Three-dimensional facial analysis using a video imaging system

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One of the objectives of orthodontic treatment is an esthetically pleasing and balanced face that is in harmony with the dental and skeletal structures. This harmony is primarily determined by the soft tissue integument, along with the underlying skeletal framework. Disproportions and malrelationships of the facial skeleton can often be compensated for by the soft tissue drape. The common assumption that the soft tissue facial integument is correlated with the underlying dental and skeletal features has been proven erroneous. It is also a fact that there is considerable variability in the thickness of the soft tissue drape.[1-6] Treatment focused on dental and skeletal relationships may result in good occlusions but poor facial esthetics. A rigid adherence to average dental and skeletal parameters in orthodontic treatment does not always lead to posttreatment stability of treated occlusion,[7] nor does it always lead to balanced faces, because a proportionate change or improvement in the soft tissue profile does not necessarily accompany dentition changes.[8]

Czarnecki et al.[9] evaluated the perception of facial balance by varying the length of the nose, lip protrusion, and chin development and found that in order to achieve facial harmony the relationship of these facial features must be balanced. They recommended that orthodontic treatment be designed to the face rather than only to dental or skeletal norms.

A knowledge of normal facial balance and symmetry in the adult is essential, especially due to the popularity of adult orthodontic and orthognathic surgical procedures in the correction of severe dentofacial disharmonies. Recent advances in facial video imaging techniques,[10-12] such as the Digigraph system (Dolphin Imaging

Abstract

The purpose of this article was twofold: (1) to provide an estimate of error in the digitization of various soft tissue landmarks using a video imaging system, and (2) to evaluate the relationships of various soft tissue measurements in balanced young adult faces. A video imaging system was used to digitize frontal and lateral soft tissue landmarks on 25 male and 25 female Caucasian young adults with Class I occlusion and esthetically pleasing and balanced soft-tissue profiles. Twenty subjects were redigitized and only two measurements showed a statistically significant error. Large variabilities were found for several measurements. Males, in general, had greater soft tissue thickness, facial depth and width, and lip length than females. The measurements were found to compare favorably with previous reports. Imaging systems were seen to have the advantage of providing reliable measurements in all three dimensions without the potential hazards of ionizing radiation.

Key Words

Imaging systems • Three-dimensional facial analysis • Soft-tissue analysis • Facial balance

