The reliability of analytical reference lines for determining esthetically pleasing lip position

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The reliability of analytical reference lines for determining esthetically pleasing lip position: An assessment of consistency, sensitivity, and specificity

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Introduction: This study aimed to identify a simple yet reliable soft-tissue parameter for the clinical determination of esthetic lip position by investigating the most consistent reference lines and assessing their sensitivity and specificity. **Methods:** A total of 5745 records from Chinese patients aged >18 years were screened. In part I of the study, lateral view photographs of 96 subjects (33 males, 63 females) with esthetic facial profiles were selected. The profile esthetics of each photograph was first scored by 52 dental students, followed by 97 laypeople on a 5-point attractiveness scale. For the top 25% of photographs with the highest score for each sex (8 males, 16 females), the consistency of 6 commonly used reference lines were assessed to determine the esthetic lip position. In part II of the study, lip positions relative to Steiner's (S) and Ricketts' (E) lines in the profile photographs of 86 patients (43 males, 43 females) deemed to have an esthetically unpleasing profile were compared with those in 86 Chinese movie star idols (43 males, 43 females). **Results:** In part I of the study, the S, E, and Burstone's (B) lines exhibited the lowest standard deviations for the upper and lower lips. B line was excluded from further analysis because of its higher mean absolute values, and S and E lines were used for the subjective assessment in part II of the study. In part II, the S line showed a sensitivity of 86.0% and 86.0% and a specificity of 81.4% and 83.7% for males and females, respectively. In contrast, the E line presented a sensitivity of 88.4% and 93.0% and a specificity of 79.1% and 74.4% for males and females, respectively. **Conclusions:** S, E, and B lines were the most consistent soft-tissue parameters among both sexes; however, because of the smaller absolute values, the S line would be more convenient among the 3 for a quick clinical assessment of lip position. Moreover, the performance of both S and E lines was similar among both sexes, which supports using these lines in assessing the esthetic lip position. (Am J Orthod Dentofacial Orthop 2023;■:e1-e13)

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Facial attractiveness is an important physical characteristic often associated with perceptions of beauty. A well-balanced facial profile influences a patient's social acceptance, psychological well-being, self-esteem, and quality of life.[1-3] One of the primary goals of orthodontic-orthognathic treatment is to achieve facial harmony by correcting the skeletal and dental tissues, resulting in a change of the overlying soft tissues.[4-7] Lip position, in particular, has been shown to significantly influence facial esthetics and is an integral part of contemporary orthodontic-orthognathic treatment planning.[8]

Although the concept of beauty has evolved and varies across different populations, lip position has consistently been an area of interest.[9-11] Numerous clinical parameters have been reported for the assessment of lip position, including cephalometric angles such as Legan & Burstone's nasolabial angle, labiomental fold, angle of

convexity,[12] Merrifield (Z) angle or line,[13] Holdaway (H) angle or line,[14] and analytical lines, such as Ricketts' (E),[15] Steiner's (S),[16] Burstone's (B),[8] Sushner's (S2),[17] Subnasal vertical,[18] soft-tissue nasion vertical,[19] zero meridian,[20] and glabella vertical lines.[21] For the assessment parameter to be valid, 2 main factors need to be considered. First, whether the normative values for 1 ethnic group are valid for other ethnicities; and second, whether the consistency or agreement, sensitivity, and specificity of the parameters are appropriate for clinical application. The available literature suggests that only 2 studies have reported some work.[19,22] Hsu[22] compared 5 reference lines, including the E, H, B, S, and S2 lines, and showed that the B line is the most consistent and sensitive parameter for 12-year-old patients. However, there is no evidence to conclude if this result holds for adults too. In contrast, Spradley et al[19] evaluated the anteroposterior position of 5 soft-tissue landmarks relative to 4 different vertical reference planes and reported that the subnasal vertical plane had the lowest standard deviation. Interestingly, neither of these 2 studies reported estimates for sensitivity along with specificity, thus making it challenging to evaluate the true measure of clinical performance of the investigated reference lines.

In the clinical context, reference lines are relatively more convenient for routine clinical use and are more commonly adopted to assess the lip position. Given the limited evidence to evaluate their clinical performance, the choice of reference lines often depends on the clinician's judgment. Therefore, investigating whether these reference lines are valid parameters for preferred lip position in terms of esthetic profiles is worthwhile. With this intention, this study had 2 objectives: (1) to identify the most consistent reference lines for determining esthetic lip position and (2) to assess the sensitivity and specificity of the identified reference lines. This is the first study to evaluate the sensitivity and specificity of reference lines commonly used to ascertain esthetic lip positions.

The objective of part I of the study was to identify the most suitable reference line by assessing the consistency of commonly used reference lines for determining esthetic lip position; a narrower standard deviation referred to better consistency of the reference line in judging the lip position.

MATERIAL AND METHODS

This study was conducted in accordance with the Declaration of Helsinki 2013 (http://www.wma.net) after obtaining ethics approval from the Institutional Review Board of the University of Hong Kong, Hospital Authority Hong Kong West Cluster (Institutional Review Board reference no. UW 19-357).

Part I

A total of 5745 records of patients who presented to the Department of Pediatric Dentistry and Orthodontics at the University of Hong Kong between 1994 and 2018 were screened by 2 dental students (J.H.H.N. [male] and Z.W. [female]). Initial screening was based on the following inclusion criteria: (1) adults aged 18-40 years, (2) Chinese ethnicity, and (3) no apparent facial disharmony, such as gross facial deformities, obvious facial asymmetry, severe maxillary and/or mandibular protrusion and/or retrusion. Subjects aged ≤18 years, those who underwent facial and/or orthognathic surgery, or whose photographs were poor quality were excluded. The records of 1300 subjects fulfilled the predefined screening inclusion criteria; the remaining 4475 subjects were excluded. Next, 2 senior orthodontists (M.G. [male] and Y.Y. [female]) assessed the facial profile photographs of 1300 patients, and both unanimously agreed on which patients had pleasing faces. In total, 96 subjects with esthetic facial profiles, 33 males (mean age, 23.5 ± 4.0 years; range, 18-37 years) and 63 females (mean age, 23.3 ± 4.5 years; range, 18-37 years) were chosen.

