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Angular photogrammetric analysis of the soft tissue facial profile

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SUMMARY All medical specialties interested in improving facial appearance need to measure the face to quantify the desired facial changes. The purpose of this investigation was to obtain objective average measurements of the soft tissue facial profile to use them as a guide for aesthetic treatment goals.

The analysis of the soft tissue facial profile from photographic records provides information on the morphology of the profile and its relationship with the underlying dentoskeletal tissues. In this investigation the soft tissue facial profile of a young adult European Caucasian population (212 individual, 50 males and 162 females, 18–20 years of age) was studied by means of standardized photographic records taken in the natural head position (NHP). Angular measurements were analysed digitally.

Sexual dimorphism was found for several angles: nasofrontal (G–N–Prn: $P < 0.01$), vertical nasal (Cm–Sn/N–Prn: $P < 0.01$), nasal (N–Prn/TV: $P < 0.01$), nasal dorsum (N–Mn–Prn: $P < 0.05$), and mandibular contour (C–Me/G–Pg: $P < 0.01$). Wide individual variations in nasolabial and mentolabial angles were also observed.

Introduction

Social acceptance, psychological well-being, and the self-esteem of an individual are related to physical appearance. It has been established that self-esteem is strongly dependent on facial appearance (Hershon and Giddon, 1980; Varela and García-Camba, 1995, 1996; Canut, 1996). Appearance, therefore, is one of the primary functions of the face. However, the definition of an attractive and pleasing face is subjective, with many factors involved (culture, personality, ethnic background, age) (Şahin Sağlam and Gazilerli, 2001).

On the other hand, several medical specialties (orthognathic and plastic surgery, orthodontics, dental prosthesis) have the ability to change facial features. Hence, there is a need for clinicians working in the maxillofacial area to know the aesthetic standards of a face that guide the aesthetic soft tissue treatment goals in their patients. It is well known that races, ethnic groups, age, sex, etc. influence average facial traits (Mandall *et al.*, 2000).

In orthodontics, different authors have included soft tissue parameters in cephalometric analysis (Burstone, 1958, 1967; Subtelny, 1959; Lines *et al.*, 1978; Holdaway, 1983) (Figure 1). Various soft tissue facial analyses based on photogrammetry have also been described (Stoner, 1955; Peck and Peck, 1970; Powell and Humphreys, 1984; Epker, 1992; Arnett and Bergman, 1993a,b). Other photographic methods to quantify facial aesthetics have also been used (Peerlings *et al.*, 1995).

After standardization of the teleradiographic technique (Broadbent, 1931), analysis of the soft tissue facial profile was relegated in favour of dentoskeletal relationships that, since then, have decided the objectives in diagnosis and orthodontic treatment planning. However, it was observed that not all parts of the soft tissue profile directly follow the underlying dentoskeletal profile (Subtelny, 1959).

Some authors, such as Downs (1956), incorporated measurements of the soft tissue profile in the cephalometric analysis (Figure 1), introducing filters in the teleradiographic technique that allowed visualization of the soft tissues.

Merrifield (1966) created the line of the profile tangent to pogonion and the most prominent lip, usually the upper one, forming the Z angle with the Frankfort plane (FH). Burstone (1958, 1967) carried out an exhaustive aesthetic analysis of the facial profile in which he included the nasolabial angle (Cm.Sn–Ls), the mentolabial angle (Li–Sli–Me), and the total facial contour (G–Sn–Me). Lines *et al.* (1978) incorporated the nasal angle formed by the tangent to the nasal dorsum and the facial plane. Holdaway (1983) defined the reference line H:Ls–Pg and the angle it forms with the facial plane (H angle).

On the other hand, Stoner (1955) started to use analysis of the soft tissues of the face on photographic records.

Powell and Humphreys (1984) described the aesthetic triangle formed by the nasofrontal angle (tangent to the nasal dorsum/G–N), nasofacial angle (G–Pg/tangent to the nasal dorsum), nasomental angle (tangent to the nasal dorsum/Ricketts' E plane), and the cervicomental angle (G–Pg/C–Me).