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Figure 1

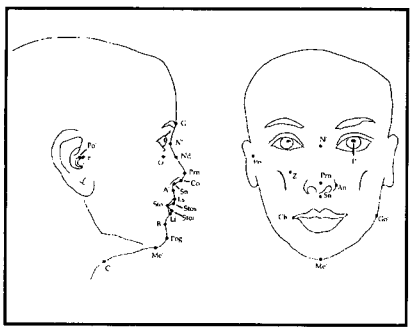

Figure 2

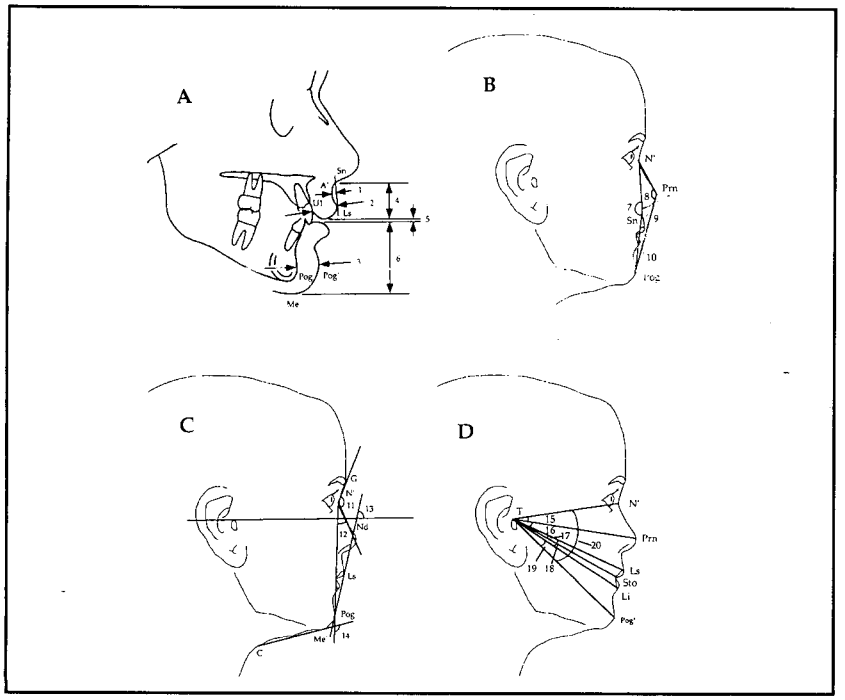

Figure 3

Figure 1
The Digigraph imaging system.

Figure 2
Facial soft tissue landmarks digitized in the lateral and frontal views. Lateral: Glabella (G), Nasion (N'), Orbitale (O), Tragion (T), Porion (Po'), Nasal dorsum (Nd), Pronasale (Prn), Columella (Co), Subnasale (Sn), Soft tissue A point (A'), Labrale superius (Ls), Upper lip Stomion (Stos), Stomion (Sto), Lower lip stomion (Stoi), Labrale inferius (Li), Soft tissue supramentale (B'), Soft tissue Pogonion (Pog'), Menton (Me'), Cervical point (C). Frontal: Bilateral points: Pupil (P), Porion (Po'), Zygomatic point (Z), Alae of Nose (An), Cheilion (Ch), Gonion (Go'). Midline Points: Soft Tissue Nasion (N'), Pronasale (Prn), Subnasale (Sn), Menton (Me').

Figure 3
Various profile measurements used in this study. Description of the measurements are as follows: A, 1, Superior sulcus depth (A' to line Sn-Ls), 2, Upper lip thickness at vermilion border (U1 - Ls), 3, Soft tissue chin thickness (Pog - Pog'), 4, Upper lip length (Sn - Stos), 5, Interlabial space (Stos - Stoi), 6, Lower lip length (Me' - Stoi). B, 7, Soft tissue facial convexity (N' - Sn - Pog'), 8, Total facial convexity (N' - Prn - Pog'), 9, Nasolabial angle (Co - Sn - Ls), 10, Mentolabial angle (Li - B' - Pog'). C, 11, Nasofrontal angle (G - N' - Nd), 12, Nasofacial angle (Nd - N' - Pog'), 13, Upper lip Z angle (Pog'-Ls to Frankfort horizontal plane), 14, Lower face - throat angle (Sn-Pog' to C-Me'). D, 15, Nasal angle (N' - T - Prn), 16, Maxillary angle (Prn - T - Ls), 17, Upper lip vermillion angle (Ls - T - Sto), 18, Interlabial angle (Ls - T - Li), 19, Lower lip angle (Sto - T - Pog'), and 20, Total vertical angle (N' - T - Pog')

Systems, Valencia, Calif) have made it possible to get superimposition of skeletal and facial images without the use of radiography. Diagnostic procedures have advanced with "cut-and-paste" features and other image modification methods made possible on these systems. This may result in better feedback to the patients and the collaborating doctors.

The purpose of this study was to evaluate relationships of various soft-tissue measurements in balanced young adult faces. The objectives were to provide an estimate of error in digitization of various soft tissue landmarks using a video imaging system and to provide basic data for comparison of harmonious and disharmonious faces.

Materials and methods

A sample of 25 male and 25 female Caucasian young adults was selected among dental, dental hygiene and graduate students at the University of Oklahoma College of Dentistry. The criteria for selection included age between 21 and 36 years, Class I occlusion with normal overjet-overbite relationships, and an esthetically pleasing and balanced soft-tissue profile. Frontal and lateral facial photographs of the candidates, standardized to one-fourth of actual size, were taken during the screening process. Facial esthetics were subjectively evaluated by each author. The sample was selected irrespective of whether orthodontic treatment had been performed at an earlier age. The age of the male subjects ranged from 21 years 6 months to 36 years 1 month (mean age 26 years 9 months). Female subjects ranged in age from 22 years 10 months to 32 years 4 months (mean age 25 years 6 months).

