

ALGORITHM FOR CALCULATION OF CEPHALOMETRIC SOFT TISSUE FACIAL TRAITS

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ABSTRACT

Treatment planning of facial attractiveness is difficult. One of the primary goals of orthodontic treatment is to attain and preserve optimal facial attractiveness. For this, it is important that the orthodontist conduct a thorough facial examination so that the orthodontic correction will not adversely affect the normal facial traits. By knowing the soft tissue traits and the normal range, a treatment plan can be designed to normalize the facial traits for a given individual. This paper presents development of a new soft tissue analysis algorithm, which will be used as an analysis tool in Computer Assisted Craniofacial Surgery Planner – a surgery planning system under development. This analysis tool may be used by surgeons as an aid in diagnosis and treatment planning. This research uses 19 landmarks to calculate 18 facial traits such as facial profile angle, nasal projection, nasolabial angle, lower face height, maxillary sulcus contour, interlabial gap, throat length etc. The proposed algorithm allows picking the required landmarks interactively and then allows adjustment in the position of each landmark precisely. The source data used to get 3D digital models of human soft tissues include CT data and 3D laser scanner data. Up to now Malaysia does not have any source for normal trait values of human face. This algorithm can be used to calculate facial traits for building a nationwide database that can be used to compare normal traits with abnormal ones and then plan the surgery procedures. The system is the result of collaboration between a university, an industrial research organization and a research hospital. In this paper, components of the cephalometric analysis tool are detailed. Issues related to future research and plans for expanding the current system are discussed.

Keywords: CAS, Soft tissue, Craniofacial, Cephalometric, CT, Surgery Planning.

1.0 INTRODUCTION

One of the main applications of cephalometrics is as a shape descriptor. Various linear and angular measurements are used to arrive at a concise and comprehensive description of the craniofacial pattern and to classify each patient, making it easier to identify treatment goals, choose treatment modalities, and predict treatment success [1] [2].

One of the primary goals of orthodontic treatment is to attain and preserve optimal facial attractiveness. To accomplish this, it is important that the orthodontist conduct a thorough facial examination so that the orthodontic correction will not adversely affect the normal facial traits [3]. Recognizing facial disharmonies can maximize efforts to improve negative facial traits. By knowing the soft tissue traits and their normal range, a treatment plan can be designed to normalize the facial traits for a given individual.

Cephalometrics is the process used to evaluate whether a patient falls into the skeletal class I, II or III categories. It determines whether a patient has a skeletal open bite growth pattern, a deep bite growth

pattern or a normal growth pattern. It also helps decide whether a facial profile is retrusive, protrusive or straight [4].

Current methods used to visualize and register changes during and after orthodontic treatments are not as accurate as desired. An exact quantification of the skeletal and dental changes during treatment, at the end of the treatment, and after the retention period has not been accurately established. Two-dimensional (2D) imaging has limitations in the evaluation of 3-dimensional (3D) structures and changes. It has been stated that much information is lost when 3D structures are assessed with 2D methodologies [5].

There are different analysis procedures that can be followed to arrive at a diagnosis. One of them is a cephalometric approach for facial examination and diagnosis by identifying individual facial traits and their balance with one another proposed by Bergman [3]. Having knowledge of standard facial traits along with the patient's soft tissue features, individualized norm can be established for each patient to optimize facial attractiveness.

Cephalometric procedure for craniofacial analysis is a very important procedure in orthodontics and involves tedious geometric and analytic manual calculations to be performed on the x-ray or tracing of the profile of a skull [4]. In this research we have attempted to emulate this manual operation by modeling the process and creating an algorithm that automatically calculates the required measurements using 3D human face model instead of lateral x-ray.

Sixteen landmarks have been used for facial traits measurements. These landmarks have been shown on a 3D model in Figure 1 and Table 1 illustrates their definitions.

Table 1: List of soft tissue landmarks for facial traits

Landmark	Description
G	Soft tissue Glabella
P	Pronasale
Col	Columella
Sn	Subnasale
A	Soft Tissue A point
ULA	Upper Lip Anterior Point
ULM	Upper Lip mucosa side opposite A
ULI	Upper Lip Inferior
Sts	Stomion Superious
I/Tip	Tip of Upper Incisor
Stl	Stomion Inferious
LLA	Lower Lip Anterior Point
B	Soft Tissue B point
LLM	Lower Lip mucosa side opposite B
Pg	Soft Tissue Pogonion
Me	Soft Tissue Menton
CP	Cervical Point

As illustrated in Figure 2, once the digitized three-dimensional image has been acquired and displayed, the proposed system will allow selection of the cephalometric landmarks of interest by picking points on the model in the 3D window. Each landmark will be uniquely numbered and named describing its anatomical location. It is crucial that the landmarks are placed in their correct anatomical location. So any landmark can be selected and relocated to a preferred position.