Arnett and Bergman (1993a,b) defined their frontal and lateral analysis from the photographic records taken in

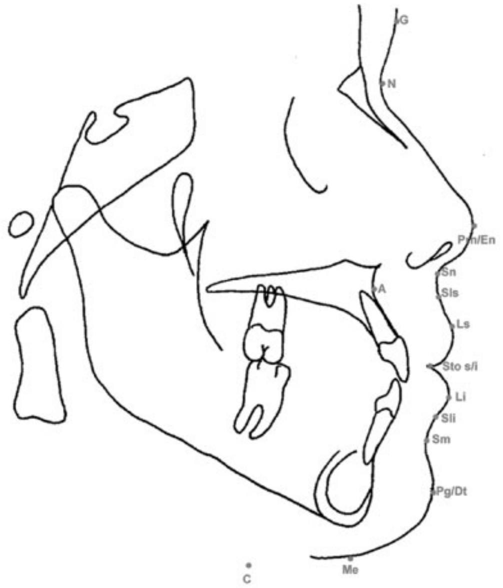

Figure 1 Soft tissue landmarks used in cephalometric analysis. G, Glabella; N, nasion; Prn/En, pronasal; Sn, subnasal; Sls, sulcus labial superior; Ls, labial superior; Sto s/i, stomion superior/inferior; Li, labial inferior; Sli, sulcus labial inferior; Sm, supramental; Pg/Dt, pogonion; Me, menton; C, cervical.

the natural head position (NHP). They used, among others, the nasolabial angle and the angle of the contour of the maxillary and mandibular sulcus. They also described the facial profile in Class I (165–175 degrees), Class II (<165 degrees), and Class III profiles (>175 degrees) according to the angle of the facial convexity (G–Sn–Pg).

In the present cross-sectional study, the aim was to quantify average parameters that define the soft tissue facial profile of a young adult Caucasian sample of Galicians. Angular measurements were defined in a standardized photogrammetric technique to analyse the profile.

Materials and methods

The population of this study were medical and dental students of the faculty of Medicine and Dentistry of the University of Santiago de Compostela. The age range was 18–20 years. A sample of 275 individuals was randomly obtained: 67 males and 208 females. A brief questionnaire was completed for all individuals that included name, age, origin, previous orthodontic treatment, and maxillo-mandibular relationship. For the purposes of this study an individual was considered to be 'Galician' if their four grandparents were of Galician origin, a region located in the northwest of Spain. Subjects with craniofacial anomalies were excluded from the study.

Photographic set-up (Figure 2)

The photographic set-up consisted of a tripod (Manfroto tripod, model FB 10 Series 075, 141 RC; Manfrotto Nord SRL, Villapaiera Bl., Italy) that held a 35 mm camera (Canon, model EOS 5 35 mm; Shimomaruko, Tokyo, Japan) and a primary flash (Cullman primary flash, model BC 42; Cullman Gmbh, Langenzenn, Germany). The tripod controlled the stability and the correct height of the camera according to the subject's body height. This ensured the correct horizontal position of the optical axis of the lens (Macro Canon lens 100 mm; Tokyo, Japan). A 100 mm focal lens was selected in order to maintain the natural proportions.

A primary flash was attached to the tripod by a lateral arm, at a distance of 27 cm from the optical axis of the camera and 75 degrees from the upper right angle to avoid the 'red-eye effect' on the photographs. Another element of the set-up was a secondary flash (Starblitz secondary flash, model Sure-Hite 2600-GMS; Fuji Koeki Corporation, Tokyo, Japan), placed behind the subject. Its function was to light the background and eliminate undesirable shadows from the contours of the facial profile. A slave cell allowed synchronization with the main flash.

Record-taking

The camera was used in its manual position, the shutter speed was 1/125 per second and the opening of the diaphragm f/11. The film was Agfachrome (Agfachrome film CTX ISO 100; Germany) developed using the E-6 process in the same laboratory so that the processing was identical throughout the study.

