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Correlations between Cephalometric Measurements of Hard Tissues and Photogrammetric Features of Facial Soft Tissues.

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Abstract

Background: Facial soft tissues cover the teeth and the facial skeleton; maintain close anatomical relations with them and may nevertheless vary in their morphology and position. The objective of this study was to determine the correlations between soft facial tissue measurements and craniofacial hard tissue measurements..

Methods: A cross-sectional descriptive study was performed using standardised tele-radiographic and photographic images of young children who had come for orthodontic care. On each selected subject, cephalometric and photogrammetric measurements were made. The data collected was analysed using the IBM SPSS 20.0 statistical software. The correlation between hard tissue cephalometric measurements and photogrammetric soft tissue measurements was investigated by a Pearson correlation. The significance is fixed at p = 0.05.

Results: ANB was significantly and positively correlated to Sn-N'-Sm. I / A-Pog was significantly and positively correlated with Ls-E and Li-E. Significant and positive correlations were found between the position of the pogonion and Sn-H. It is the same between the position of point A and Trg-Sn distance; and between S-Ar and the variables N'-Sn and N'-Me '. Ar-Go was also significantly and positively correlated to Sn-Me ', Sn-Sts and N'-Me'.

Conclusion: The many significant and positive correlations found between cephalometric and photogrammetric variables show that these could advantageously be used to evaluate skeletal and dentoalveolar variables. This would limit the significant risks of ionizing radiation during orthodontic treatment.

Keywords: Photogrammetry, cephalometry, hard tissue, soft tissue

ORIGINAL ARTICLE

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Introduction

The photogrammetry of the soft tissues of the face is a measurement method that objectively quantifies the characteristics of the face through the photographic tool. Researchers have used it to evaluate the characteristics of the face [1,2] Unlike cephalometry, it is inexpensive and does not expose the patient to ionizing radiation. In addition, it is reliable and sufficiently reproducible because it is easy to achieve in a conventional context, without the need for special equipment.[1] Facial soft tissues cover the teeth and the facial skeleton, maintain close anatomical relationships with them and can vary considerably in their morphology and position. These variations may be related to the existence of inter-ethnic, racial and geographical variability in the facial skin tissues[2] but also to the existence of a positional and morphological variability of the underlying skeletal and dentoalveolar structures.[3] The formulation of a treatment plan based solely on cephalometric measurements of skeletal and dentoalveolar structures is therefore insufficient and often leads to aesthetic problems.[4-7] Therefore, it is necessary to have these cephalometric measurements coupled with photogrammetric measurements in order to better identify the skeletal and dentoalveolar abnormalities on the one hand and the cutaneous ones on the other, and their possible associations. However, little importance has been devoted to quantifying the relationships between the position or dimensions of the components of soft facial tissues and different skeletal and dentoalveolar parameters.

Most research in this area focuses on the study of cephalometric and photogrammetric projection and identification errors [8] and the response of soft tissues to the movements of orthopedic, orthodontic or orthognathic therapy.[9-12]

Separate cephalometric and photogrammetric measurements have been performed in a Senegalese population,[13,14] but no study of associations between these two parameters has been performed in this population. The objective of this study was to determine the correlations between the photogrammetric measurements of the face and different profile teleradiographic measurements in Senegalese subjects.

Materials and methods

It is a transversal analytical study carried out at the orthodontic clinic of the Department of Odontology of Cheikh Anta Diop University in Dakar. The study is based on a sample of a group of Senegalese children aged between 6 and 12 who came for consultation to the Dentofacial Orthopedics Clinic of the Department of Odontology of the Faculty of Medicine, Pharmacy and Dentistry of the Faculty of Medicine, Pharmacy and Dentistry of Cheikh Anta Diop University in Dakar. Subjects who received orthodontic or prosthetic treatment, plastic or orthognathic surgery were not included in the study. It is the same for those who had orofacial soft tissue pathologies (swelling, ulcerations ...) or severe craniofacial abnormalities. The pictures on which one could see a contracture of the muscles of the chin tassel (pleated or flattened chin) were also excluded from the study.