A video imaging system (Digigraph Work Station, Dolphin Imaging Systems, Valencia, Calif) was used to collect the records in this study (Figure 1). The Digigraph imaging system produces cephalometric measurements comparable with those of cephalometric radiographs.[12] In addition, the repeatability and consistency of the measurements obtained from the imaging system has also been demonstrated.[12] The system consisted of a head holding device, a digitizing probe, a four-microphone array to record the landmarks, video cameras to record extraoral and intraoral photographs, and a computer to process the data. The patient was instructed to look at a distant point and the natural head position obtained was stabilized in the head holder with the help of ear rods; care was taken to minimize head rotation. A forehead rest and two positioning devices on the parietal bones and one on the occipital bone were used to prevent any

Table 1
Hard tissue (bony) and dental landmarks

Hard tissue points, lateral view
1. Estimated A point (A): The gingiva overlying hard tissue A point.
2. Estimated pogonion (Pog): The point as close as possible to hard tissue pogonion with the overlying soft tissue chin deflected.

Dental landmarks, lateral view
1. U1: Most labial point of the more protruded maxillary central incisor.
2. Midpoint of incisal edge of maxillary right central incisor.
3. Midpoint of gingival margin of maxillary right central incisor.

Dental landmarks, frontal view
1. Midline of the maxillary dental arch.
2. Midline of the mandibular dental arch.

Sagittal linear measurements (mm)
1. Upper lip to esthetic line (Ls - E)
2. Lower lip to esthetic line (Li - E)
3. Superior sulcus depth (A' to line Sn-Ls) (Figure 3)
4. Upper lip thickness at A point (A - A') (Figure 3)
5. Upper lip thickness at vermilion border (U1 - Ls) (Figure 3)
6. Nasal prominence (Prn to line perpendicular from Ls to Frankfort horizontal plane)
7. Soft tissue chin thickness (Pog - Pog') (Figure 3)

Facial depth
8. Tragion - soft tissue Nasion (T - N')
9. Tragion - Tip of the nose (T - Prn)
10. Tragion - Upper lip vermillion (T - Ls)
11. Tragion - Lower lip vermillion (T - Li)
12. Tragion - Stomion (T - Sto)
13. Tragion - Soft tissue pogonion (T - Pog')

Sagittal agular measurements (degrees)
1. Soft tissue facial convexity (N' - Sn - Pog') (Figure 3)
2. Total facial convexity (N' - Prn - Pog') (Figure 3)
3. Nasofrontal angle (G - N' - Nd) (Figure 3)
4. Nasofacial angle (Nd - N' - Pog') (Figure 3)
5. Upper lip Z angle (Pog'-Ls to Frankfort horizontal plane) (Figure 3)
6. Lower lip Z angle (Pog'-Li to Frankfort horizontal plane)
7. Nasolabial angle (Co - Sn - Ls)
8. Mentolabial angle (Li - B' - Pog')
9. Lower face - throat angle (Sn-Pog' to C-Me') (Figure 3)
10. Nasal angle (N' - T - Prn) (Figure 3)
11. Maxillary angle (Prn - T - Ls) (Figure 3)
12. Interlabial angle (Ls - T - Li) (Figure 3)
13. Upper lip vermillion angle (Ls - T - Sto) (Figure 3)
14. Lower lip angle (Sto - T - Pog') (Figure 3)
15. Total vertical angle (N' - T - Pog') (Figure 3)

Vertical linear measurements (mm)
1. Ratio of mid- to lower face (N'-Sn / Sn-Me' %)
2. Nasal height (N' - Sn)
3. Upper lip length (Sn - Stos)
4. Lower lip length (Me' - Stoi)
5. Ratio of upper to lower lip length (%)
6. Interlabial space (Stos - Stoi)
7. Upper incisor exposure on smiling (Incisal edge of maxillary right central incisor to Stos)
8. Gingival exposure on smiling (Gingival margin of maxillary right central incisor to Stos. A positive valence indicates exposure of gingiva; a negative valence indicates that the lip covers the maxillary central incisor.)