The subject was positioned on a line marked on the floor, and framed alongside a vertical scale divided in 5-cm segments. From the scale hung a plumbline held by a thick black thread that indicated the True Vertical (TV). The scale allowed measurements at life size (1:1). On the opposite side of the scale and outside the frame

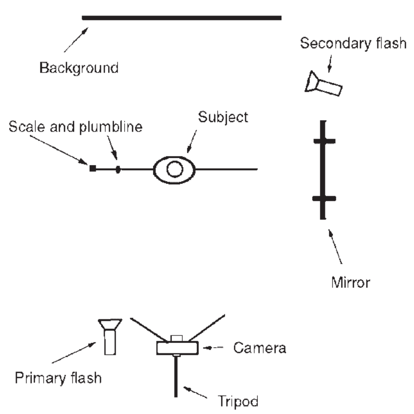

Figure 2 Photographic assembly.

there was a vertical mirror, approximately 110 cm from the subject.

In order to take the records in NHP, the subjects were asked to walk a few steps, stand at rest facing the camera and near the scale, look into their eyes in the mirror, and place their arms at their side. The lips should also be relaxed, adopting the position they normally show during the day. Previously, glasses had been removed and the operator ensured that the patient's forehead, neck, and ears were clearly visible during the recording.

Digitalization

The photographic records, 35-mm slide format, were digitized and analysed using Nemoceph 2.0® (Nemotec Dental Systems, Madrid, Spain) software program for the Windows operating system. The program was previously customized with the landmarks used in this investigation.

Analysis

The software calculated all the measurements once they were identified on each landmark record (Figures 3–5), which had previously been digitized and scaled to life size. All the manual procedures were undertaken by the same operator.

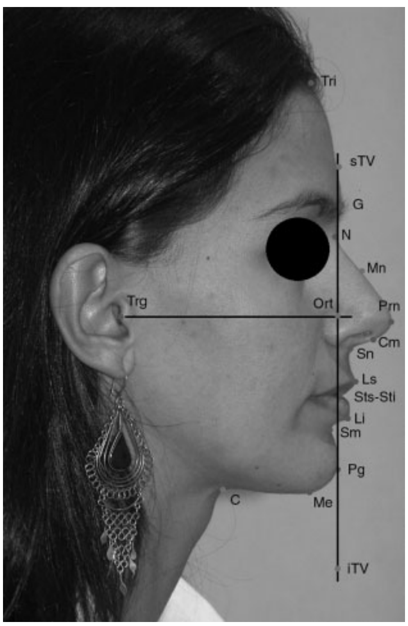

Figure 3 Landmarks and reference lines used in this investigation. G, glabella; N, nasion; Mn, mid nasal; Prn, pronasal; Cm, columella; Sn, subnasal; Ls, labial superior; Li, labial inferior; Sm, supramental; Pg, pogonion; Me, menton; C, cervical; Trg, tragus; sTV, superior point of the True Vertical; iTV, inferior point of the True Vertical; Ort Point, junction of the True Vertical and the True Horizontal. Reference lines: sTV–iTV, True Vertical; N–Ort (parallel to TV through nasion), True Vertical in nasion; Trg–Ort (perpendicular to TV through Trg), True Horizontal.