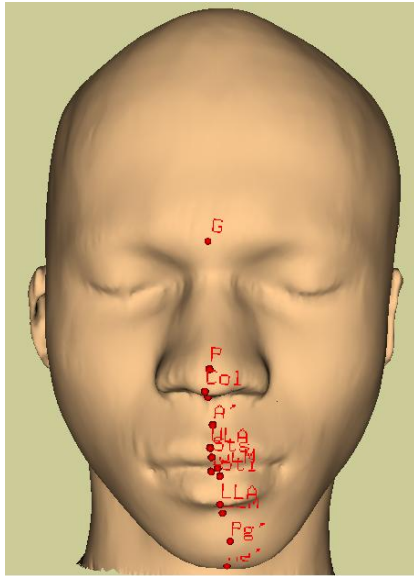


Figure 1: Soft tissue landmarks

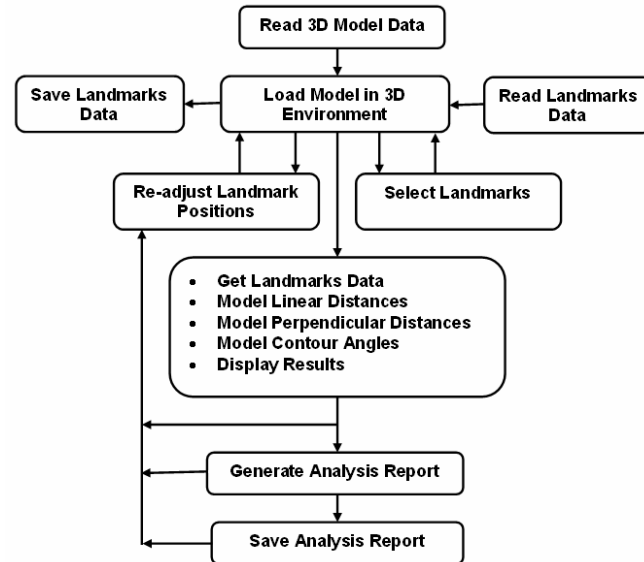


Figure 2: Flow diagram for facial traits algorithm

At any time during the analysis, the landmark positions data can be saved into a data file for future use or reference. Similarly, reading their position from this data file can place the landmarks on model. This provides another way for landmark selection from a previously stored data file and saves time to pick landmarks. After the completion of landmark placement and fine adjustment, the proposed algorithm will perform measurements for the various facial traits. In this analysis, 17 measurements have been computed and are in Table 2.

Table 2: List of facial trait measurements

Trait	Unit
Facial Angle	degree
Nasal Projection	mm
Nasolabial Angle	degree
Lower face Percentage	mm
Lower Face Height	mm
Upper Lip Length	mm
Upper Lip Thickness	mm
Maxillary Sulcus	degree
Upper Lip to Subnasale-Pogonion Line	mm
Interlabial Gap	mm
Lower Lip – Chin Length	mm
Lower Lip Thickness	mm
Mandibular Sulcus	degree
Lower Lip to Subnasale-Pogonion Line	mm
Distance from B to Sn-Pg line	mm
Lower Face Throat Angle	degree
Throat length	mm

After the calculation of these measurements, the algorithm allows saving the result of facial traits analysis into a result file in the form of analysis sheet. The next section presents the geometrical computations based mathematical model for the proposed algorithm.

2.0 MATHEMATICAL MODEL

This section presents mathematical model for several facial traits (Table 2) that are recognized as optimal treatment goals. The analysis is based on key cephalometric soft tissue landmarks relevant to optimal orthodontic and surgical-orthodontic treatment. As explained in the article by Bergman [3], the analysis includes those soft tissue measurements that are most important to treatment planning.

2.1 Facial Profile Angle

The facial profile angle is a primary factor for classification and it determines patient's profile. This angle is formed by connecting soft tissue glabella (G) and soft tissue pogonion (Pg) at subnasale (Sn), as shown in Figure 3.