For part I of the study, a subjective rating methodology was adopted on the basis of a protocol from a previous study.[23] As per the methodology, 2 groups of raters, dental students and laypeople, were used to rate the profile photographs. The following steps were involved in this process: (1) reference photograph set acquisition, (2) selection of attractive profiles, (3) image processing, and (4) measurements and assessment.

Reference photograph set acquisition

The color profile photographs of the 96 subjects with esthetic profiles were converted to black and white photographs and cropped to show only the face (Fig 1). The edited photographs were presented as a Powerpoint presentation. For the assessment of facial attractiveness, 52 dental students (18 males and 34 females; mean age, 22.0 ± 1.8 years [range, 19-25 years]) from the University of Hong Kong were asked to rate each photograph individually on a 5-point attractiveness scale with scores ranging from 1 (least attractive) to 5 (most attractive) and the median scores were obtained. The photographs with the median score for each sex (1 male and 1 female) were then selected as the reference photograph set (Fig 2) for the next round of rating.

Selection of attractive profiles

For the second rating assessment, 97 laypeople (laypeople group) (37 males and 60 females; mean age, 23.7 ± 6.2 [range, 18-40 years]) were recruited on the basis of the sample size calculation (power of 0.8 and α of

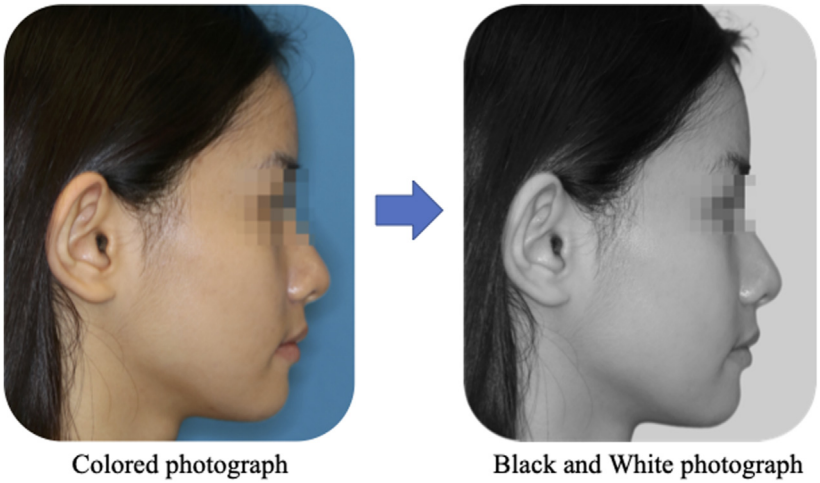

Fig 1. Representation of a profile view colored photograph transformed into a black and white photograph with the hairstyle area cropped

Fig 2. Profile photographs of a male and a female subject with a median score and selected as a reference set.

0.05) from a previous study[24] using G*Power[25] (version 3.1.9.3; Franz Faul, Universitat Kiel, Kiel, Germany), which yielded a minimum sample size of 80 laypeople. The laypeople group was asked to score the same profile photographs (except 2 for the reference set) in relation to the reference photograph set, using the 5-point attractiveness scale. The reference photograph set was assigned a score of 3 on the attractiveness scale. The acquired scores were analyzed using a spreadsheet program (Microsoft Excel; Microsoft Corp, Redmond, Wash), and the median scores for each photograph were calculated. The median scores were ranked from high to low, and the upper quartile (25%) of profile photographs for each sex were selected. In total, 8 males (mean age, 22.6 ± 2.0 years; range, 18-37 years) and 16 females (mean age, 24.3 ± 5.3 years; range, 18-37 years) were deemed to have attractive facial profiles.

Image processing

For each of the 8 males and 16 females with attractive facial profiles, their previously acquired lateral cephalograms (LCs) were retrieved. The LCs were taken within 6 months of the profile photograph capture dates, with subjects in the natural head position and maintaining a stabilized position with ear rods in place. The purpose of using LCs was to transfer the true

Table I. Definition of the landmarks and reference lines used in the study

Abbreviation	*Landmark*	*Definition*	*Reference*
G¢	Soft-tissue Glabella	The most anterior projection of the lower forehead	Resnick et al[27]
N¢	Soft-tissue Nasion	The point of deepest concavity of the soft-tissue contour of the root of the nose	Athanasiou[29]
Pn¢	Pronasale	The most prominent point of the nose	Athanasiou[29]
Sn¢	Subnasale	The point in which the lower border of the nose meets the outer contour of the upper lip	Athanasiou[29]
Col	Columella point	The most anterior point on the columella of the nose	Aljabaa et al[28]
UL	Upper lip	The most anterior point on the upper lip	
LL	Lower lip	The most anterior point on the LL	
Pog¢	Soft-tissue pogonion	The most prominent point on the soft-tissue contour of the chin	Athanasiou[29]
Reference lines			
B line		A line drawn from Sn¢ to Pog¢	Burstone et al[8]
S line		A line drawn from Col to Pog¢	Steiner[16]
E line		A line drawn from Pn¢ to Pog¢	Ricketts et al[15]
Glabella vertical		A vertical reference line passing through G¢	Andrews et al[21]
Nasion vertical		A line drawn perpendicular to true horizontal and passing through N¢	Spradley et al[19]
Subnasal vertical		A line drawn perpendicular true horizontal and passing through Sn¢	Jacobson et al[18]

vertical (Tv) and magnification factor of the profile photographs. This was necessary as the magnification of the profile photographs was unknown. Each LC was scanned and rotated along the true vertical (the vertical edge of the film) using the software Computer-Assisted Simulation System for Orthognathic Surgery (CASSOS) (SoftEnable Technology Limited, Hong Kong, China).[26]

A total of 11 soft-tissue landmarks, 3 on the LCs and 8 on profile photographs, as previously defined,[26-29] were identified (Table I).