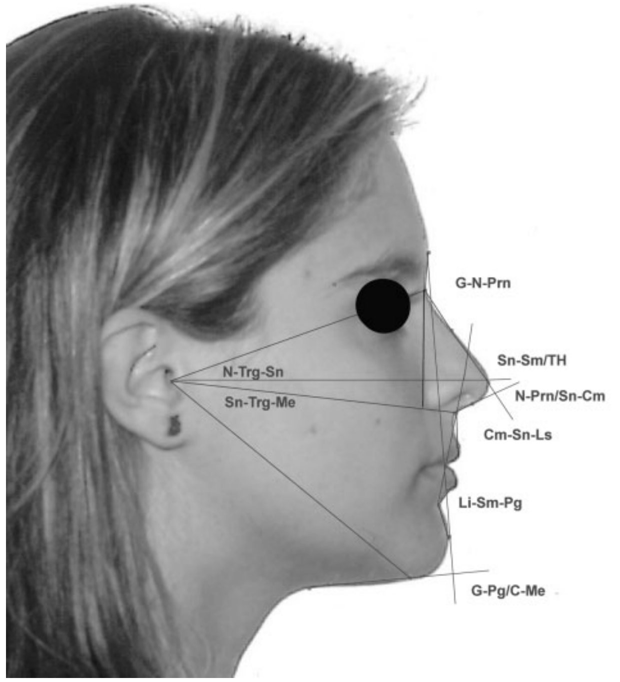

Figure 4 Angular measurements of the analysis (clockwise): N–G–Prn, nasofrontal angle; N–Prn/N–Ort, vertical nasal angle; Cm–Sn–Ls, nasolabial angle; Li–Sm–Pg, mentolabial angle; Sn–Cm/N–Prn, nasal angle; N–Mn–Prn, angle of the nasal dorsum; G–Pg/C–Me, cervicomental angle; N–Trg–Sn, angle of the medium facial third; Sn–Trg–Me, angle of the inferior facial third; Trg–Ort/Sn–Sm, angle of the head position.

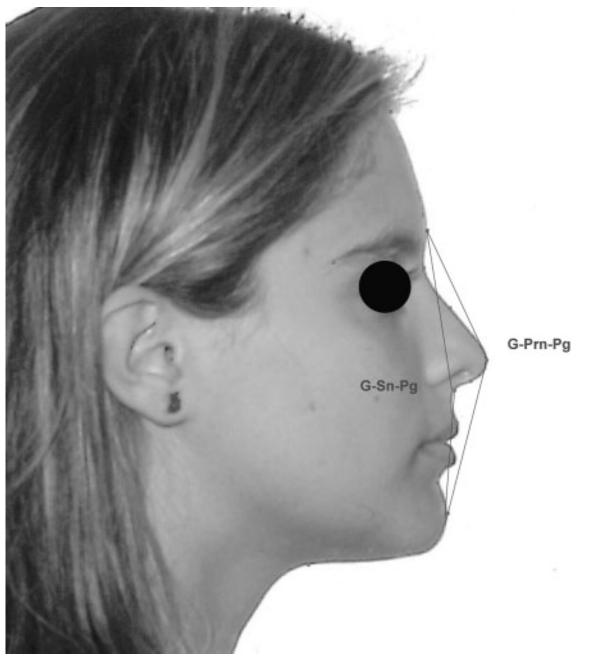

Figure 5 Angular parameters of the facial convexity. G–Sn–Pg, angle of facial convexity; G–Prn–Pg, angle of total facial convexity.

Statistical analysis

To compare males and females a Student's *t*-test was used (Table 1). Descriptive statistics of the variables are shown in Table 2.

The reliability of the method was analysed using Dalhberg's formula that determined the method error, $ME = \sqrt{\Sigma(x_1 - x_2)^2/2n}$, in which x_1 was the first measurement, x_2 was the second measurement, and n the number of repeated records (Houston, 1983). Fifty-four randomly selected sets of photographs were retraced and redigitized 2 weeks after the first set of recordings to calculate the method error (Table 3).

Table 1 Application of the Student's *t*-test in relation to sex.

Variable	P < 0.05*	Inferior limit of confidence interval (95%)	Superior limit of confidence interval (95%)
G–N–Prn	0.001*	1.41	5.40
Cm–Sn/N–Prn	0.009*	0.96	6.39
N–Prn/TV	0.002*	–4.11	–0.98
N–Mn–Prn	0.035*	–3.13	–1.62
Cm–Sn–Ls	0.24	–1.62	6.36
Li–Sm–Pg	0.68	–2.7	4.12
C–Me/G–Pg	0.000*	2.16	6.49
N–T–Sn	0.59	–42.9	74.68
Sn–T–Me	0.31	–1.56	0.51
Sn–Sm/TH	0.063	–3.28	0.09
G–Sn–Pg	0.156	–2.89	0.46
G–Prn–Pg	0.40	–2.13	0.86

*Differences statistically significant, $P < 0.05$.