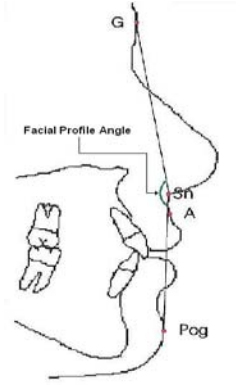


Figure 3: Facial profile angle

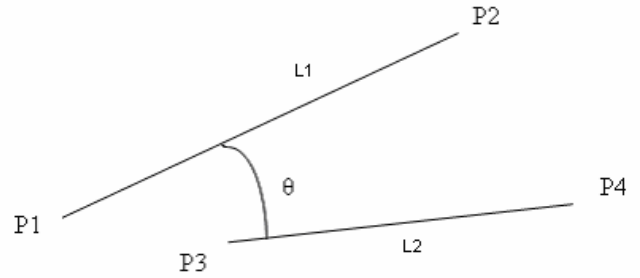


Figure 4: Angle between two lines

Consider two lines L1 and L2 as shown in Figure 4. The line L1 is defined by end points P1(x1, y1, z1), P2(x2, y2, z2) whereas line L2 is defined by end points P3(x3, y3, z3) and P4(x4, y4, z4). The angle between these lines L1 and L2 can be calculated using Equation (1), detailed mathematical derivation of the formula can be found in [5];

$$\theta = \cos^{-1} \left(\frac{(x_2 - x_1)(x_4 - x_3) + (y_2 - y_1)(y_4 - y_3) + (z_2 - z_1)(z_4 - z_3)}{\sqrt{[(x_2 - x_1)^2 + (y_2 - y_1)^2 + (z_2 - z_1)^2][(x_4 - x_3)^2 + (y_4 - y_3)^2 + (z_4 - z_3)^2]}} \right) \quad (1)$$

Consider G(g1, g2, g3), Sn(s1, s2, s3) and Pg(p1, p2, p3) as coordinates for the landmarks G, Sn, and Pg respectively. Then by using Equation (1), the maxillary sulcus contour (θ) can be calculated as;

$$\theta = \cos^{-1} \left(\frac{(g_1 - s_1)(p_1 - s_1) + (g_2 - s_2)(p_2 - s_2) + (g_3 - s_3)(p_3 - s_3)}{\sqrt{[(g_1 - s_1)^2 + (g_2 - s_2)^2 + (g_3 - s_3)^2][(p_1 - s_1)^2 + (p_2 - s_2)^2 + (p_3 - s_3)^2]}} \right) \quad (2)$$

2.2 Nasal Projection

The nasal projection is the distance measured horizontally from the subnasale (Sn) to the nasal tip (P) as shown in Figure 5. Consider P(p1, p2, p3) and Sn(s1, s2, s3) as coordinates for landmarks P and Sn, the nasal projection denoted by Nasal_Projection is given as;

$$\text{Nasal_Projection} = (p_3 - s_3) \quad (3)$$

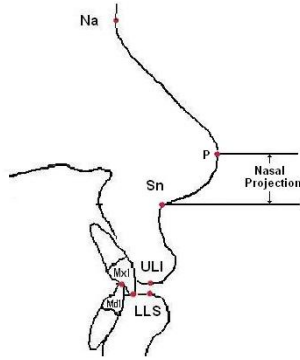


Figure 5: Nasal projection

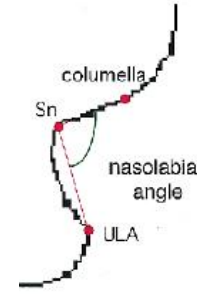


Figure 6: Nasolabial angle

2.3 Nasolabial Angle

The nasolabial angle is the angle formed by the intersection of the upper lip anterior (ULA) and columella (Col) at subnasale (Sn), as shown in Figure 6. Consider Col(c_1, c_2, c_3), Sn(s_1, s_2, s_3) and ULA(u_1, u_2, u_3) as coordinates for the landmarks Col, Sn and ULA respectively. Then by using Equation (1), the nasolabial angle (θ) is given as;

$$\theta = \cos^{-1} \left(\frac{(c_1 - s_1)(u_1 - s_1) + (c_2 - s_2)(u_2 - s_2) + (c_3 - s_3)(u_3 - s_3)}{\sqrt{[(c_1 - s_1)^2 + (c_2 - s_2)^2 + (c_3 - s_3)^2][(u_1 - s_1)^2 + (u_2 - s_2)^2 + (u_3 - s_3)^2]}} \right) \quad (4)$$

2.4 Lower Facial Height

The lower facial height is the lower one third of the face. The face divides vertically into thirds, one third from hairline to midbrow, one third from midbrow to subnasale and the lower third from subnasale to soft tissue menton (Arnett *et al.*, 1999). The lower face height is measured from the subnasale (Sn) vertically to the soft tissue menton (Me) as shown in Figure 7.