Transverse measurements (mm)
1. Interpupillary width (PR-PL)
2. Bi-zygomatic width (ZL-ZR)
3. Nasal width (AnR-AnL)
4. Width of commissure (ChR-ChL)
5. Bi-gonial width (Go'R-Go'L)

Distances (mm) to the facial midline(N'-Sn line) from:
1. Right porion
2. Left porion
3. Nasal tip (Prn)
4. Midline of maxillary dental arch
5. Midline of mandibular dental arch
6. Right gonion
7. Left gonion
8. Menton (Me')

movement. Still frames of frontal and lateral facial views with the lips in repose and teeth in occlusion were recorded using the extraoral video camera. Landmarks on the patient were then directly digitized using a hand-held probe that emitted a high frequency inaudible sound. This sound was picked up independently by the four microphones mounted on a frame situated above the patient. The time taken by each microphone to receive this sound was used to compute distances and thereby locate the landmark point in space on a three-dimensional coordinate system.

Landmarks

The soft tissue landmarks digitized are shown in Figure 2. Hard tissue (bony) and dental landmarks were digitized in the lateral and frontal views and are described in Table 1.

The digitizing and measurement errors were determined by redigitizing a random sample of 10 male and 10 female subjects for both frontal and lateral landmarks. The initial and repeat measurements were compared with the paired t-test to determine the significance of any errors.

Results

The means and standard deviations for the difference between initial and repeat measurements for the lateral analysis are reported in Table 2; frontal analysis data are reported in Table 3. The significance of the error (P-value) is also indicated. In the lateral analysis, only two of the 36 measurement variables demonstrated a statistically significant error. The superior sulcus depth measurement had a statistically significant error at the 1% level for the female group and 5% level for the male group, whereas the nasal height measurement had a statistically significant error at the 5% level for the male group. All other variables showed an insignificant error of measurement at $P<0.05$. None of the measurements in the frontal analysis showed a statistically significant error.

Table 2
Mean and standard deviation values for differences between initial and repeat measurements for estimate of error in the lateral analysis. The P-values from a paired t-test to determine significance are also indicated.
*** indicates statistically significant difference at P<0.05.**