Photogrammetric recordings and measurements: On each subject selected according to the above criteria, a standardised profile photographic snapshot is made according to the method described by Ferrario et al.[15] All photos were taken with the same digital camera (Samsung type, with a resolution of 14.2 megapixels, optical zoom × 3). The images obtained were digitised on a computer using a photo software (photoshop type elements 7.0) with a resolution of 300 DPI (dot per inch or PPP point par pouce). These scanned images were printed on a white sheet from a single printer (HP Deskjet 3050). The magnification of the images obtained was calculated from that of the image of a metric scale taken as a reference. From that moment, the actual linear measurements could be obtained. The points and lines used for this approach are defined in Table I. The photogrammetric variables are defined in Table II and illustrated in Figures 1 and 2.

Cephalometric recording: Cephalometric measurements were then made from a tele-radiographic profile of each selected subject. Informed consent was obtained from the parents before the snapshot was taken. Plotting all the tele-radiographies was done manually by a single examiner (JD) on an acetate paper sheet. The points and lines chosen are defined in Table 1. The measured cephalometric variables are defined in Table II and anatomically illustrated in Figures 3 and 4.

Statistical analyses: The data collected was analysed using the IBM SPSS 20.0 statistics software for windows. The power of the association between photogrammetric measurements and cephalometric variables was sought by the Pearson correlation coefficient. The materiality threshold is set at $p = 0.05$.

Method error: The reliability of photogrammetric and cephalometric measurements was assessed by measuring again, at random, the variables in a group of 30 children (representing 30% of study subjects), one month after the first assessment. The Cronbach test was performed to determine the error of the method. An intra-class coefficient between 0.789 and 0.971 was found. This result shows that there is no significant difference between the first and second measurements.

Results: One hundred subjects comprising 49 boys and 51 girls aged between 6 and 12 years with an average age of 9.5 ± 1.08 years were included in this study.

Correlations between Sagittal Photogrammetric Variables and Sagittal Teleradiographic Parameters

The position of point A was significantly and positively correlated with Trg-Sn ($r = 0.40$ and $p =$

0.04) and Sn-N'-Sm (r = 0.52 and p = 0.008). I / A-Pog was also significantly and positively correlated with Ls-E (r = 0.51 and p = 0.01), Li-E (r = 0.48 and p = 0.01), Ls-S (r = 0.47, p = 0.01) and Li / Sn-Sm (r = 0.46, p = 0.02). The convexity was significantly and positively correlated with Sn-N'-Sm (r = 0.41 and p = 0.04). It is the same between the position of the pogonion and the Sn-H photogrammetric variable (r = 0.42, p = 0.03). The ANB angle was also significantly and positively correlated with the Sn-N'-Sm angle (r = 0.52 and p = 0.009) (Table 3).

Correlations between vertical photogrammetric variables and vertical teleradiographic parameters

The N-Me height was significantly and positively correlated with Sn-Me 'and N'-Sn distances with r equal to 0.46 and 0.56 respectively; and p respectively equal to 0.02 and 0.004. This N-Me height was also significantly and positively correlated with Sti-Sm and N'-Me 'with r respectively equal to 0.66 and 0.67 and p values < 0.001. N-ENA was significantly and positively correlated to N'-Sn, Sti-Sm and N'-Me' with r respectively equal to 0.51; 0.55 and 0.56; and p respectively equal to 0.01; 0.001 and 0.004. ENA-Me was significantly and positively correlated with Sn-Me' (r = 0.48 and p = 0.01), N'-Sn (r = 0.51 and p = 0.01), Sn-Sts (r = 0.45 and p = 0.02), Sti-Sm (r = 0.55 and p = 0.005) and N'-Me '(r = 0.66 and p < 0.001). S-Go was significantly and positively correlated to the distances N'-Sn, Sn-Sts, Sti-Sm and N'-Me' with r respectively equal to 0.59; 0.41; 0.65 and 0.61 and p respectively equal to 0.002; 0.04; 0.001 and 0.001. The S-Ar height was significantly and positively correlated with N'-Sn distances (r = 0.63 and p = 0.001), Sti-Sm (r = 0.51 and p = 0.009) and N'-Me' (r = 0.55 and p = 0.005). The Ar-Go distance was significantly and positively correlated with Sn-Me ', N'-Sn, Sn-Sts, Sti-Sm, Sm-Me' and N'-Me' with r respectively equal to 0.41; 0.41; 0.48; 0.65; 0.42 and 0.55 and p respectively equal to 0.04; 0.04; 0.01; 0.001; 0.03 and 0.005. The Y axis was significantly and positively correlated with the Sm-Me '/ Li-Sm angle (r = 0.40 and p = 0.04) and negatively correlated with angle Z (r = -0.54 and p = 0.006). The gonadal angle was significantly and positively correlated with Sm-Me '/ Li-Sm (r = 0.43 and p = 0.03) (Table 4).