Consider Sn(s_1, s_2, s_3) and Me(m_1, m_2, m_3) as coordinates for the landmarks Sn and Me respectively, then lower facial height denoted by LFH can be calculated as;

$$LFH = s_3 - m_3 \quad (5)$$

2.5 Lower Face Percentage

The lower one third of the face from the base of the nose (Sn) to the soft tissue menton (Me) is extremely important in surgical orthodontic diagnosis and treatment planning. The lower face percentage is used to establish the proportion for the lower face height. The lower face height is measured from the subnasale (Sn) vertically to the soft tissue menton (Me). The percent is the total face height measured from soft tissue glabella (G) vertically to soft tissue menton (Me). This percentage is relatively constant throughout development. It is extremely important to control the vertical dimension in patients with excessive lower face heights.

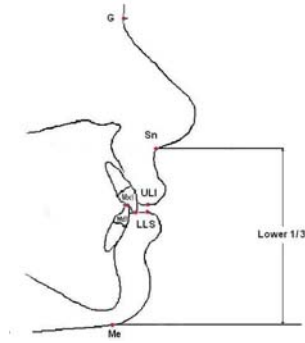


Figure 7: Lower facial height

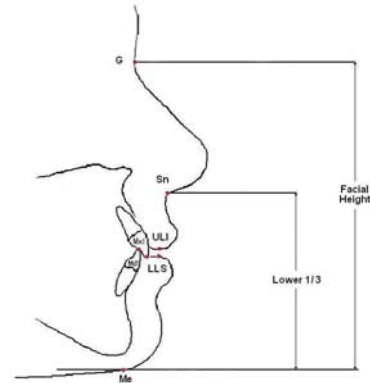


Figure 8: Lower one third of the face

Consider $G(g_1, g_2, g_3)$, $Sn(s_1, s_2, s_3)$ and $Me(m_1, m_2, m_3)$ as coordinates for the landmarks G, Sn and Me respectively. Then the value for facial height denoted by FH comes out to be;

$$FH = g_3 - m_3 \quad (6)$$

Hence by using the value of lower one third from Equation 5, lower face percentage (LFP) is finally calculated as given by;

$$LFP = \frac{LFH}{FH} \times 100\% \quad (7)$$

2.6 Upper Lip Length

The upper lip length is measured in a relaxed-lip position. It is the length measured from subnasale (Sn) vertically to upper lip inferior (ULI) as shown in Figure 9.

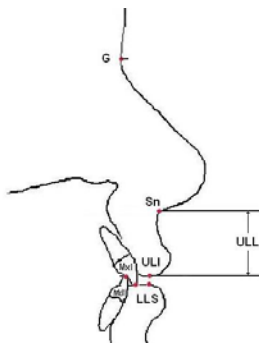


Figure 9: Upper lip length

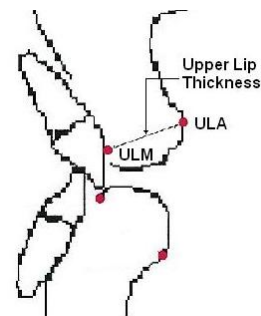


Figure 10: Upper lip thickness

Consider $Sn(s_1, s_2, s_3)$ and $ULI(u_1, u_2, u_3)$ as coordinates for the landmarks Sn and ULI respectively, then the upper lip length denoted by ULL is as given;

$$ULL = s_3 - u_3 \quad (8)$$

2.7 Upper Lip Thickness

The upper lip thickness is measured at the vermillion border to the inner lining of the lip. It is measured as distance between upper lip anterior (ULA) and upper lip mucosa (ULM) as shown in Figure 10.