No.	Variable	Female (n=10) Mean Diff	SD Diff	p value	Male (n=10) Mean Diff	SD Diff	p value
Sagittal linear (mm)							
1	Upper lip to esthetic line	-0.51	0.95	0.1239	-0.36	0.94	0.2587
2	Lower lip to esthetic line	-0.41	0.90	0.1852	0.04	0.84	0.8834
3	Superior sulcus depth	-0.71*	0.58	0.0036	-0.75*	0.83	0.0192
4	Upper lip thickness at A point	-0.13	1.64	0.8073	-0.03	1.78	0.9586
5	Upper lip thickness at verm. border	-0.70	2.34	0.3680	-0.35	2.31	0.6435
6	Nasal prominence	0.44	1.40	0.3479	0.74	1.76	0.2166
7	Soft tissue chin thickness	-0.51	1.23	0.2221	-0.26	1.89	0.6741
8	Tragion - N'	0.76	2.61	0.3806	-0.78	2.33	0.3164
9	Tragion - Prn	0.74	2.62	0.3950	-0.55	2.50	0.5046
10	Tragion - Ls	0.25	2.15	0.7213	-0.68	2.35	0.3833
11	Tragion - Li	0.47	1.88	0.4485	-0.15	2.32	0.8427
12	Tragion - Sto	0.53	2.33	0.4902	-0.21	2.07	0.7553
13	Tragion - Pog'	1.28	1.89	0.0605	0.53	2.69	0.5488
Sagittal angular (degrees)							
1	Soft tissue facial convexity	0.30	2.06	0.6559	-0.29	3.34	0.7901
2	Total facial convexity	0.14	1.96	0.8259	0.11	3.63	0.9258
3	Nasofrontal angle	-1.25	6.31	0.5464	-1.19	9.05	0.6872
4	Nasofacial angle	-0.12	1.70	0.8281	-0.50	2.55	0.5502
5	Upper lip Z angle	0.64	3.44	0.5713	-0.07	3.62	0.9526
6	Lower lip Z angle	1.07	4.57	0.4780	-0.72	4.14	0.5961
7	Nasolabial angle	0.80	11.96	0.8371	4.12	11.71	0.2945
8	Mentolabial angle	-0.53	8.60	0.8498	0.47	5.08	0.7765
9	Lower face-throat angle	-0.05	3.53	0.9652	-0.57	3.03	0.5666
10	Nasal angle (N'-T-Prn)	-0.35	1.56	0.4964	0.29	0.86	0.3124
11	Maxillary angle (Prn-T-Ls)	-0.17	0.68	0.4484	0.47	0.98	0.1627
12	Interlabial angle (Ls-T-Li)	0.10	0.91	0.7356	-0.05	0.68	0.8214
13	Upper lip vermillion angle (Ls-T-Sto)	-0.17	0.83	0.5353	0.10	0.55	0.5819
14	Lower lip angle (Li-T-Pog')	0.25	0.93	0.4179	0.43	1.31	0.3275
15	Total vertical angle (N'-T-Pog')	-0.01	1.98	0.9876	1.04	1.57	0.0657
Vertical linear (mm)							
1	Ratio mid- to lower face height (N-Sn/Sn-Me %)	0.25	4.96	0.8769	1.80	2.95	0.8540
2	Nasal height	0.09	2.18	0.8992	1.16*	1.14	0.0104
3	Upper lip length	-0.47	1.44	0.3294	-0.18	1.11	0.6209
4	Lower lip length	-0.22	1.33	0.6139	-0.17	1.54	0.7356
5	Ratio of upper to lower lip length %	-0.93	2.77	0.3156	-0.03	3.28	0.9775
6	Interlabial space	0.44	1.08	0.2311	0.01	0.81	0.9697
7	Upper incisor exposure on smiling	-0.04	1.53	0.9358	-0.07	1.93	0.9112
8	Gingival exposure on smiling	-0.29	1.86	0.6341	-0.08	2.41	0.9188

The mean and standard deviation values for the measurements in the lateral analysis are reported in Table 4 and those for the frontal analysis are in Table 5.

Discussion

The use of imaging systems for the study of facial balance and harmony using soft tissue surface points has been minimal. In the present study, most of the landmarks digitized were soft tissue or surface points which, despite being more variable, are easier to digitize than hard tissue or dental landmarks. A significant error was noted for only two measurements, i.e., superior sulcus depth and nasal height, and was probably caused by inherent variability in upper lip position and resultant inconsistency in landmark identification. However, large standard deviation values were also obtained for some of the repeat measurements, prominent among these being the nasolabial, mentolabial and nasofrontal angles.

Table 3
Mean and standard deviation values for differences between initial and repeat measurements for estimate of error in the frontal analysis. The P-values from a paired t-test to determine significance are also indicated. None of the measurements was found to be significantly different at P<0.05.

No. Variables	Female (n=10) Mean diff	SD diff	p value	Male (n=10) Mean diff	SD diff	p value
Transverse measurements (mm)						
1 Interpupillary width	1.03	2.20	0.1730	1.62	2.77	0.0974
2 Bi-zygomatic width	0.85	2.50	0.3103	0.01	1.85	0.9867
3 Nasal width	0.56	1.63	0.3055	-0.24	1.00	0.4693
4 Width of commissure	0.25	0.95	0.4280	-0.66	2.34	0.3958
5 Bi-gonial width	-0.21	6.83	0.9246	0.70	3.16	0.5013
Distances to the facial midline (N'-Sn) (mm)						
1 From right Po'	0.93	2.25	0.2234	-0.48	2.35	0.5343
2 From left Po'	0.34	1.61	0.5218	0.21	2.02	0.7503
3 From nasal tip (Prn)	0.08	0.58	0.6744	-0.17	0.76	0.4949
4 From maxillary dental midline	0.60	1.13	0.1273	-0.14	1.12	0.7020
5 From mandibular dental midline	0.07	1.91	0.9103	-0.09	2.36	0.9066
6 From right Go'	0.60	3.97	0.6442	0.26	3.55	0.8222
7 From left Go'	-0.89	2.54	0.2971	0.29	1.63	0.5880
8 From Me'	0.72	1.38	0.1331	-0.45	1.51	0.3718