Figure 1: Sagittal photogrammetric variables: 1 = Trg-Sn; 2 = Sn-H; 3 = Ls-E; 4 = Ls-S; 5 = Ls / Sn-Sm; 6 = Li-S; 7 = Li-E; 8 = Li / Sn-Sm; 9 = Pog '/ Sn-Sm; 10 = Sn-N'-Sm.

Figure 2: vertical photogrammetric variables: 1 = Sn-Me '; 2 = Sn-Sts; 3 = Sti-Sm; 4 = Sm-Me '; 5 = N'-Sn; 6 = N'-Me '; 7 = Z-angle; 8 = Prn-Sn-Ls; 9 = Sn-Ls / Li-Sm; 10 = Sm-Me '/ Li-Sm.

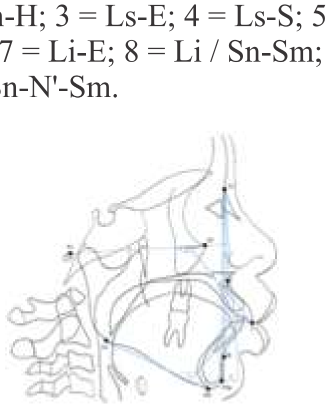

Figure 3: sagittal cephalometric variables: 1 = I / F; 2 = ANB; 3 = position of point A; 4 = convexity; 5 = I / A-Pog; 6 = sagittal position of the pogonion point; 7 = i / M.

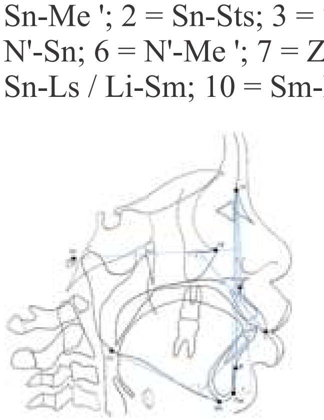

Figure 4: Vertical cephalometric variables: 1 = N-ENA; 2 = ENA-Me; 3 = N-Me; 4 = Y axis; 5 = S-Go; 6 = S-Ar; 7 = Ar-Go; 8 = angular / bony angle; 9 = FMA.