Results

Two hundred and twelve individuals (50 males, 23.6%, and 162 females, 76.4%) comprised the sample. Sixty-three individuals did not fulfil the requirements (presence of craniofacial anomalies, origin different from Galicia) and were excluded from the study.

The skeletal relationship of the sample included 143 subjects (67.7%) with a Class I, 61 subjects (28.6%) with a Class II, and eight individuals (3.7%) with a Class III relationship. Sixty-nine subjects (33%) had received previous orthodontic treatment.

The Student's *t*-test was applied to all variables to determine the influence of sex in the measurements (Table 1). Five of the angles showed sexual differences: nasofrontal (G–N–Prn, $P = 0.001$), nasal (Cm–Sn/N–Prn, $P = 0.009$), vertical nasal (N–Prn/TV, $P = 0.002$), nasal dorsum (N–Mn–Prn, $P = 0.035$), and cervicomental (C–Me/G–Pg, $P = 0.000$).

Table 2 gives the means, standard deviations, and ranges for the variables of males and females. A wider nasofrontal angle was found in females (141.9 ± 6 degrees) than in males (138.6 ± 7 degrees). Other angles such as

Table 2 Average values for the measurements in males and females.

Parameter	Sex	n	Min.	Max.	Mean	SD	Confidence interval (95%)
G–N–Prn*	male	50	124	153.6	138.57	6.81	(124.9 – 145.3)
	female	162	122.2	156.3	141.98	6.06	(129.8 – 154.1)
Cm–Sn/N–Prn*	male	50	47.4	99.3	72.6	9.04	(54.6 – 90.6)
	female	162	63.7	93.9	76.28	5.8	(64.6 – 87.8)
N–Prn/TV(N)*	male	50	24	51.3	33.8	5.82	(22.1 – 45.4)
	female	162	20	47.1	31.25	4.5	(22.2 – 40.2)
N–Mn–Prn*	male	50	160	179.9	174.21	4.26	(165.6 – 182.7)
	female	162	153.4	179.9	172.58	5.9	(160.7 – 184.3)
Cm–Sn–Ls	male	50	71.7	137.6	105.2	13.28	(78.6 – 131.7)
	female	162	76.5	134.5	107.57	8.5	(90.5 – 124.5)
Li–Sm–Pg	male	50	113.2	153.1	130.75	9.64	(111.4 – 150)
	female	162	95.8	159.8	131.45	11.01	(109.4 – 153.4)
C–Me/G–Pg*	male	50	65.5	99.8	79.85	7.19	(65.4 – 94.2)
	female	162	65.3	104	84.18	6.65	(70.8 – 97.4)
N–T–Sn	male	50	23.5	34.5	28.9	2.61	(23.7 – 34.2)
	female	162	22.8	34.3	28.2	2.61	(22.9 – 33.4)
Sn–T–Me	male	50	31	45.9	36.8	3.59	(29.6 – 43.9)
	female	162	29.7	44.8	36.2	3.14	(30 – 42.5)
Sn–Sm/TH	male	50	65.4	87.4	76.1	5.32	(65.4 – 86.7)
	female	162	60.2	88.5	74.5	5.28	(63.9 – 85)
G–Sn–Pg	male	50	160	178.4	168.2	4.96	(158.3 – 178.1)
	female	162	150.8	179	167.0	5.36	(156.3 – 177.7)
G–Prn–Pg	male	50	126.9	152.5	139.9	5.38	(129.1 – 150.6)
	female	162	128	149.6	139.2	4.48	(130.3 – 148.2)

*Differences statistically significant, $P < 0.05$.

Table 3 Method error according to Dalhberg's formula.