Standard deviations that were large relative to the means were found for several variables, as shown in Tables 4 and 5. In the lateral analysis (Table 4), these variables included the upper and lower lips to the E-line, measurements of facial depth from tragus, Z angle, nasolabial, mentolabial and nasofrontal angles, and ratio of upper to lower face height. Similar findings were reported by Zylinski et al.[6] in their study using cephalometric radiographs. In the frontal analysis (Table 5), large standard deviations were noted for most of the measurements. This can be explained by the variability between the subjects in this study. Since the criteria for an esthetic face is subjective, there cannot be one rigid mean for any measurement; rather, a range of values should always be considered. Other authors[5,6,13] have also recommended allowing for variation rather than rigid adherence to a normative value. In addition, the large standard deviation values of the differences between some of the repeat measurements (Tables 2 and 3) could also account for a portion of the standard deviations of the measurements obtained for the entire sample (Tables 4 and 5).

A comparison between the male and female groups reveals that male subjects in general had a thicker soft tissue drape, greater facial depth and greater lip lengths. Whereas the soft tissue convexity was similar for both sexes, the male subjects had a slightly more retrusive lip profile as indicated by their more negative E-line measurements. From a frontal view, the male subjects had greater width measurements and they demonstrated slightly greater asymmetry than the female subjects. The normality of facial asymmetry has been mentioned in previous reports.[14-17]

The findings of this study were compared with those of Subtelny,[2] Bishara et al.,[18] Nanda et al.,[5] and Zylinski et al.,[6] and with relevant measurements from other studies. These comparisons are summarized in Table 6. The esthetic line measurements were similar to other studies; the more negative values in this study as well as that of Zylinski et al.[6] (mean age 26.2 years) may have been due to the growth of the nose and chin in the older samples as compared with the values observed by Nanda et al.[5] at age 18 years. The thickness of the upper lip at A point was observed to be less in this study than others since A point is digitized on the alveolar mucosa overlying the hard tissue landmark. The thickness of the upper lip at the vermilion border, however, was comparable with Park and Burstone[4] and less than that measured by Nanda et al.[5] The thickness of the soft tissue chin was also less in this study since direct digitization of hard tissue pogonion on a patient requires the overlying soft tissue to be pushed upward and includes some soft tissue thickness over the landmark. The upper and lower lip lengths were similar to other studies, as was the ratio of the upper to the lower lip that showed the length of the upper lip to be one-third that of the lower third of the face.

The nasolabial and mentolabial angle measure-

Table 4
Mean and standard deviation values for 36 soft tissue lateral measurements in young adult Caucasian males and females. The P-values from a t-test to determine differences between male and female values are also indicated.