Consider a line passing through points $P_1(x_1, y_1, z_1)$, $P_2(x_2, y_2, z_2)$, the length L of this line segment can be calculated by the formula [5];

$$L = |P_2 - P_1| = \sqrt{[(x_2 - x_1)^2 + (y_2 - y_1)^2 + (z_2 - z_1)^2]} \quad (9)$$

Consider $ULA(u_1, u_2, u_3)$ and $ULM(m_1, m_2, m_3)$ as coordinates for the landmarks ULA and ULM respectively, then the upper lip thickness denoted by ULT can be calculated by using Equation 4.16 as;

$$ULT = \sqrt{[(u_1 - m_1)^2 + (u_2 - m_2)^2 + (u_3 - m_3)^2]} \quad (10)$$

2.8 Maxillary Sulcus Contour

The maxillary sulcus contour is normally a gentle curve. It gives information regarding upper lip tension. Lip tension can cause the sulcus contour to flatten, whereas flaccid lips have an accentuated curve and are often thick with the vermillion lip area showing (Bergman, 1999). The angle of the maxillary contour can be measured from the subnasale (Sn) to the soft tissue point A (A) to the anterior point of the upper lip (ULA) as shown in Figure 11.

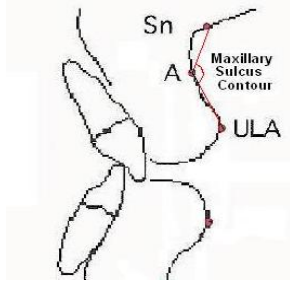


Figure 11: Maxillary sulcus contour

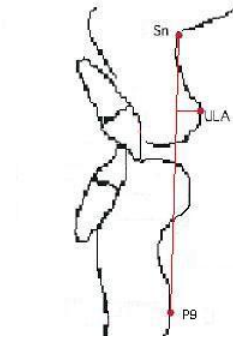


Figure 12: Upper lip to subnasale-pogonion line

Consider $Sn(s_1, s_2, s_3)$, $A(a_1, a_2, a_3)$ and $ULA(u_1, u_2, u_3)$ as coordinates for the landmarks Sn, A and ULA respectively. Then by using Equation 4.7, the maxillary sulcus contour (θ) can be calculated as;

$$\theta = \cos^{-1} \left(\frac{(s_1 - a_1)(u_1 - a_1) + (s_2 - a_2)(u_2 - a_2) + (s_3 - a_3)(u_3 - a_3)}{\sqrt{[(s_1 - a_1)^2 + (s_2 - a_2)^2 + (s_3 - a_3)^2][(u_1 - a_1)^2 + (u_2 - a_2)^2 + (u_3 - a_3)^2]}} \right) \quad (11)$$

2.9 Upper Lip to Subnasale-Pogonion Line

The upper lip to subnasale-pogonion line is the distance between the upper lip anterior (ULA) and the line between subnasale (Sn) and pogonion (Pg) as shown in Figure 12. The relationship of the lips to the subnasale-pogonion line is an important aid in orthodontic soft tissue analysis and treatment. Tooth movement changes the relationship of the lips to the subnasale-pogonion line and, therefore, the esthetic result.

Consider a line defined by points $P1(x_1, y_1, z_1)$ and $P2(x_2, y_2, z_2)$ along a unit vector \hat{n} and having a length of L . Let the point $P3(x_3, y_3, z_3)$ has perpendicular D from line between point $P1$ and $P2$ as shown in Figure 13. Then the distance D is given by the relation [5];

$$D = \frac{1}{L} \sqrt{\left[\begin{aligned} &[(y_3 - y_1)(z_2 - z_1) - (z_2 - z_1)(y_2 - y_1)]^2 \\ &+ [(z_3 - z_1)(x_2 - x_1) - (x_2 - x_1)(z_2 - z_1)]^2 \\ &+ [(x_3 - x_1)(y_2 - y_1) - (y_2 - y_1)(x_2 - x_1)]^2 \end{aligned} \right]} \quad (12)$$

Now consider $Sn(s_1, s_2, s_3)$, $Pg(g_1, g_2, g_3)$ and $ULA(u_1, u_2, u_3)$ as coordinates for the landmarks Sn , Pg and ULA respectively. Then by using Equation (12), the perpendicular distance D from ULA to the line between Sn and Pg has the value;

$$D = \frac{1}{L} \sqrt{\left[\begin{aligned} &[(u_2 - s_2)(g_3 - s_3) - (g_3 - s_3)(g_2 - s_2)]^2 \\ &+ [(u_3 - s_3)(g_1 - s_1) - (u_1 - s_1)(g_3 - s_3)]^2 \\ &+ [(u_1 - s_1)(g_2 - s_2) - (u_2 - s_2)(g_1 - s_1)]^2 \end{aligned} \right]} \quad (13)$$

2.10 Interlabial Gap

The interlabial gap (ILG) is the distance between the inferior border of the upper lip and the upper border of the lower lip. It is calculated as vertical distance between upper lip inferior (ULI) and stomion inferius (StI) as shown in Figure 14.