Parameter	Method error (°)
G–N–Prn	2
Cm–Sn/N–Prn	3.5
N–Prn/TV(N)	1
N–Mn–Prn	2.7
Cm–Sn–Ls	4
Li–Sm–Pg	4.5
C–Me/G–Pg	1.25
N–T–Sn	0.82
Sn–T–Me	0.93
Sn–Sm/TH	0.72
G–Sn–Pg	0.92
G–Prn–Pg	1.73

Sn–Cm/N–Prn (females = 76.3 ± 6 degrees, males = 72.6 ± 9 degrees) and C–Me/G–Pg (females = 84.2 ± 6 degrees, males = 79.8 ± 7 degrees) were also wider in females. The rest of the angles that presented sexual dimorphism were wider in males: the vertical nasal angle (N–Prn/TV males = 34 ± 6 degrees, females = 31 ± 4 degrees) and the nasal dorsum angle (N–Mn–Prn, males = 174 ± 4 degrees, females = 172.6 ± 6 degrees).

The greatest variability was found for the nasolabial and mentolabial angles, with high standard deviations and large confidence intervals. These angles also showed the highest method error (4–4.5 degrees). The nasal angle also showed a significantly high error (3.5 degrees).

Discussion

It was the purpose of this investigation to obtain average parameters that define the soft tissue facial profile of the investigated population. When comparing the present results with other studies, the characteristics of the method and the sample used should be borne in mind.

In this investigation, standardized photogrammetric records taken in NHP were analysed using angular measurements. The records were obtained from a sample of 212 (50 males, 162 females) Caucasians from Galicia. Many authors such as Yuen and Hiranaka (1989) and Arnett and Bergman (1993a,b) also used NHP in their studies. In relation to the photogrammetric technique, the focal lens used was 100 mm to avoid facial distortion. Adequate portrait focal lenses that maintain the facial proportions have a range of 90–135 mm. The height of the camera was at the same time adapted to the subject's body height by raising or lowering the height of the tripod.

The selected sample were 18–20 years old, and their race was European Caucasian (Galician). Excluding facial deformities, all the subjects that fulfilled the requirements participated in the study. All types of jaw relationship were included since it has been observed that not all parts of the soft tissue facial profile directly follow the underlying dentoskeletal profile (Subtelny, 1959). The difference in the number of males and females in the sample was due to the distribution of students at the Faculty of Medicine and Dentistry (64% female, 24% male). This lack of proportion in sex distribution is a bias that should be kept in mind.

The means, standard deviations, and ranges of the confidence interval for the variables is provided in Table 2. The nasofrontal angle (G–N–Prn) showed statistically significant sexual differences ($P < 0.01$) (males = 138 ± 7 degrees, females = 142 ± 6 degrees). Epker (1992), in a study of Caucasians undertaken on frontal and lateral facial views, observed no sexual differences in this angle (130 degrees).

The vertical nasal angle (N–Prn/TV) and the nasal dorsum angle (N–Mn–Prn) also showed significantly ($P < 0.05$) wider angles in males than in females (Table 2).

The nasal angle (Sn–Cm/N–Prn) also showed sexual dimorphism (males = 72.6 ± 9 degrees, females = 76.2 ± 6 degrees). McNamara *et al.* (1992) found sexual differences in the nasal tip angle in a study of 141 adult Caucasians that satisfied the criteria of pleasing facial aesthetics and Class I occlusal relationships. The method employed was based on cephalograms. Lines *et al.* (1978) provided a mean range of 60–80 degrees for the angle of the intersection of the nasal dorsum and a tangent to columella. In that study, facial profile silhouettes were selected by several groups of 'judges'. The origin of the silhouettes was not mentioned.

The relationship between the nasal base (columella) and the upper lip, analysed by the nasolabial angle, is one of the facial profile parameters with broader clinical uncertainty. In the present sample this angle showed large variability, males = 105 ± 13 degrees (range 78.6–131.7 degrees), females = 107.6 ± 8.5 degrees (range 90.5–24.5 degrees). The method error was also high. For these reasons, the results of this measurement should be interpreted with caution. Burstone (1967) reported a nasolabial angle of 74 ± 8 degrees (range 60–90 degrees) in a Caucasian adolescent sample with a normal facial appearance. Yuen and Hiranaka (1989) in a study of Asian adolescents on standardized photographic records reported an angle of 102.7 ± 11 degrees for males and 101.6 ± 11 degrees for females. McNamara *et al.* (1992) reported similar results in a study on lateral cephalograms of adult Caucasians with pleasing facial aesthetics (males = 102.2 ± 8 degrees, females = 102.4 ± 8 degrees).

