	Wilks Statistic	F	Num D. F	Significance
1	**.696**	.940	.324	11.252	12.000	**0.000**
2	**.607**	.584	.628	8.452	6.000	**< 0. 001**
3	.068	.005	.995			

Table 4 displays the canonical result for the lower jaw variables and demonstrates that the correlation ranged from 0.696 to 0.068. The squared values of the first and second canonical variates were found to be 48% and 37%, respectively, and the first and second correlations were found to be statistically significant ($p < 0.001$).

Table (4a and 4b): Loading and standardized canonical coefficients between set 1 and set 2 variables for the canonical variates in lower jaw.

Table 4a: Hard tissue set 1 canonical Loadings in lower jaw.

Hard tissue variables	Loading 1	Std. CCC	Loading 2	Std. CCC
LI TO NB line	**-.941**	-.524	-.179	1.032
IMPA	**-.929**	-.490	-.072	-1.410
Hard tissue chin	**.603**	.085	**-.420**	-.562

IMPA= Lower incisor to mandibular plane. LI = Lower incisor. Std. CCC: standardized canonical correlation coefficient

Table 4b: Soft tissue Set 2 canonical Loadings in lower jaw.

Soft tissue variables	Loading 1	Std. CCC	Loading 2	Std. CCC
LL TO EL	**-.591**	-.886	**.498**	.466
LL Thickness	**.601**	.771	.230	.120
M L A	.301	.153	**.719**	.797
Soft tissue chin	-.136	.248	**.621**	.270

MLA= Mentolabial angle. LL= Lower Lip. EL= Esthetic line

Lower jaw

The loading and standardized canonical correlation coefficient values between set 1 (hard tissue variables) and set 2 (soft tissue variables) for the canonical variates in the lower jaw were presented in tables (4a) and (4 b).

The first canonical variates for hard tissue variables had a heavy negative loading with LI NB line (-0.941) IMPA (-0.929) and moderately positive loading with Hard tissue chin (0.603). The first canonical variates for soft tissue variables had a moderately positive loading with lower lip thickness (0.601) and moderately negative for LL to EL (-0.591).

The second canonical variates for set 1 had a moderate loading value with hard tissue chin (0.420) and in set 2, the canonical variates are moderately positive loading to mentolabial angle (0.719) and soft tissue chin (0.621).

Discussion

Interpreting face soft tissue analysis is difficult because various factors, such as skeletal relationships, tooth position, soft tissue thickness, ethnic origin, gender, and age, can influence cephalometric findings [1]. Nevertheless, a balanced face structure is not necessarily produced by a good occlusion based on standard cephalometric [28]. Further, momentary factors such as muscular activity, lip position, and facial expression at the time of exposure can affect them, especially in children. In orthognathic surgery, cephalometric study of face soft tissue is also essential [29].

When comparing the cephalometric mean values between present study and the results reported among Saudis by Shamlan and AL-Drees [27], it was observed that there were statistically significant differences in most of the dental and soft issue variables. On the other hand, no statistically significant differences were noticed in the skeletal sagittal relationship. However, there was significant difference at 5% level when comparing the skeletal vertical relationship (SN-ML 35.4 SD 5.8) indicating that the Saudis had higher tendency towards open basal configuration.

Upon comparing the cephalometric mean values between the present study and the study conducted by Shamlan and AL-Drees [27] among Saudis, significant differences were found in most of the dental and soft tissue variables. However, no significant differences were observed in the skeletal sagittal relationship. Notably, there was a significant difference observed at a 5% level when comparing the skeletal vertical relationship, with the Saudis demonstrating a higher tendency towards an open basal configuration as evidenced by the SN-ML value of 35.4 and standard deviation of 5.8.

Furthermore, the majority of previous investigations used lateral skull radiographs to explore facial soft tissue features [28,30]. They have noted the importance of the soft tissue in the determination of facial aesthetics on the basis that soft tissue behaves independently from the underlying skeleton [31-33].

Previous studies have primarily utilized lateral skull radiographs to investigate the characteristics of facial soft tissue [28,30]. These studies have emphasized the significance of soft tissue in determining facial aesthetics, noting that it behaves independently of the underlying skeleton [31-33].

In the present study, we used the Canonical correlation test for the statistical analysis. The Canonical correlation analysis is considered as a powerful statistical test [34,35]. It was used to enable examination of multiple predictor and multiple criterion variables and assessing relationships as well as summarizing dependence between two groups of variables (Hard tissue variables versus Soft tissue variables). However, Tanak et al and Lupacheva et al reported that canonical analysis has served as an instrument for obtaining new knowledge about how important factors interact with each other [35,36]. Moreover, the canonical correlation analysis explored the relationship or association between hard tissue and soft tissue. Further, the canonical correlation was used since we were comparing 2 sets of multiple Variables, whereas standard correlation could only compare 2 variables. Hence, it was the intention of the present study is to explore the correlation between the facial hard tissue and facial soft tissues components of Sudanese adults using the canonical correlation analysis in order to obtain a basis for normal hard and soft tissues.