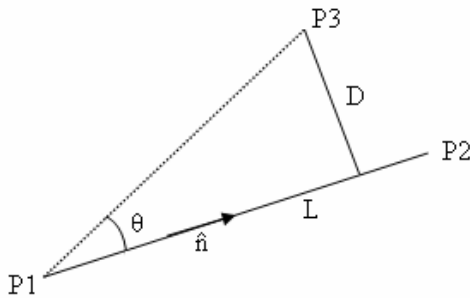


Figure 13: Perpendicular distance from a point to a line

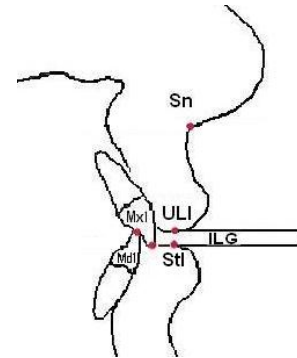


Figure 14: Interlabial gap (ILG)

Consider $ULI(u_1, u_2, u_3)$ and $StI(s_1, s_2, s_3)$ as coordinates for the landmarks ULI and StI respectively, then the interlabial gap denoted by $Interlabial_Gap$ is as given;

$$Interlabial_Gap = u_3 - s_3 \quad (14)$$

2.11 Lower Lip–Chin Length

The lower lip–chin length is measured from the superior border of the lower lip (StI) to the soft tissue menton (Me) as shown in Figure 15. Consider $StI(s_1, s_2, s_3)$ and $Me(m_1, m_2, m_3)$ as coordinates for the landmarks StI and Me respectively, then lower lip to chin length denoted by $Lowerlip_Length$ is as given;

$$LLL = s_3 - m_3 \quad (15)$$

2.12 Lower Lip Thickness

The lower lip thickness is measured from the superior border of the lower lip (Stl) to lower lip anterior point (LLA) as shown in Figure 16. Consider Stl(s₁, s₂, s₃) and LLA(l₁, l₂, l₃) as coordinates for the landmarks Stl and LLA respectively. Then by using Equation (9), lower lip thickness denoted by LLT is as given;

$$LLT = \sqrt{[(s_1 - l_1)^2 + (s_2 - l_2)^2 + (s_3 - l_3)^2]} \quad (16)$$



Figure 15: lower lip-chin length (LLL)

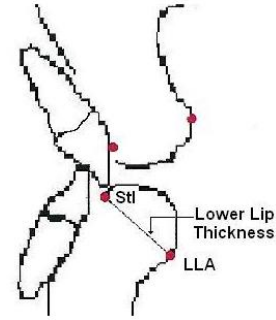


Figure 16: Lower lip thickness

2.13 Mandibular Sulcus Contour

The mandibular sulcus contour is a gentle curve and can indicate lip tension. A measurement of this curve can be taken by measuring the angle formed by lower lip anterior (LLA), soft tissue point B, and soft tissue pogonion (Pg) as shown in Figure 17.

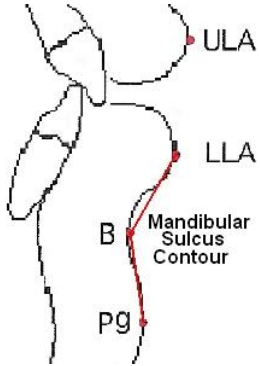


Figure 17: Mandibular sulcus contour

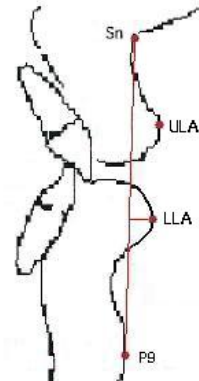


Figure 18: Upper lip to subnasale-pogonion line

Consider LLA(l₁, l₂, l₃), B(b₁, b₂, b₃) and Pg(p₁, p₂, p₃) as coordinates for the landmarks LLA, B and Pg respectively. Then by using Equation (1), the maxillary sulcus contour (θ) can be calculated as;

$$\theta = \cos^{-1} \left(\frac{(l_1 - b_1)(p_1 - b_1) + (l_2 - b_2)(p_2 - b_2) + (l_3 - b_3)(p_3 - b_3)}{\sqrt{[(l_1 - b_1)^2 + (l_2 - b_2)^2 + (l_3 - b_3)^2][(p_1 - b_1)^2 + (p_2 - b_2)^2 + (p_3 - b_3)^2]}} \right) \quad (17)$$