The other measurement that should be evaluated with caution because of its large variability (SD 9–11 degrees) and high error (4.5 degrees) is the mentolabial angle (Li–Sm–Pg, males = 130.7 ± 9 degrees, females = 131.4 ± 11 degrees). These findings are similar to those of McNamara *et al.* (1992), Li–Sm–Pg = 133–134 ± 10 degrees. Lines *et al.* (1978) found in the silhouettes a mentolabial angle of 120–130 degrees.

The cervicomental angle, G–Pg/C–Me, was significantly ($P < 0.01$) more acute in males (79.8 ± 5 degrees) than in females (84 ± 6 degrees).

The lower profile orientation was analysed by the line Sn–Sm and the True Horizontal or angle of the head position. Sexual dimorphism was not found (male = 76.1 ± 5.3 degrees, female = 74.5 ± 5 degrees). Wider angles indicate a tendency to prognathic and lower angles to retrognathic profiles.

Peck and Peck (1970) studied standardized cephalometric and photographic records of Caucasians with pleasing faces. Those authors used the facial angle T–P/N–Pg (102.5 ± 3 degrees) to describe the profile orientation. Both angles complete the the information provided by the facial (G–Sn–Pg) and total facial (G–Prn–Pg) convexity angles.

Burstone (1958) used an angle called the 'total facial contour', which was defined as the intersection of the upper facial (G–Sn) and anterior lower facial (Sn–Pg) components. From a sample of lateral and frontal photographs of 40 young adult Caucasians with acceptable or pleasing faces, the mean value was 11.3 ± 4 degrees. Arnett and Bergman (1993a,b) presented a clinical facial analysis based on previous studies and their surgical experience. For the facial examination the angle G–Sn–Pg was used to assess the convexity/concavity of the profile. According to the authors, a Class I profile presented an angle range of 165–175 degrees, a Class II profile less than 165 degrees, and a Class III greater than 175 degrees. Yuen and Hiranaka (1989) reported from their Asian adolescent sample on photographic records a G–Sn–Pg angle of 162 ± 5 degrees in females and 161 ± 6 degrees in males. The G–Prn–Pg angle was 135 ± 4 degrees in males and 135 ± 3 degrees in females. No sexual dimorphism was found. In the present investigation, the facial convexity and total facial convexity angles obtained were similar. G–Sn–Pg: 168 ± 5 degrees in males and 167 ± 5 degrees in females. The G–Prn–Pg angle: 140 ± 5 degrees in males and 139 ± 4.5 degrees in females. Following the classification of Arnett and Bergman (1993a,b), the Class I profiles in the present sample were between 162 and 172 degrees.

Peck and Peck (1970) used a profilometric analysis based on standardized cephalograms and photographs to assess the sof tissue facial profile. They analysed vertical height by means of angles such as the total vertical (N–T–Pg), the nasal (N–T–Prn), the maxillary (Prn–T–Ls), and the mandibular (Ls–T–Pg) angles. In this investigation the middle and inferior facial thirds were evaluated by the N–T–Sn and Sn–T–Me angles. The inferior third was larger (36–37 ± 4 degrees) than the middle third (28–29 ± 2.6 degrees). Epker (1992) also reported in Caucasian subjects that the linear lower face height (Sn–Me) was larger (38%) than the upper (G–Sn: 32%) in relation to total face height.

Conclusions

Analysis of the soft tissue facial profile and its comparison with standard soft tissue facial profile measurements are necessary in all medical specialties that can change facial traits. The mean values obtained from this sample can be used for comparison with records of subjects with the same characteristics and following the same photogrammetric technique.

The results showed sexual differences in five of the measurements: the nasofrontal, the nasal vertical, the nasal, and the nasal dorsum angles. Another important finding was the high method error and large variability for the nasolabial and mentolabial angles. The results of these two measurements should be assessed with caution.

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