To transfer the true vertical from each LC to the corresponding profile photograph, the soft-tissue landmarks, subnasale (Sn¢) and columella point (Col) were identified on the LC, and the angle (∠ Tv-Sn¢Col_{LC}) between the true vertical (Tv) and the columellar line (Sn¢Col) was measured using CASSOS (Fig 3, *A*). Using this angle as a reference, a line "v" was constructed on the photograph of each patient using ImageJ (https://ij.imjoy.io/), an open-source image processing and analysis program,[30] such that the angle (∠ v-Sn¢Col_{Photo}) between the v line and the columellar line on the photograph was same as the Tv-Sn¢Col_{LC} angle (∠ v-Sn¢Col_{Photo} = ∠ Tv-Sn¢Col_{LC}; Fig 3, *B*). After that, each edited photograph was saved in jpg file format and subsequently imported into CASSOS, in which it was rotated along the v line until this line was aligned as true vertical (tv) on the screen (v → tv), thus completing the transfer of the Tv from the LC to the profile photograph (tv) (Fig 3, *C*).

To determine the magnification of the profile photograph, nasal tip protrusion (Sn′-Pn¢), the distance between the soft-tissue subnasale (Sn¢) and pronasale (Pn¢), was measured on each of the LCs and profile photographs using CASSOS. Next, to resolve the scaling discrepancy between the 2, a scaling factor defined as the mathematical ratio of Sn¢-$Pn¢_{LC}$ to Sn¢-$Pn¢_{Photo}$ distances was calculated.

Subsequently, the multiplication of all prospective measurements on the profile photograph with the obtained scaling factor provided more accurate final measurements that followed the measurement scale of the LC.

Measurements and assessment

For the assessment of lip position, each profile photograph was imported into ImageJ, and 6 different reference lines were drawn on the digital profile photographs. The distance from the most convex part of the upper lip (UL) and lower lip (LL) relative to 6 different reference lines (Table I, Fig 4) was measured on each profile photograph, and preliminary measurements were obtained. Subsequently, each preliminary measurement was multiplied by the scaling factor, and the final corrected measurement values were calculated and imported into a spreadsheet program (Microsoft Excel). Following statistical analysis, the reference lines with the lowest standard deviation were considered the most consistent for each sex.

Error study. All measurements were performed by a single orthodontist (M.G.). After a washout period of 4 weeks, the same assessor repeated all measurements to test intraassessor reliability and method error.

Part II

Study sample. Based on a sample size calculation performed with G*Power,[25] using a power of 0.8 and

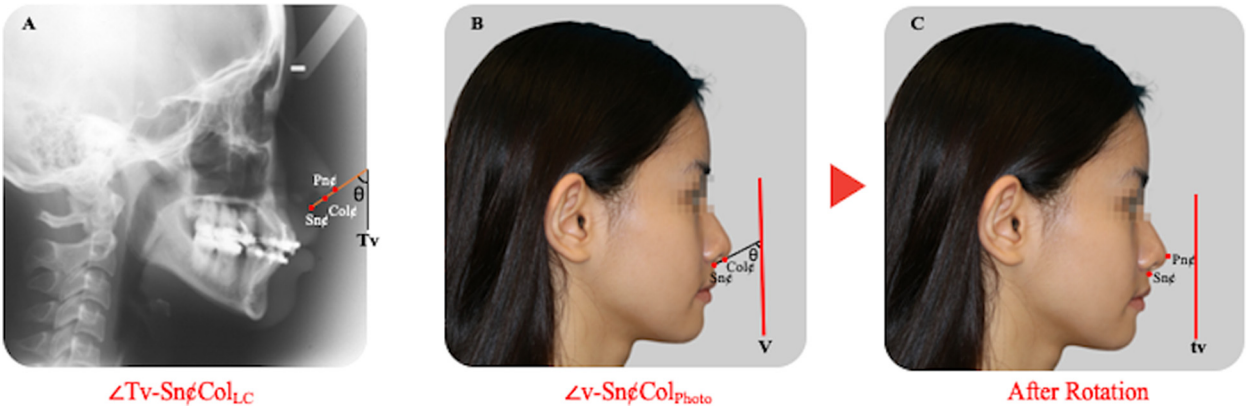

Fig 3. Transfer of true vertical orientation from the lateral cephalogram to the photograph: **A,** Depicts the angle (∠ Tv-SnɕCol_{LC}) between the Tv and the columellar line (SnɕCol_{LC}) on the LC; Tv (*black* coinciding with cephalogram's edge). SnɕCol_{LC}, Subnasale to Columella (*orange*); **B,** Depicts the angle (∠ v-SnɕCol_{Photo}) between the v line (*red*) and the columellar line (SnɕCol_{Photo}) on the photograph; SnɕCol_{Photo}, subnasale to columella (*black*). ∠ Tv-SnɕCol_{LC} was equal to ∠ v-SnɕCol_{Photo}; **C,** Depicts the rotated photograph with v line aligned as Tv on the screen (v → Tv).