The present study utilized Canonical correlation analysis as a statistical test. This test is considered powerful and enables the examination of multiple predictor and multiple criterion variables, assessing relationships and summarizing dependence between two groups of variables (hard tissue versus soft tissue variables) [34,35]. According to Tanak et al. [35] and Lupacheva et al. [36] canonical analysis serves as an instrument for obtaining new knowledge about how important factors interact with each other [35,36].

The canonical correlation analysis in the present study explored the relationship or association between hard tissue and soft tissue. This was important since the study was comparing two sets of multiple variables, whereas standard correlation could only compare two variables. Utilizing this test helps in exploring the correlation between facial hard tissue and facial soft tissue components of Sudanese adults in order to establish normal values for hard and soft tissues.

The result of the canonical analysis revealed that the first canonical variates was significant (0.004) and the percentage of squared value was discovered to be 19.1% in upper jaw whereas as in the lower jaw, the squared values of the first and second conical variates were found to be 48% and 37%, respectively, and the first and second correlations were found to be significant 0.000, < 0.001 respectively. The percentage of the squared canonical correlation of the first correlation in the Saudi study group reported by Shamlan and ALDrees [27] was 84%, which is higher than the result of the present study.

The result of the current study revealed that in the upper jaw, the first canonical variate was found to be significant with a squared value of 19.1%. On the other hand, in the lower jaw, both the first and second canonical variates were significant, with squared values of 48% and 37%, respectively. The first and second correlations were also found to be significant with p-values of 0.000 and <0.001, respectively.

Furthermore, it is mentioned that the percentage of squared canonical correlation of the first correlation in the Saudi study group reported by Shamlan and ALDrees [27] was 84%, which is higher than the result of the present study. This suggests that the relationship between the variables in the present study is not as strong as in the Saudi study group

The result of the analysis of the Sudanese adults showed that the variation in nasolabial angle and lower lip thickness could be explained by variation in the inclination of the upper incisors and the inclination of the lower incisors. However, Shamlan and AL-Drees [27] result reported that the variation in upper lip length and lower lip position could be explained by variation in the position of the upper incisors and the position and inclination of the lower incisors. Comparison between the two studies is not possible since different variables were used. Nevertheless, these findings could be of great value in the process of treatment planning of patient needs orthodontic treatment or orthognathic surgery. Saxby and Freer reported that they found a correlation between the upper and lower incisors horizontal position and the upper incisors angulation to lip position and concluded that; the Ricketts E line, the Steiner S- line and the soft tissue facial plane all seem to be equally acceptable bases for assessment of the soft tissues of the profile [28]. In the current investigation Rickett's E- line was used in the measurement of upper and lower lip and incisors position.

The analysis of the lower lip thickness in the present study was significantly correlated with the inclination of the lower incisors. Kasai [37] noted an association between the position of the lower incisors and upper lip thickness whereas Yogosawa, reported the influence of the maxillary incisors on lower lip position. The findings of Kasai and Yogosawa [38]. Are not possible to compare with the present study since they did not investigate the lip thickness variable. Furthermore, the soft tissue chin was highly correlated with the hard tissue chin. This variable was not investigated by Kasai [37] and Yogosawa [38] as well as by Shamlan and AL-Drees [27].

The post-treatment facial profile could be predicted using soft tissue changes in the face. Using the pretreatment cephalometric tracing as a guide, estimate the projected incisor retraction amounts, and then redraw the anticipated soft tissue movement taking both the direction and the amount into consideration [39]. This finding was confirmed by Bloom [40] who found high correlation between maxillary central incisor changes and the superior sulcus, upper and lower lips. He also found strong relationship of the lower incisor to the inferior sulcus and the lower lip and concluded it was possible to predict the perioral soft-tissue profile changes in relation to the expected amount of anterior tooth movement.

The general tendency of facial soft tissue response toward incisors retraction could be expected in various malocclusions. However, different initial malocclusion no doubt leads to differences in this response. However, very recently AL-Shakhs and Hashim [39] conducted study in soft tissue facial profile changes associated with Incisors retraction. They reported that the upper incisors to Labrale superius ratio (1.9:1, UIP: Ls) exhibited the highest correlation (r=0.55**) among the other established ratios. The lower incisors to Labrale inferius ratio was (1.1:1, LIP: Is) with significant correlation (r=0.44**), whereas no significant correlation was observed with Labrale superius (r=0.27) and concluded "There are changes in the soft tissue facial profile after incisors retraction." This finding was in line with previous study reporting that the retraction of the lips has been observed following retraction of the incisors to a variable degree. Further, these changes in upper and lower lip length are another outcome that was under consideration by the clinicians [27,41-45].

Finally, the canonical correlations between hard tissue and dentoskeletal hard tissue discovered in this current investigation shed some light on the understanding of the role of soft tissue and hard tissue in the development of the occlusion, despite the limitations of interpretation in any two-dimensional cephalometric study [35].

Conclusion

The canonical analysis of the current study; revealed that the upper and lower incisors inclinations had strong negative loading whereas the nasolabial angle and lower lip thickness and position had moderate loading. This finding shows the impact of these variables, which can help the clinician in diagnosis, prediction and assessment of post treatment changes. Additionally, the multivariate statistical analysis extracted a clinically significant association between soft tissue and hard tissue.

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