2.14 Lower Lip to Subnasale-Pogonion Line

The lower lip to subnasale-pogonion line is the distance between the lower lip anterior (LLA) and the line between subnasale (Sn) and pogonion (Pg) as shown in Figure 18. Considering Sn(s1, s2, s3), Pg(g1, g2, g3) and LLA(l1, l2, l3) as coordinates for the landmarks Sn, Pg and LLA respectively. Then by using Equation (12), the perpendicular distance D from LLA to the line between Sn and Pg has the value;

$$D = \frac{1}{L} SQRT \left\{ \begin{aligned} &[(l_2 - s_2)(g_3 - s_3) - (g_3 - s_3)(g_2 - s_2)]^2 \\ &+ [(l_3 - s_3)(g_1 - s_1) - (l_1 - s_1)(g_3 - s_3)]^2 \\ &+ [(l_1 - s_1)(g_2 - s_2) - (l_2 - s_2)(g_1 - s_1)]^2 \end{aligned} \right\} \quad (18)$$

2.15 Point B to Subnasale-Pogonion Line

The soft tissue B point–subnasale soft tissue pogonion is the distance of the soft tissue B point to the subnasale soft tissue pogonion line as shown in Figure 19.

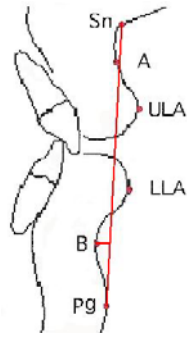


Figure 19: Soft tissue point B lip to subnasale-pogonion line distance



Figure 20: Lower face-throat angle

Now consider Sn(s1, s2, s3), Pg(g1, g2, g3) and B(b1, b2, b3) as coordinates for the landmarks Sn, Pg and B respectively. Using Equation (12), the perpendicular distance D from B to the line between Sn and Pg has the value;

$$D = \frac{1}{L} SQRT \left\{ \begin{aligned} &[(b_2 - s_2)(g_3 - s_3) - (g_3 - s_3)(g_2 - s_2)]^2 \\ &+ [(b_3 - s_3)(g_1 - s_1) - (b_1 - s_1)(g_3 - s_3)]^2 \\ &+ [(b_1 - s_1)(g_2 - s_2) - (b_2 - s_2)(g_1 - s_1)]^2 \end{aligned} \right\} \quad (19)$$

2.16 Lower Face–Throat Angle

The lower face–throat angle is the angle formed by the subnasale-pogonion line and the throat line passing through menton (Me) and cervical point (Cp) as shown in Figure 21. Considering Sn(s1, s2, s3), Pg(p1, p2, p3), Cp(c1, c2, c3) and Me(m1, m2, m3) as coordinates for Sn, Pg, Cp and Me respectively. Then by using Equation (1), the lower face-throat angle (θ) can be calculated as;

$$\theta = \cos^{-1} \left(\frac{(s_1 - p_1)(c_1 - m_1) + (s_2 - p_2)(c_2 - m_2) + (s_3 - p_3)(c_3 - m_3)}{\sqrt{[(s_1 - p_1)^2 + (s_2 - p_2)^2 + (s_3 - p_3)^2][(c_1 - m_1)^2 + (c_2 - m_2)^2 + (c_3 - m_3)^2]}} \right) \quad (20)$$

2.17 Throat Length

The throat length is the distance measured from the neck-throat junction (cervical point) to the intersection of the subnasale-soft tissue pogonion and the throat line as illustrated in Figure 21.