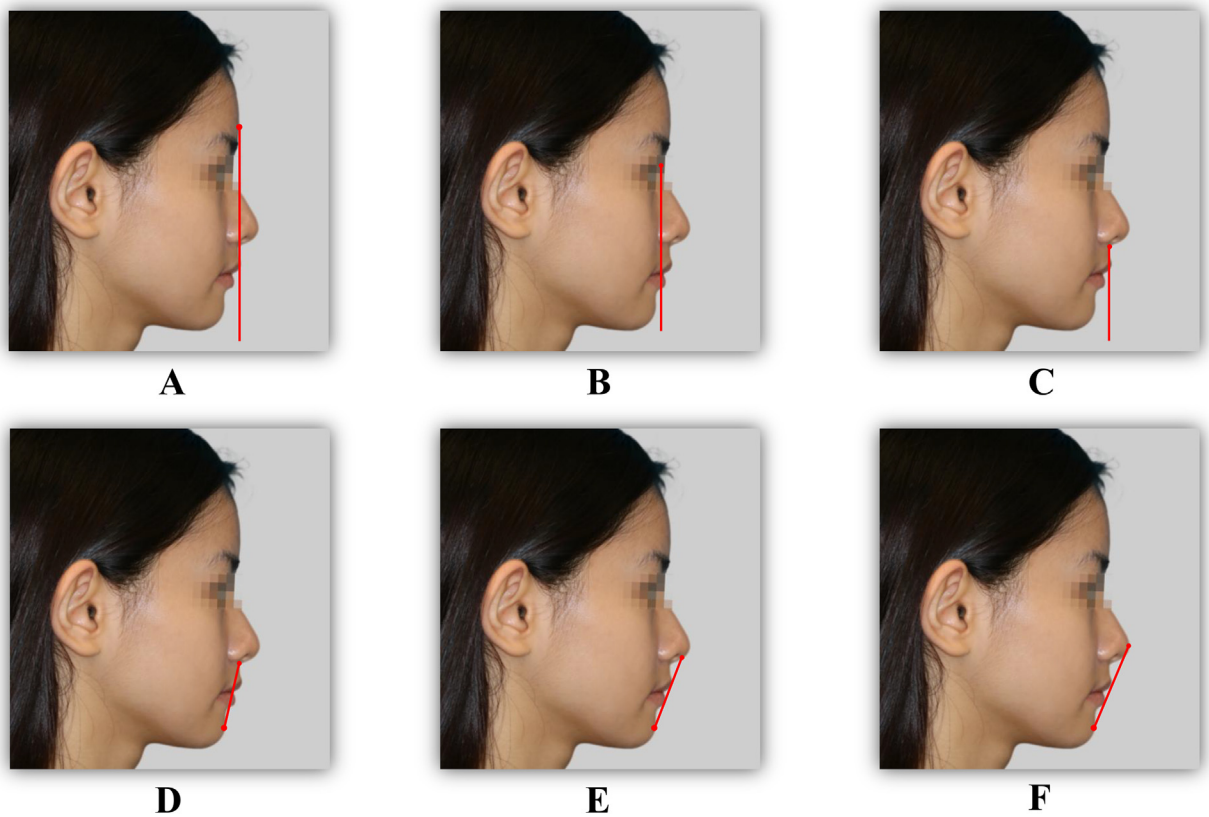

Fig 4. Representative image illustrating the 6 different reference lines analyzed in the study: **A,** Glabella vertical; **B,** Nasion vertical; **C,** Subnasal vertical; **D,** B line; **E,** S line; **F,** E line.

Fig 5. Comparison of lip positions between attractive young MSI and AUP groups based on S and E line criteria. S and E lines have been represented by *red* and *black*, respectively.

width of the 95% confidence interval (CI) for the sensitivity and specificity to be within 30%, a minimum sample size of 43 per group was considered sufficient for part II of the study.

A random sample of 86 subjects (43 males and 43 females) was generated through a Microsoft Excel spreadsheet from the previously screened remaining patient pool of 1204 subjects (1300 subjects with no apparent facial disharmony minus 96 subjects with esthetic facial profiles, in part I of the study), was deemed to have esthetically unpleasing profiles (esthetically unpleasing profile [AUP] group, Fig 5). For the attractive young movie star idol (MSI) group, profile photographs of 86 Chinese MSIs (43 males, 43 females) that were considered to be attractive by the general public, by their popularity,[21,31–33] were retrieved from the internet (Fig 5). All MSIs in the sample were also judged attractive by the panel of the same 2 dental students and 2 senior orthodontists, as in part I of the study. In addition, all subjects in the AUP and MSI groups had normal facial profiles according to the Chinese population's preestablished norms for facial convexity angle (male, 155.9°-178.7°; female, 160.6°-178.5°).[34]

Assessment of the lip position. To assess lip position, analytical reference lines, namely, S and E lines, were drawn on the profile digital photographs of each subject within the MSI and AUP groups using ImageJ (Fig 5), and lip positions were relative to these lines were assessed by employing the subjective criterion, developed on the basis of results from part I. Next, lip positions in the MSI and AUP groups were compared.

A complete workflow of the methodology employed in part I and II studies is presented in Figure 6.

Error study. A single examiner (J.H.H.N.) performed all assessments, and after a washout period of 4 weeks, 30 randomly selected subjects were reassessed according to the subjective criterion by the same examiner to test for intrarater reliability.

Statistical analysis

Methodology. For part I of the study, the intraassessor reliability and method error was determined using the intraclass correlation coefficient and Dahlberg's formula,[35] respectively. Next, for each indicator, descriptive statistics, including mean, standard deviation (SD), and 95% CI, were computed according to sex. Data analysis for parts I and II of the study was performed using SPSS (version 27.0; IBM, Armonk, NY) at a significance level of $P < 0.05$.

In part II of the study, intrarater reliability was assessed using Cohen's kappa statistic. Following this, the association between perceived attractiveness and attractiveness identified by the analytical reference lines among the 2 groups (MSI and AUP) was assessed using the chi-square test. Contingency tables were constructed to calculate the sensitivity, specificity, and positive and