No. Variables	Female (n=25) Mean	SD	Male (n=25) Mean	SD	p value
Sagittal linear (mm)					
1 Upper lip to esthetic line	-4.59*	2.49	-6.03*	1.87	0.0253
2 Lower lip to esthetic line	-2.30**	2.27	-3.95**	2.01	0.0090
3 Superior sulcus depth	3.24	1.39	2.92	1.49	0.4316
4 Upper lip thickness at A point	11.30**	2.30	13.38**	2.42	0.0030
5 Upper lip thickness at verm. border	10.23***	2.21	12.68***	2.29	0.0003
6 Nasal prominence	12.30	2.78	13.93	3.30	0.0646
7 Soft tissue chin thickness	6.43***	1.72	8.53***	2.00	0.0002
8 Tragion - N'	92.08***	4.17	98.94***	4.90	0.0001
9 Tragion - Prn	112.74***	4.89	122.21***	4.19	0.0001
10 Tragion - Ls	106.22***	4.31	115.85***	4.62	0.0001
11 Tragion - Li	110.79***	4.45	120.33***	4.71	0.0001
12 Tragion - Sto	103.36***	4.31	113.28***	4.22	0.0001
13 Tragion - Pog'	118.56***	4.18	132.08***	5.23	0.0001
Sagittal angular (degrees)					
1 Soft tissue facial convexity	164.74	4.29	165.74	4.94	0.4450
2 Total facial convexity	132.12	4.14	132.81	4.73	0.5823
3 Nasofrontal angle	143.58	6.42	140.99	9.03	0.2485
4 Nasofacial angle	29.68	2.85	30.06	3.70	0.6794
5 Upper lip Z angle	81.62	5.00	83.92	4.93	0.1092
6 Lower lip Z angle	80.04*	7.07	84.14*	5.90	0.0304
7 Nasolabial angle	102.78	14.01	108.15	13.18	0.1686
8 Mentolabial angle	128.79	13.42	129.21	11.59	0.9071
9 Lower face-throat angle	105.7**	8.10	112.12**	7.88	0.0066
10 Nasal angle (N'-T- Prn)	23.88*	1.94	22.35*	2.10	0.0104
11 Maxillary angle (Prn-T-Ls)	14.10	1.50	14.98	1.71	0.0617
12 Interlabial angle (Ls-T-Li)	7.78**	1.60	6.43**	1.62	0.0046
13 Upper lip vermillion angle (Ls-T-Sto)	3.2*	1.19	2.4*	0.93	0.0108
14 Lower lip angle (Li-T-Pog')	12.44	1.15	12.49	1.55	0.8937
15 Total vertical angle (N'-T-Pog')	54.99	2.84	53.85	3.80	0.2352
Vertical linear (mm)					
1 Ratio mid- to lower face height (N'-Sn/Sn-Me' %)	77.41**	7.12	71.36**	6.26	0.0025
2 Nasal height	49.74*	2.85	51.49*	3.11	0.0438
3 Upper lip length	20.96***	1.86	23.49***	2.60	0.0003
4 Lower lip length	42.25***	2.69	47.9***	2.97	0.0001
5 Ratio of upper to lower lip length %	49.66	4.24	49.20	6.41	0.7658
6 Interlabial space	2.06	1.33	2.01	1.19	0.8763
7 Upper incisor exposure on smiling	8.93	2.26	8.42	2.47	0.4474
8 Gingival exposure on smiling	-1.31*	2.31	-2.70*	2.26	0.0371

* indicates significant difference at P<0.05
** indicates significant difference at P<0.01
*** indicates significant difference at P<0.001

ments were similar to those reported by others.[19,20] The nasofrontal and nasofacial angles, which indicate the inclination of the nose relative to the forehead and the face, differed slightly from the ideal values suggested by Powell and Humphreys,[21] probably because the soft tissue facial plane in this study was drawn between nasion and pogonion instead of glabella and pogonion as used by Powell and Humphreys. The measurements for the angles of soft tissue convexity, excluding and including the nose, were similar to those reported by Subtelny,[2] Cox and van der Linden,[13] and Bishara et al.,[18] as was the measurement for the total vertical angle compared with that found by Peck and Peck.[22]

Facial analyses derived from cephalometric radiographs have revolved primarily around anteroposterior dimensions.[1,23-28] Powell and Rayson[29] have demonstrated that the overall appearance of a face cannot be reliably assessed

Table 5
Mean and standard deviation values for 13 soft tissue frontal measurements in young adult Caucasian males and females. The P-values from a t-test to determine differences between male and female values are also indicated.