Table 1: Definition of points and lines used

Skin points and lines	Definitions
Nasion (N')	the point of the midline at the root of the nose
Pronasal (Prn)	the most salient point of the tip of the nose
Sub nasal (Sn)	the point where the upper lip joins the columella
Upper labial (Ls)	the point that indicates the mucocutaneous limit of the upper lip
Upper Stomion (Sts)	the lowest point of the upper lip
Lower stomion (Sti)	the highest point of the lower lip
Lower labial (Li)	the point that indicates the mucocutaneous border of the lower lip
Supramental (Sm)	the deepest point of the sub-labial lower concavity
Pogonion (Pog ')	the most anterior point of the chin
Chin (Me ')	the lowest point of the lower edge of the chin
Tragus (Trg)	the most posterior point of the atrial tragus
Suborbital (Or ')	perceptible point on the finger of the outer orbital rim
Line H	Line passing through the skin chin point and tangent to the upper lip
Line Sn-Sm	Aesthetic line of Canut, right joining Sn and Sm points
(Trg-Or ')	Frankfurt horizontal cutaneous plane, joining tragus and under orbital points
Line E	Ricketts E aesthetic line tangent to the tip of the nose and the tip of the chin
Line S	Line S is the line joining the point Pog and the middle between Prn and Sn
Line Z	line tangent to the chin and the most prominent lip
Skeletal and dentoalveolar points	
Nasion (N)	anteroposterior point of the image of the naso-frontal suture
Sella Turcica (S)	Sella Turcica (S)
Articulare (Ar)	point of the image of the posterior border of the ramus with the exocranial face of the occipital clivus
Porion (Po)	highest point of the external auditory canal located on the vertical passing through its middle
Anterior nasal spine (ANS)	tip of the anterior nasal spine
A	most sloping point of the concavity of the maxillary image
Orbital (Or)	lowest point of the orbit image
Upper Incisor (Ui)	free edge of the most anterior superior incisor
B	most sloping point of the concavity of the image of the symphysis
Chin (Ch)	lowest point of the image of the mandibular symphysis
Gonion (Go)	point equidistant from the most posterior point of the horizontal branch of the mandible, and from the lowest point of the rising branch
Pogonion (Pog)	most salient point of the image of the symphysis
Gnathion (Gn)	equidistant point between the point Pog and Me
Basion (Ba)	lowest point of the occipital basi

Table 2: Definition of chosen variables

Cephalometric variables	**Definitions**
I / A-Pog	distance from the incisal edge of the medial incisor superior to line A-Pog.
Sagittal position of the pogonion	distance between the point pogonion and the perpendicular to the Frankfurt plane passing through point Na.
Position of point A	distance between A and the perpendicular to PHF passing through point N
Convexity	distance from A to Na-Pog facial plane
I / F	angle that makes the axis of the upper incisor with the horizontal plane of Frankfurt
i / M	angle made by the axis of the lower incisor with the mandibular plane
ANB	maxillomandibular sagittal shift
N-Me	Total anterior facial height
N-ENA	upper anterior facial height
ENA-Me	lower anterior facial height
S-GB	total posterior head height
S-Ar	superior posterior head height
Ar-Go	lower posterior facial height
FMA	angle between the Frankfurt plane and the Downs mandibular plane
1- Y axis	angle formed by the line (SGn) and the Frankfurt plane
2- Gonic / Angular / Bony angle	angle formed by the mandibular plane (GoMe) and the tangent to the posterior edge of the mandible (ArGo).
1- Photogrammetric variables	
Trg- Sn	1- depth of the face
Ls-E	distance from the upper lip Ls to line E
Li-E	distance from lower lip Li to line E
Sn-H	distance from sub nasal point Sn to line H
Ls-S	distance from Ls to line S
Li-S	Li's distance to S line
Ls/ Sn- Sm	distance from Ls to Canut line (Sn-Sm)
Li/ Sn-Sm	distance from Li to Canut line (Sn-Sm)
Pog'/Sn- Sm	distance from Pog to Canut line (Sn-Sm)
Sn- N'- Sm	cutaneous ANB angle
Sn-Me’	lower third of the face
N'-Sn	nose length
Sn-Sts	length of the upper lip
Sti-Sm	length of the lower lip
Sm-Me’	chin height
N'-Me’	height of the lower floor
Prn-Sn-Ls	naso labial angle
Sn-Ls/Li-Sm	Inter labial angle
Sm-Me'/Li-Sm	Mento-labial angle
Z angle	formed by the intersection of the plane Frankfurt horizontal cutaneous (Trg-Or ') and line Z

Table 3: Correlations between sagittal photogrammetric variables and sagittal teleradiographic parameters