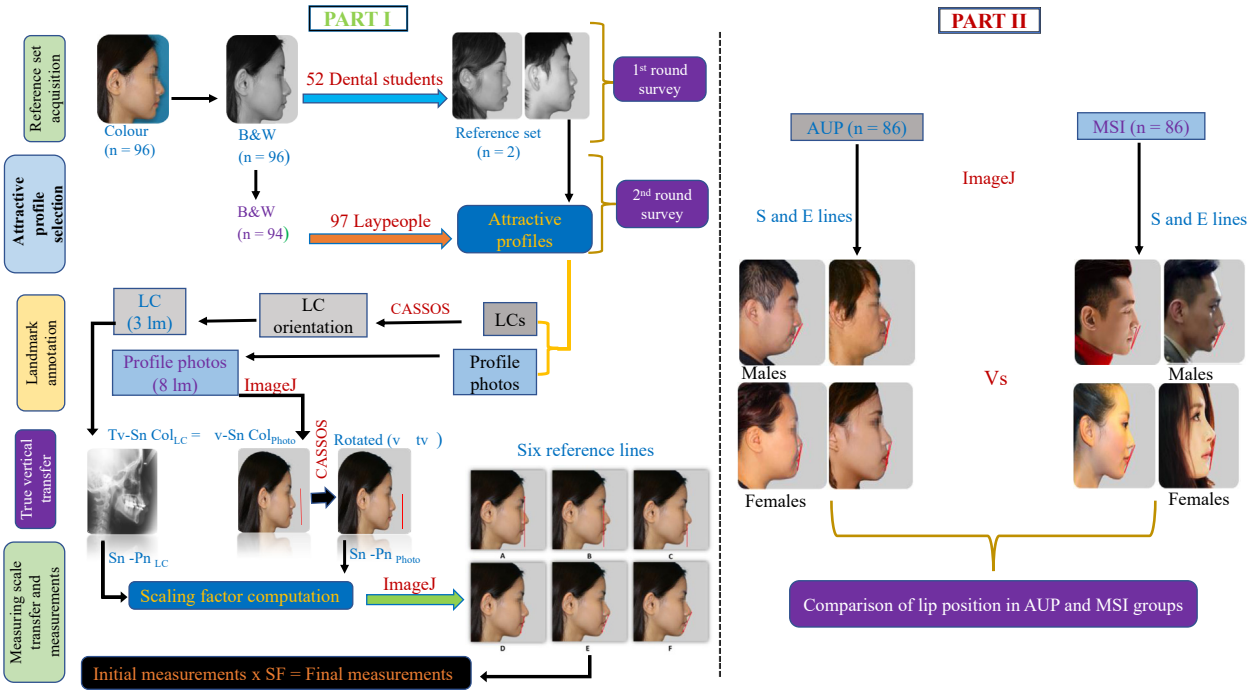

Fig 6. The complete workflow of the methodology employed in part I and II studies. *B&W*, Black and white; *lm*, landmark.

negative predictive values (PPV and NPV) for the 2 reference lines according to sex. A true positive meant that the lip position of the MSI was consistent with the reference line criterion. Their photograph was accurately judged to be attractive by the soft-tissue parameter. In contrast, a true negative indicated that the lip position of the subject in the AUP group was not in line with the reference line criterion. Their photograph was accurately judged to be unattractive by the soft-tissue parameter. Conversely, a subject in the AUP group with a lip position not in harmony with the reference line definition yet judged to be attractive by the soft-tissue parameter meant a false positive, and an MSI with a lip position in harmony with the reference line definition, but deemed unattractive by the soft-tissue parameter, was considered a false negative. Furthermore, the McNemar test was performed for each sex to compare the sensitivity and specificity[36] of the S line with the E line regarding attractiveness within MSI and AUP groups.

RESULTS

Part I

The intraassessor reliability was excellent for all the measurements as the intraclass correlation coefficient values were >0.9 (range, 0.92-0.99), and the method error was <0.5 mm (range, 0.25-0.47). Descriptive statistics, including the mean, SD, and 95% CI for each variable, are shown in Table II. Among males, the E line showed the lowest SD (UL, −3.2 ± 1.5 mm; LL, −1.5 ± 1.4 mm), followed by the S and B lines, and was the most consistent reference line for both UL and LL. Conversely, B and S lines were the most consistent reference lines among females, with the lowest SDs for UL (B line-UL, 4.1 ± 1.2 mm) and LL, respectively (S line-LL, 0.8 ± 1.5 mm), followed by the E line. Consequently, the S, E, and B lines were the most consistent reference lines for assessing esthetic lip position.

The mean absolute values for the S and E lines were comparatively lower than the B line among both sexes. Lower mean absolute values for the S line (males: UL, −0.7 mm; LL, 0.0 mm; females: UL, 0.1 mm; LL, 0.8 mm) and the E line (males: UL, −3.2 mm, LL, −1.5 mm; females: UL, −2.6 mm, LL, −0.8 mm) indicated that these lines could be used for subjective clinical assessment of the esthetic lip position, without acquiring physical measurements. In contrast, because of higher mean absolute values for the B line (males: UL, 3.5 mm, LL, 2.5 mm; females: UL, 4.1 mm, LL, 3.2 mm), a subjective clinical judgment of the esthetic lip position based on the B line may be practically

Table II. Descriptive statistics for the position of upper and lower lips in relation to different soft-tissue parameters

	Males		*Females*	
Soft-tissue indicators	*Mean ± SD (mm)*	*95% CI*	*Mean ± SD (mm)*	*95% CI*
UL				
E Line	−3.2 ± 1.5	−4.5 to −2.0	−2.6 ± 1.4	−3.4 to −1.9
S Line	−0.7 ± 1.8	−2.2 to 0.8	0.1 ± 1.3	−0.6 to 0.8
B Line	3.5 ± 2.2	1.7-5.3	4.1 ± 1.2	3.4-4.8
Subnasal vertical	2.1 ± 2.5	0.0-4.2	4.0 ± 1.8	3.1-5.0
Nasion vertical	11.8 ± 5.8	7.0-16.7	16.6 ± 6.1	13.4-19.9
Glabella vertical	8.7 ± 6.2	3.5-13.8	15.5 ± 6.9	11.8-19.2
LL				
E Line	−1.5 ± 1.4	−2.6 to −0.3	−0.8 ± 1.5	−1.6 to 0.0
S Line	0.0 ± 1.5	−1.2 to 1.3	0.8 ± 1.5	0.0-1.6
B Line	2.5 ± 1.9	0.9-4.1	3.2 ± 1.5	2.4-4.0
Subnasal vertical	−0.3 ± 2.6	−2.4 to 1.9	2.9 ± 3.3	1.1-4.7
Nasion vertical	9.4 ± 5.8	4.6-14.2	15.5 ± 7.5	11.5-19.5
Glabella vertical	6.2 ± 6.0	1.2-11.2	14.3 ± 8.3	9.9-18.7

Table III. Distribution of young MSI and esthetically unpleasing profile groups according to the reference lines

	Males			*Females*		
Variables	*MSI*	*AUP*	P *value*	*MSI*	*AUP*	P *value*
S Line[†]						
Attractive	86.0	18.6	<0.001	86.0	16.3	<0.001*
Unattractive	14.0	81.4		14.0	83.7	
E Line[†]						
Attractive	88.4	20.9	<0.001	93.0	25.6	<0.001*
Unattractive	11.6	79.1		7.0	74.4	

Note. Data are expressed in frequency (percentage).
[†]Chi-square test; *Statistically significant (P <0.05).