No.	Variables	Female (n=25) Mean	SD	Male (n=25) Mean	SD	p value
	Transverse measurements (mm)					
1	Interpupillary width	61.45*	3.64	65.11*	4.44	0.0025
2	Bizygomatic width	117.36*	5.43	121.93*	5.50	0.0048
3	Nasal width	34.85	8.41	36.08	2.36	0.4843
4	Width of commissure	47.04**	2.80	50.44**	3.09	0.0002
5	Bigonial width	107.12**	4.53	119.64**	6.42	0.0001
	Distances to the facial midline (N'-Sn)					
1	From right Po'	67.62*	2.57	70.91*	4.09	0.0013
2	From left Po'	69.49**	3.88	73.18**	3.22	0.0006
3	From nasal tip (Prn)	-0.25	0.96	-0.30	1.39	0.8875
4	From maxillary dental midline	0.89	2.09	1.42	1.95	0.3639
5	From mandibular dental midline	0.69	1.94	1.11	2.66	0.5229
6	From right Go'	53.38**	2.77	59.36**	4.39	0.0001
7	From left Go'	53.9**	3.65	60.58**	4.33	0.0001
8	From Me'	0.15	2.67	0.63	2.98	0.5476

* indicates significant difference at P<0.01
** indicates significant difference at P<0.001

Table 6
A comparison of means of soft tissue profile measurements from this study and other investigations.

Variable	Gender	Present Study	Nanda et al.[5]	Zylinski et al.[6]	Other Studies
Upper lip to esthetic line (mm)	Male	-6.03	-4.2	-7.1	-5.18[18]
	Female	-4.59	-5.4		
Lower lip to esthetic line (mm)	Male	-3.95	-2.7	-5.2	-3.98[18]
	Female	-2.3	-2.5		
Upper lip length (mm)	Male	23.49	22.5	23.7	
	Female	20.96	20.2		
Lower lip length (mm)	Male	47.9		57.5	
	Female	42.25			
Upper to lower lip length ratio (%)	Male	49.2			50[19,21]
	Female	49.66			
Upper lip thickness at A point (mm)	Male	13.38	17.2		
	Female	11.3	14.9		
Upper lip thickness at verm. border (mm)	Male	12.68	17.1		
	Female	10.23	12.5		
Soft tissue chin thickness (mm)	Male	8.53	12.8		
	Female	6.43	11.2		
Angle of soft tissue convexity	Male	165.74		166	163.5,[2] 162.3,[13] 173[18]
	Female	164.74			163.8[13]
Angle of total facial convexity	Male	132.81		130.4	133,[2] 128.7,[13] 140.2[18]
	Female	132.12			130.2[13]
Nasolabial angle	Male	108.15	105.8	110.8	102,[19] 110[20]
	Female	102.78	110.7		
Mentolabial angle	Male	129.21	125.1	124.3	122[1]
	Female	128.79	127.1		122[1]
Nasofrontal angle	Male	140.99			125-135[21]
	Female	143.58			
Nasofacial angle	Male	30.06			36-40[21]
	Female	29.68			
Total vertical angle (N'-T-Pog')	Male	53.85			
	Female	54.99			54.5[23]

Data from Burstone[1] are for men and women at 24 years.

Data from Subtelny[2] are for men at 18 years.

Data from Nanda et al.[5] are at age 18 years.

Data from Bishara et al.[18] are for men of unspecified age.

Data from Legan & Burstone[19] are for men and women between age 20 and 30 years.

Data from Zylinski et al.[6] are for men at 26 years.

Data from Powell and Humphreys[21] are unspecified.

Data from Cox & Van der Linden[13] are for men and women between ages 18 and 20 yrs.

Data from Peck and Peck[23] are from 49 women and 3 men at 21 years.

from the profile outline. A three-dimensional analysis, therefore, is necessary for diagnosis and treatment planning. The lateral and frontal analyses in this study, while providing a description of several key facial features in the dimensions of width, height, and depth, do not attempt to be all-encompassing. These analyses may be used as an auxiliary treatment planning tool to complement the existing database of dental casts and cephalometric radiography.

Imaging systems have the advantage of providing reliable measurements without losing sight of facial balance and harmony. The orthodontist can analyze the face in all three dimensions using this system without the potential hazards of ionizing radiation. The development of imaging systems has proven to be a valuable adjunct to orthodontic diagnosis and treatment planning.

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