Settings / Parameters (mm,°)	I/A-Pog r (p)	Position Pog r (p)	Position A r (p)	Convexité r (p)	I/F r (p)	i/M r (p)	ANB r (p)
Trg-Sn	0.16 (0.43)	0.33 (0.11)	0.40* (0.04)	0.25 (0.22)	0.04 (0.83)	0.05 (0.81)	0.19 (0.35)
Ls-E	0.51* (0.01)	-0.22 (0.28)	0.09 (0.66)	0.36 (0.07)	-0.13 (0.52)	-0.02 (0.89)	0.25 (0.23)
Li-E	0.48* (0.01)	-0.36 (0.08)	-0.24 (0.25)	0.11 (0.60)	0.03 (0.88)	-0.26 (0.20)	-0.03 (0.86)
Sn-H	-0.28 (0.17)	0.42* (0.03)	0.24 (0.25)	-0.14 (0.50)	0.21 (0.32)	0.14 (0.51)	-0.03 (0.85)
Ls-S	0.47* (0.01)	-0.08 (0.68)	0.18 (0.39)	0.31 (0.13)	-0.07 (0.72)	0.01 (0.94)	0.26 (0.20)
Li-S	0.34 (0.10)	-0.39 (0.05)	-0.36 (0.08)	-0.02 (0.91)	-0.13 (0.53)	-0.16 (0.44)	-0,12 (0.55)
Ls/ Sn- Sm	0.14 (0.50)	0.19 (0.36)	0.39 (0.05)	0.25 (0.23)	-0.10 (0.61)	0.18 (0.38)	0.35 (0.09)
Li/ Sn-Sm	0.46* (0.02)	-0.1 (0.64)	-0.20 (0.33)	-0.04 (0.82)	0.11 (0.6)	-0.18 (0.39)	-0.10 (0.63)
Pog'/Sn- Sm	-0.01 (0.93)	0.30 (0.14)	0.09 (0.66)	0.11 (0.58)	0.19 (0.36)	0.08 (0.68)	0.01 (0.96)
Sn- N'- Sm	-0.08 (0.70)	0.28 (0.18)	0.52** (0.008)	0.41* (0.04)	-0.08 (0.70)	-0.03 (0.87)	0.52** (0.009)

***= The correlation is significant at the 0.05 level (bilateral). ** = The correlation is significant at the 0.01 level (bilateral).**

Table 4: Correlation between vertical photogrammetric variables and vertical teleradiographic Parameters

Parameters (mm,°)	N-Me r (p)	N-ENA r (p)	ENA-Me r (p)	S-Go r (p)	S-Ar r (p)	Ar-Go r (p)	FMA r (p)	Y Axis r (p)	Angular / Bony angle r (p)
Sn-Me'	0.46* (0.02)	0.39 (0.05)	0,48* (0.01)	0.38 (0.06)	0.25 (0.23)	0.41* (0.04)	-0.18 (0.4)	-0.11 (0.60)	0.17 (0.40)
N'-Sn	0.56** (0.004)	0.49* (0.01)	0.51* (0.01)	0.59** (0.002)	0.63** (0.001)	0.41* (0.04)	-0.19 (0.37)	0.02 (0.91)	-0.01 (0.92)
Sn-Sts	0.33 (0.11)	0.17 (0.41)	0.45* (0.02)	0.41* (0.04)	0.08 (0.69)	0.48* (0.01)	-0.10 (0.62)	0.07 (0.73)	-0.07 (0.74)
Sti-Sm	0.66** (<0.001)	0.62** (0.001)	0.55** (0.005)	0.65** (0.001)	0.51** (0.009)	0.65** (0.001)	-0.23 (0.26)	0.19 (0.35)	-0.20 (0.34)
Sm-Me'	0.38 (0.06)	0.30 (0.15)	0.40 (0.05)	0.33 (0.10)	0.25 (0.23)	0.42* (0.03)	0.01 (0.96)	0.18 (0.39)	0.27 (0.19)
N'-Me'	0.67** (<0.001)	0.56** (0.004)	0.66** (<0.001)	0.61** (0.001)	0.55** (0.005)	0.55** (0.005)	-0.18 (0.37)	0.02 (0.91)	0.08 (0.70)
Prn-Sn-Ls	0.08 (0.68)	-0.08 (0.68)	0.27 (0.19)	0.02 (0.89)	0.07 (0.74)	-0.03 (0.85)	0.39 (0.05)	0.29 (0.16)	-0.04 (0.83)
Sn-Ls/Li-Sm	-0.07 (0.74)	-0.12 (0.55)	0.01 (0.96)	-0.06 (0.75)	-0.09 (0.67)	-0.001 (0.99)	0.15 (0.46)	0.09 (0.67)	0.12 (0.55)
Sm-Me'/Li-Sm	-0.08 (0.71)	-0.11 (0.58)	-0.04 (0.85)	-0.07 (0.74)	-0.18 (0.37)	0.17 (0.42)	0.28 (0.17)	0.40* (0.04)	0.43* (0.03)
Z Angle	0.17 (0.42)	0.25 (0.23)	0.10 (0.63)	-0.04 (0.84)	-0.04 (0.83)	-0.09 (0.66)	-0.37 (0.07)	-0.54** (0.006)	-0.33 (0.11)