Table IV. Measures of performance for S and E lines according to sex

	S Line		*E Line*	
Variables	*Males*	*Females*	*Males*	*Females*
Sensitivity	86.0	86.0	88.4	93.0
Specificity	81.4	83.7	79.1	74.4
PPV	82.2	84.1	80.9	78.4
NPV	85.4	85.7	87.2	91.4

Note. Values are presented as %.
PPV, positive predictive value; *NPV*, negative predictive value.

impossible. Hence, considering the clinical practicality and ease of usage, the B line was excluded from further analysis and a subjective criterion was devised on the basis of the S and E lines, wherein lips that were on or slightly behind the S line were considered attractive in males, whereas slightly ahead or on the S line lip position was considered attractive in females. For the E line, a lip position behind the E line was deemed attractive for both sexes. In addition, a LL positioned slightly behind or on the E line was also deemed attractive in females. The sensitivity and specificity of the S and E lines based on this subjective criterion were further analyzed in part II of the study.

The objective of part I of this study was to assess the sensitivity and specificity of the most suitable reference lines identified in part I. To this end, lip positions relative to reference lines in an AUP sample were compared with those in an attractive young MSI sample.

Part II

Lip assessment criteria had excellent intrarater reliability, with kappa values[37] of 0.867 and 0.930 for the S and E line criteria, respectively. The distribution of the MSI and AUP groups based on the attractiveness determined by the analytical reference lines is shown in Table III. Based on the S line, a significantly higher proportion of MSIs were identified as attractive compared with the AUP group among both sexes (86.0%, P <0.001, for both males and females;). Similarly, according to the E line, the proportion of MSIs identified as attractive was significantly higher (males, 88.4%, P ≤0.001; females, 93.0%, P ≤0.001) than those in the AUP group.

Table IV presents the performance measures for the S and E lines. For each line, the sensitivity, specificity, PPV, and NPV were calculated according to sex. When performance measures for both lines were compared, the E line showed a higher sensitivity (males, 88.4%; females, 93.0%) and NPV (males, 87.2%; females, 91.4%) than

Table V. Comparative evaluation of the sensitivity and specificity of the S and E lines between MSI and AUP groups

	Males			*Females*			*Overall*		
Variables	*MSI n = 43*	*AUP n = 43*	*Total n = 86*	*MSI n = 43*	*AUP n = 43*	*Total n = 86*	*MSI*[†] *n = 86*	*AUP*[‡] *n = 86*	*Total*[§] *n = 172*
Both attractive	35 (81)	8 (19)	43 (50)	38 (88)	6 (14)	44 (51)	73 (85)	14 (16)	87 (51)
S attractive but E unattractive	2 (5)	0 (0)	2 (2)	1 (2)	1 (2)	2 (2)	3 (3)	1 (1)	4 (2)
E attractive but S unattractive	3 (7)	1 (2)	4 (5)	3 (7)	5 (12)	8 (9)	6 (7)	6 (7)	12 (7)
Both unattractive	3 (7)	34 (79)	37 (43)	1 (2)	31 (72)	32 (37)	4 (5)	65 (76)	69 (40)
P value	1.000	1.000	0.683	0.617	0.221	0.114	0.505	0.131	0.080

Note. Values are presented as n (%). McNemar chi-square test was performed unless otherwise mentioned. $P < 0.05$ was considered statistically significant.
[†]Male and female movie stars; [‡]Male and female unattractive; [§]Overall movie star and overall unattractive.

the S line. Conversely, the S line showed higher specificity (males, 81.4%; females, 83.7%) and PPV (males, 82.2%; females, 84.1%) than the E line. Similarly, when the performance of the 2 lines were analyzed among both sexes, the S line presented similar sensitivity (86.0% for males and females each) and NPV (males, 85.4%; females, 85.7%) within both sexes and a marginal higher specificity (83.7%) and PPV (84.1%) for females as compared with males (specificity, 81.4%; PPV, 82.2%). However, the E line presented higher sensitivity (93.0%) and NPV (91.4%) for females as compared with males (sensitivity, 88.4%; NPV, 87.2%) and higher specificity (79.1%) and PPV (80.9%) for males as compared with females (specificity, 74.4%; PPV, 78.4%).

The results for the comparative evaluation of the sensitivity and specificity of the S and E lines between the MSI and AUP groups (individually) have been illustrated in Table V. There was no significant difference between the sensitivity and specificity of the S and E lines in the MSI group and the AUP group with regard to both sexes.

DISCUSSION

Based on the novel methodology, this study identified the most suitable soft-tissue parameters for clinically determining esthetic lip positions. Previous reports have shown that although rating perceived facial attractiveness, laypeople may be distracted by other esthetic variables, such as skin complexion and hairstyle, thereby introducing bias in the esthetic scores.[24,38-40] The use of black and white photographs with cropped hairstyle areas showing only the lateral profiles used in this study aimed to reduce these confounding variables.