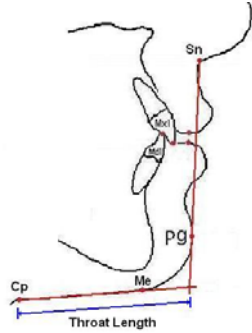


Figure 21: Lower face-throat angle

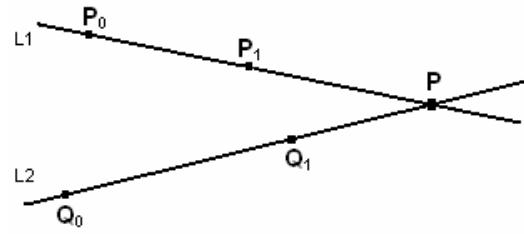


Figure 22: Lower face-throat angle

Consider two lines L1 and L2, defined by end points $P_0(x_0, y_0, z_0)$, $P_1(x_1, y_1, z_1)$, $Q_0(x_0, y_0, z_0)$ and $Q_1(x_1, y_1, z_1)$ respectively as shown in Figure 22. The given lines intersect at point $P(x, y, z)$. Suppose u and v are two constants, and then equations of the two lines can be written as [5];

$$\mathbf{P}(u) = \mathbf{P}_0 + u(\mathbf{P}_1 - \mathbf{P}_0) \quad (21)$$

$$\mathbf{Q}(v) = \mathbf{Q}_0 + v(\mathbf{Q}_1 - \mathbf{Q}_0) \quad (22)$$

If the lines intersect, then their point of intersection $P(x, y, z)$ is given by the solution of the equations (421) and (22). Details of the solution can be found in [5]. The value for constant u is;

$$u = - \frac{(\mathbf{Q}_0 \times \mathbf{Q}_1) \cdot \mathbf{P}_0}{(\mathbf{Q}_0 \times \mathbf{Q}_1) \cdot (\mathbf{P}_1 - \mathbf{P}_0)} \quad (23)$$

Hence coordinates for the point of intersection of the two lines are;

$$\left. \begin{aligned} x &= P_{0x} + u(P_{1x} - P_{0x}) \\ y &= P_{0y} + u(P_{1y} - P_{0y}) \\ z &= P_{0z} + u(P_{1z} - P_{0z}) \end{aligned} \right\} \quad (24)$$

Therefore, for calculation of throat length, the Equations (23) and (24) have been used. Now consider $Sn(s_1, s_2, s_3)$, $Pg(p_1, p_2, p_3)$, $Cp(c_1, c_2, c_3)$ and $Me(m_1, m_2, m_3)$ as coordinates for points Sn, Pg, Cp and Me respectively. Using Equation (4.34), the value for u is;

$$u = - \frac{(C_p \times M_e) \cdot S_n}{(C_p \times M_e) \cdot (P_g - S_n)} \quad (25)$$

Hence the coordinates of point of intersection of the lines through Sn-Pg and Cp-Me are given by;

$$\left. \begin{aligned} x &= s_1 + u(p_1 - s_1) \\ y &= s_2 + u(p_2 - s_2) \\ z &= s_3 + u(p_3 - s_3) \end{aligned} \right\} \quad (26)$$

Therefore, the throat length denoted by TL is the distance between point Cp(cx, cy, cz) and the point of intersection given by Equation (26), which is computed as

$$LLT = \sqrt{(cx - x)^2 + (cy - y)^2 + (cz - z)^2} \quad (27)$$

3.0 RESULTS AND DISCUSSION

The use of 3D model for evaluation of facial analysis has been demonstrated. There is no study on 3D cephalometric standard norms for Malaysians to compare the results. Further study on Malaysians samples is required. Table 3 lists the values of facial traits calculated by the proposed algorithm.

Table 2: Facial trait measurements

Trait	Value
Facial Angle	153.06
Nasal Projection	8.68210
Nasolabial Angle	109.652
Lower face Percentage	51.8922
Lower Face Height	59.653
Upper Lip Length	27.125
Upper Lip Thickness	6.636
Maxillary Sulcus	135.877
Upper Lip to Subnasale-Pogonion Line	6.559
Interlabial Gap	6.320
Lower Lip – Chin Length	32.527
Lower Lip Thickness	9.759
Mandibular Sulcus	26.212
Lower Lip to Subnasale-Pogonion Line	7.719
Distance from B to Sn-Pg line	4.517
Lower Face Throat Angle	112.249
Throat length	51.663

The development of 3D cephalometric is a multidisciplinary initiative that provides an important reference in medical application. In this study, the computerized technique was used to evaluate facial traits for facial analysis based on 3D CT landmark system that gives greatly benefit diagnosis, treatment planning.

Certainly, the use of 3D model for facial traits calculation has distinct advantages as compared to 2D cephalograms. This can evaluate the specific measurements that cannot be easily evaluated by 2D radiographs because of the overlapping structures. Both the measurement values, the actual images in three planes of space are available to move and rotate to show all the structures clearly giving good information of the whole picture of the deformities.

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