*** = The correlation is significant at the 0.05 level (bilateral). ** = The correlation is significant at the 0.01 level (bilateral).**

Discussion

The position of point A was significantly and positively correlated with Trg-Sn (r = 0.40 and p = 0.04). In other words, the deeper the face was, the closer point A was to the line perpendicular to the Frankfurt plane passing through the Nasion point. This correlation could be related to the fact that the advanced point A located on the maxillary alveolar rampart can cause that of the Sn point of the upper lip which rests on this alveolar rampart. When Sn moves forward, the Trg-Sn distance increases. Similarly, when A moves forward, its distance to the line perpendicular to the Frankfurt plane passing through the Nasion point decreases but the variable of the position of A increases since it is negatively noted.

The significant and positive correlations between the position of point A and Sn-N'-Sm on the one hand and between the convexity and Sn-N'-Sm on the other hand can be related to the simultaneous displacement of points A and Sn with the displacement of the maxillary alveolar rim and the upper lip which is overlying it. The further A point moves forward, the more its sagittal position increases as well as the convexity. Also, the more points Sn moves forward, the more the Sn-N'-Sm angle increases; hence the significant and positive correlations between these parameters. The value of the correlation coefficient between the position of point A and the Sn-N'-Sm angle of 0.52 shows a broad association between these two parameters; where the correlation coefficient between the convexity and Sn-N'-Sm of 0.41 (<0.5) shows a mean association according to Cohen [16].

Significant and positive correlations between I / A-Pog and Ls-E and Ls-S variables could also be explained by the relationship between the upper incisor and the upper lip. Several studies have shown that a retroversion of the upper incisor can lead to superior prostration [11,17]. Moreover, the orthodontic treatment of retraction of the upper incisors is often associated with a retraction of the upper lip which concomitantly corrects the prostration. The fact that the upper incisor also rests on the upper part of the lower lip and flush with its free edge explains the significant and positive correlation between the variable I / A-Pog which indicates the degree of superior incisal protrusion and the Li-E distances (r = 0.48 and p = 0.01) and Li / Sn-Sm (r = 0.46, p = 0.02).

The position of the pogonion was significantly and positively correlated with the Sn-H distance (r = 0.42, p = 0.03). In fact, the distal displacement of the pogonion leads to that of the cutaneous chin. This induces a rotation of the H line around the most prominent point of the upper lip, which means a recoil of the segment located under the center of rotation and an advance of the segment located above the center of rotation. An increase in the Sn-H distance will follow (which means a decrease of this negatively noted variable); hence the significant and positive correlation between the position of the pogonion and the Sn-H variable.