Studies analyzing facial esthetic features or facial profile assessments are often conducted through rater panels involving professionals and/or laypersons. Dental professionals often place more emphasis on facial assessment in accordance with previously set norms as a result of their dental training[41]; as a result, there is a difference in the perception of facial esthetics between professionals and laypersons.[42,43] Orthodontists may favor a more retrusive lip position than a layperson.[44] In contrast, although dental students' perceptions are somewhere between dentists and laypeople,[24] their esthetic standards may be considered closer to laypeople.[45] This is because dental students have limited clinical knowledge of esthetic norms typically used by orthodontists and oral and maxillofacial surgeons. Consequently, dental students were considered more as laypeople for the selection of subjects and first-round image assessment. After this initial screening, 2 senior orthodontists verified the subjects selected by the dental students on the basis of predefined selection criteria. Because the judgment by dental students brings in both their academic and intuitive components,[24] were deemed ideal image assessors for obtaining a reference set of photographs with a median score that the layperson could refer to while providing their rating. Laypersons were chosen as the final group of raters as most patients are laypeople, and it is important to consider their perceptions when determining a well-balanced esthetic profile.[46]

Clinical photographs lack a measuring scale; therefore, any measurements made directly on the photographs for assessing lip position may be misleading because of the magnification and distortion errors.[47] Variations in the head orientation might also influence the alignment of reference lines such as nasion vertical, subnasal vertical, and glabella vertical, which may affect the accuracy of measuring the lip positions. In addition, alterations in cranial base orientation have been shown to produce Class II or III effects.[48] Hence, the methodology focused on minimizing scaling and orientation-associated errors. To accomplish this, the exact

orientation of the natural head position, which has been reported to be extremely stable[49] and highly reproducible[50-53] in both sexes and different ethnic groups, was transferred from the LC to the profile photograph. Accordingly, the novel yet simple procedure used in this study ensured a similar scale and orientation for all the photographs analogous to the LCs, thus facilitating precise measurement of the lip position.

Several researchers have objectively assessed the horizontal lip position and its relationship with the esthetic facial profile using various reference lines. In this study, the 6 most commonly used reference lines were investigated; the results showed that the S, E, and B lines, with the lowest SDs, could be considered the most consistent determiners of esthetic lip position. The clinical applicability of the most suitable parameter in determining the esthetic lip position was assessed by employing a subjective criterion; however, the B line was excluded from the assessment because of its higher mean absolute values. According to the subjective criterion, a lip position on or close to (slightly ahead of or behind) the reference line (S or E) was considered attractive for both sexes. This was further verified on the basis of the measurements from part I, which revealed that the attractive lip position was within a distance of approximately ± 2 mm from the reference lines. Specifically, the lip position that was subjectively identified to be attractive was found to be on or slightly behind the S line in males (UL, -2.2 to 0.8 mm; LL, -1.2 to 1.3 mm), whereas on or slightly ahead of the S line in females (UL, -0.6 to 0.8 mm; LL, 0.0 to 1.6 mm), considering 95% CI.

Similarly, lips that were deemed attractive were found to be behind the E line in both sexes (males: UL, -4.5 to -2.0 mm, LL, -2.6 to -0.3 mm; females: UL, -3.4 to -1.9 mm, LL, -1.6 to 0.0 mm) at 95% CI. The results suggested that the S and E lines could be subjectively employed for the clinical judgment of esthetic lip position without precise clinical measurements. Accordingly, S and E lines were used for the subjective assessment in part II of the study.

A previous study by Spradley et al[19] reported that the subnasal vertical has a lower SD than the nasion vertical, consistent with our findings. In addition, our results showed S and E lines to be even more consistent than the subnasal vertical. Because of the lower standard deviations associated with S and E lines, as observed in this study and previous studies undertaken on the Japanese,[54] Korean,[55] and Turkish[56] populations, the S and E lines are more appropriate for assessing the esthetic lip position. Furthermore, contrary to the findings of Hsu,[22] which documented the B line as the most consistent parameter regardless of sex, this study found the E line to be the most consistent among males. A reasonable explanation for such contrasting results could be the difference in the age of the subjects and the difference in the dispersion measurement methodology adopted. In addition, this study included adult subjects (aged >18 years), whereas Hsu[22] conducted their study on 12-year-old adolescents who were reported to have an underdeveloped chin and immature facial hard and soft tissues.[5,57] Because some reference lines use chin and nasal landmarks, immaturity and underdevelopment of these facial regions may influence the performance of such reference lines.

Furthermore, this study employed the SD to assess consistency, similar to a previous study by Spradley et al,[19] whereas Hsu[22] computed the coefficient of variation for this purpose. As reported in previous studies, the application of the coefficient of variation may be invalid in some contexts[58,59] and may result in an overestimated dispersion of measurements,[60,61] in particular, when the mean of the measure is close to zero. Because the lip position may exist close to the reference lines and result in mean values close to zero, as observed for the S line in this study, the usage of the coefficient of variation in such a scenario may yield unrealistically high values. Therefore, computing the SD was considered a more valid approach.

The distance between the UL and LL to the S line runs from the midpoint of the S-shaped curve (between Sn¢ Pn¢) to soft-tissue pogonion (Pog¢); ideally, in well-balanced faces, both the lips should touch this line.[16] However, in this study, the lower lip was more protrusive than the UL in both sexes, comparable to the findings of Erbay et al[56] and can be attributed to the normal labial inclination of the mandibular incisors in Chinese subjects.[62] In addition, females presented slightly protrusive lips (UL, 0.1 mm; LL, 0.8 mm) than males (UL, -0.7 mm; LL, 0.0 mm), which agreed with the observations of previous studies.[56,63,64] A reasonable explanation for such results could be a slightly retrusive mandible in females compared with their male counterparts.[62] A similar trend of relatively protrusive lips was observed within females (UL, -2.6 mm; LL, -0.8 mm) when analyzed for the distance of the upper and lower lips from the *Ricketts* E line, which runs from Pn¢ to Pog'.[15] Ricketts et al[15] advocated that the upper and lower lips should lie at a mean distance of 3-4 mm and 2 mm behind the E line for esthetic profiles. Although the lip position was behind the E line in our investigation, the mean absolute values observed for both sexes were smaller than the range described by Ricketts et al.[15] These contrasting results can be attributed to the ethnic disparities. Although the subjects in Steiner[16] and Ricketts et al[15] were predominantly white, this study included only Chinese subjects. Normative values that are customary to 1 ethnic

group may not necessarily be pertinent to other ethnicities as well[56,65]; for instance, the Chinese race generally possesses more protrusive lips than Caucasians.[62,66]