The significant and positive correlation between the ANB and Sn-N'-Sm angles show that variations in maxillomandibular skeletal shift follow that of the maxillomandibular cutoff. Indeed, the Sn-N'-Sm angular photogrammetric variable represents the cutaneous ANB angle. The value r > 0.5 shows a wide association between maxillomandibular skeletal shift and maxillomandibular cutoff [16]. This strong association is justified by the fact that the different points which constitute these two angles are situated opposite one another. In fact, cephalometric point A is located opposite cutaneous point Sn. The same is true of the Nasion point (located at the level of the naso-frontal suture) and the Nasion point of the skin at the level of the nasal trellis. Point B (the most sloping point of the mandibular alveolar rim) is also opposite point Sm situated at the bottom of the labial sulcus. Similar results have been reported by Gomes & al. in a study involving a sample of 123 subjects, including 65 girls and 58 boys aged 7 to 12, with whom teleradiographic images and photographic images in profile were taken. The results of this study showed a significant and positive correlation between skeletal ANB and cutaneous ANB (r = 0.82, p <0.001) [18]. Adwani & al. also found similar results for a sample of 150 subjects, including 64 boys, and 86 girls aged 13-28, where r and p were 0.689 and 0.001, respectively [19].

Correlation between vertical photogrammetric variables and vertical teleradiographic parameters

The cephalometric variables N-Me, N-ENA, ENA-Me, S-Go, S-Ar and Ar-Go were all significantly and positively correlated with photogrammetric variables

N'-Sn, Sti-Sm and N'-Me'. In addition, the three variables N-Me, ENA-Me and Ar-Go were significantly and positively correlated with Sn-Me '. It is the same between the ENA-Me, S-Go and Ar-Go variables and the Sn-Sts photogrammetric parameter. Specifically, the Ar-Go variable was significantly and positively correlated with the Sm-Me photogrammetric variable. These significant and positive correlations between vertical linear teleradiographic variables and vertical linear photogrammetric variables show the close relationships between skeletal structures and their vertical cutaneous structures. Thus, vertical linear photogrammetric variables could be used to evaluate the linear variables of the skeletal structures in the vertical direction. The use of correlation coefficients makes it possible to obtain the value of cephalometric measurements from photogrammetric measurements. This contributes to a considerable reduction of the risks of irradiation of the subjects when it comes to evaluating the skeletal structures in the vertical direction.

Axis Y was significantly and positively correlated with Sm-Me '/ Li-Sm ($r = 0.40$ and $p = 0.04$) and negatively correlated with angle Z ($r = -0.54$ and $p = 0.006$). The gonadal angle was significantly and positively correlated with Sm-Me '/ Li-Sm ($r = 0.43$ and $p = 0.03$).

The significant and positive correlations between the Y axis (Frankfurt / S-Gn plane) and Sm-Me '/ Li-Sm on the one hand and between the gonic angle and Sm-Me' / Li-Sm on the other hand could be related to the concomitant displacement of the Gnathion points, Skeletal Chin and Cutaneous Chin all located in the chin area. Indeed, a recoil of the chin leads to that of the Gnathion points, skeleton chin and cutaneous chin, those which cause an increase in the angle of the Y axis and the Sm-Me '/ Li-Sm angle as well as an increase in the angle of the glands; hence these significant and positive correlations. The significant and negative correlation between the angle of the Y axis and the Z angle (between the Frankfurt plane and the straight line connecting the Chin point to the most prominent lip) can also be related to the displacement in the same direction of Gnathion and Chin points. A shift of the skin point towards the back causes a reduction of angle Z. On the other hand, a shift of the gnathion point towards the back causes an increase in the angle Y axis, which justifies the significant and negative correlation between the angle of the Y axis and angle Z.

Conclusion

These numerous correlations prove the close relationship between hard facial tissues and their overlapping skin tissues mainly with respect to vertical linear variables. Vertical linear photogrammetric variables of the soft cutaneous tissues could thus be used to evaluate the cephalometric variables of the hard tissues in the vertical direction, when the X-ray is considered too invasive. This helps to significantly reduce the risk of irradiation of subjects when evaluating facial skeletal structures for epidemiological purposes in studies involving a larger number of subjects.

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References

1. Jain SK, Anand C, Ghosh SK. Photometric facial analysis-A baseline study. J. Anat. Soc. India 2004; 53 (2): 11-13.
2. Wen YF, Wong HM, Lin R, Yin G, McGrath C. Inter-Ethnic / Racial Facial Variations: A Systematic Review and Bayesian Meta-Analysis of Photogrammetric Studies. PLoS One. 2015; 10 (8): e0134525.
3. Subtelny JD. A longitudinal study of soft tissue structures and their profile characteristics, defined in relation to underlying skeletal structures. American Journal of Orthodontics. 1959; 45 (7): 481-507.
4. Arnett GW, Bergman RT. Facial keys to orthodontic diagnosis and treatment planning. Part I. Am J Orthod Dentofacial Orthop. 1993; 103 (4): 299-312.

5. Arnett GW, Bergman RT. Facial keys to orthodontic diagnosis and treatment planning - Part II. Am J Orthod Dentofacial Orthop. 1993; 103 (5): 395-411.
6. Bergman RT. Cephalometric soft tissue facial analysis. Am J Orthod Dentofac Orthop 1999; 116 (40): 373-389.
7. Park HS, Rhee SC, Kang SR, Lee JH. Harmonized profiloplasty using balanced angular profile analysis. Aesthetic Plastic Surgery 2004, 28: 89-97.
8. Phillips C, Greer J., Vig P., Matteson S. Photocephalometry: errors in projection and landmark location. Am J Orthod. 1984; 86 (3): 233-243.
9. Del Santo LM, De Souza RP, Del Santo M JR, Marcantanio E. Alterações no perfil dos lábios de pacientes submetidos a maxilares av emerios em corticología do tipo Fort I R Dental Press Ortodon Ortop Facial 2004; 9 (5): 49-63.
10. Ramos AL, Sakima MT, AS Pinto, Bowman SJ. Upper lip changes correlated to maxillary incisor retraction - a metallic implant study. Orthod Angle 2005; 75 (4): 499-505.
11. Silvera GA, Correa FA, Vedovello M FILHO, Valdrigh HC, Vedovello SA, Such EZ. Alterations of the nasolabial joint and the incisivo central incisivo superior pós-tratamento ortodôntico.Ortodontia. 2006; 39 (1): 31-36.
12. Wen-Ching KO E, Figueroa AA, Polley JW. Soft tissue profile changes after maxillary advancement with distraction osteogenesis by use of rigid external distraction device: a 1- year follow-up. J Oral Maxillofac Surg 2000; 58 (9): 959-969.
13. Diouf JS, Diop Ba K, Badiane A, Ndiaye M, Ngom PI, Diagne F. Vertical photogrammetric characteristics of soft tissue with some Senegalese subjects. Rev. Col. Odonto-Stomatol Afr Chir Maxillo-fac. 2014, 21 (2): 21-27.
14. Diouf JS, Badiane A, Ngom PI, Niagha G, Diop Ba K, Diagne F. Cephalometric characteristics of subjects received for orthodontic consultation at the clinic of the Department of Odontology of Dakar. Tropical Odonto- Stomatology 2010; 33 (3): 27-34.
15. Ferrario VF, Sforza C, Miani A, G. Tartaglia Craniofacial morphometry by photographic evaluations. American Journal of Orthodontics and Dentofacial Orthopedics. 1993; 103 (4): 327-337.
16. Cohen J. Statistical Power and Analysis for Behavioral Science (2nd ed.). Hillsdale NJ: Lawrence Erlbaum Associates. 1988.
17. Park YC, Burstone CJ. Soft-tissue profile - fallacies of hard-tissue standard in treatment planning. Am J Orthod Dentofacial Orthop 1986; 90: 52-62.
18. Carvalho Rosas Gomes L, Horta KOC, LG Gandini, Gonçalves M, Gonçalves JR. Photographic assessment of cephalometric measurements. Orthod Angle 2013; 83 (6): 1049-1058.
19. Adwani K, Swami V, Patil A. Correlation between cephalometric and photogrammetric measurements used in orthodontic diagnosis. Journal of Contemporary Orthodontics. 2017; 1 (3): 1-4.