Movie stars are often perceived as having a highly attractive and esthetic profile.[67] With this in mind, the S and E lines were used to determine if they could successfully differentiate an attractive MSI group from the AUP group based on the criteria developed from the results of part 1 of the study. Interestingly, despite being perceived as attractive, up to 14% of the attractive faces did not meet the S-line and E-line criteria (Table III). Similarly, up to 25% of the faces perceived as unattractive were deemed attractive using the S and E lines. However, the MSI group was identified as more attractive than the AUP group for both sexes. More than 86% of the attractive faces were detected as attractive, and more than 74% were found unattractive by S and E lines. Indeed, a significant association was observed between perceived attractiveness and attractiveness, as determined by the reference lines (S and E, $P < 0.001$, Table III). Although the average lip position in Chinese adults has been reported to be more protrusive than the normative values by Steiner and Ricketts,[64] the preferred lip position observed in the present study was slightly retrusive than the average lip position in the population. These results are in agreement with those of Ioi et al,[46] who also reported slightly more retrusive lips than the average in the preferred profiles of the Korean and Japanese races.

In this study, the sensitivity and specificity of the tested reference lines reflected how likely the reference lines could correctly determine the esthetic lip position among esthetic profiles and the unesthetic lip position among unesthetic profiles. Accordingly, S and E lines showed high sensitivity and specificity in detecting esthetic lip position among both sexes. In addition, high PPVs indicated that a higher proportion of the faces detected as attractive on the basis of S and E lines were attractive. These results are, to some extent, in line with the findings of Erbay et al,[56] who reported E-line norms to closely resemble the values for an attractive profile. Furthermore, when the performance of the S and E lines was compared, both reference lines performed equally well in detecting MSIs as attractive and the AUP group as unattractive among both sexes (Table V).

An important consideration while using S and E lines for the facial analysis is that both these reference lines rely on the anteroposterior position of the chin and nose, and the lip position is assessed in relation to them. Although the growth of the nose influences both these lines, the S line is affected to a lesser extent. In addition, the position of the nose is less likely to influence the usage of these reference lines among East Asians because of lesser variation in the oriental nose morphology in this population, as reported by Aung et al.[68] Another factor that may influence the soft-tissue profile and introduce bias[8,14] is the position of the chin. Therefore, a skeletal Class I relationship with a normal chin position is a prerequisite for using these reference lines. It is important to appreciate that facial soft tissues, including the nose, lip, and chin, undergo some age-related changes[69]; however, the change associated with the progressing age may be minimal (<1 mm) in Chinese subjects.[70] Hence, age-related changes in the facial soft tissues may not affect the interpretation of these results significantly.

The methodology used in this study applies to patients from various ethnic backgrounds and has potential applications in photogrammetry analysis and image-based observational studies, which are commonly used in various medical disciplines, such as orthodontics, oral and maxillofacial surgery, and plastic surgery. In addition, the presented methodology successfully quantified normative values that may serve as baseline data for orthodontic-orthognathic treatment planning in the Chinese population. For clinical usage, both S and E lines can be considered the most consistent soft-tissue parameters for assessing the esthetic lip position. The landmarks for the E line (Pn'-Pog') are among the most prominent facial features and, therefore, easy to locate chairside.[64] In contrast, the S line is reliable as it passes through part of the nose and involves columella as a reference point.[22] Therefore, regarding clinical practicality, the S line can quickly assess lip position to the clinicians because of smaller absolute values.

Nevertheless, a few limitations need to be considered before interpreting the results of this study: First, because of the limited number of patients with esthetic profiles during the preliminary screening, the final sample size in part 1 was relatively small. Second, the results are only characteristic of the Chinese race and could differ among populations of different races and ethnicities. Third, the chin should be in a normal skeletal Class I position to use these reference lines; therefore, the present results may not hold for patients with Class II and III positions. Furthermore, soft-tissue parameters such as lip thickness, lip strain, and the thickness of soft tissues at reference points (Pn', Col, and Pog') were not considered, which may have influenced the interpretation of our results. Finally, the reference lines investigated in the present study could not assess attractiveness from the frontal view, which has a limited correlation to attractiveness in the profile view.[71] Future studies with increased sample size and 3-dimensional analysis will be needed to identify the soft-tissue indicators affecting attractiveness in the frontal view.

CONCLUSIONS

The methodology described here can provide precise measurements for photogrammetry analysis and be applied to other ethnic populations. Moreover, for the assessment of esthetic lip position in adults, the following conclusions can be drawn on the basis of the findings of this study: (1) the S, E, and B lines were the most consistent soft-tissue parameters within both sexes; however, owing to the smaller absolute values, the S line would be a more convenient parameter to the clinicians for the quick assessment of lip position; (2) retrusive lips in relation to E line and slightly retrusive or on the S line' lip position was perceived to be esthetic in males; and (3) slightly protrusive or 'on' the S line lip position, whereas retrusive ULs and slightly retrusive lower lips in relation to E line were perceived to be esthetic in females. Furthermore, both S and E lines exhibited similar performance among both sexes, and this study advocates using these lines in determining esthetic lip positions.

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AUTHOR CREDIT STATEMENT

Janson Hoi Hei Ng contributed to methodology, data curation, investigation, and formal analysis; Pradeep Singh contributed to formal analysis, original draft preparation, manuscript review and editing, and visualization; Ziling Wang contributed to data curation and investigation; Yanqi Yang contributed to resources, supervision, and validation; Balvinder S. Khambay contributed to validation and manuscript review and editing; and Min Gu contributed to conceptualization, methodology, project administration, resources, supervision, validation, and manuscript review and editing.

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