Original Article

Three-dimensional evaluation of social smile symmetry

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ABSTRACT

Objective: To evaluate the social smile symmetry using three-dimensional (3D) stereophotogrammetric images.

Materials and Methods: The study was conducted with 3D facial images of 30 individuals (age range 13–25 years). The rest position was considered as the reference image and the social smile image was aligned on this image using the best-fit alignment method. The spatial differences between the same points established on both images using 3D analyses were determined for right and left points in X, Y, and Z planes.

Results: The highest difference related to spatial distance in right and left points was −0.56 mm (95% confidence interval [CI], −1.19, 0.06 mm) between right and left commissure (Com) points. The difference was not significant, and the Bland-Altman upper and lower limits were −3.85 mm and 2.71 mm, respectively. The highest difference for the transversal plane was found in Com points, similarly to the spatial distance (mean: 0.50 mm, 95% CI, −2.62, 1.02 mm). The differences between the changes in the left and right points in the Y and Z plane were not significant ($P > .05$).

Conclusions: The social smile was observed to show asymmetry in varying amounts in the different directions. Asymmetry increases in some cases, specifically for the corners of the mouth. (*Angle Orthod.* 2017;87:96–103)

KEY WORDS: Social smile**;** Symmetry**;** 3D stereophotogrammetry

INTRODUCTION

The primary objective of the traditional orthodontic diagnosis and treatment planning termed the "Angle paradigm" was ideal dental occlusion and acceptable skeletal relationships. It was based on the measurements made on dental casts and cephalometric radiographs.[1] Today, the importance of soft tissues is better understood; in addition, we now have a greater appreciation for increased esthetic concerns. With the new soft tissue paradigm, the characteristics of facial soft tissues and harmony among them constitute one of the important phases of diagnosis and treatment planning.[2]

Achievement of an esthetic smile is one of the most important factors causing patients to request orthodontic treatment.[3] Garber and Salama[4] stated that an esthetic smile harmony forms from the teeth, the gingival scaffold, and the lip framework. According to Sarver and Jacobson,[5] smile symmetry is one of the miniesthetic components of dentofacial analyses, and a symmetric smile is considered more attractive.[6] Additionally, cases of impaired symmetry in smiles could cause clinicians to suspect the presence of a skeletal asymmetry.[7] An assessment of smile symmetry prior to orthodontic treatment or orthognathic surgery is considered important for evaluating treatment outcomes and for informing the patient about esthetic variables.[8] Traditionally, two-dimensional (2D) methods were used to evaluate smile symmetry.[7] With recent advances in imaging technology, the complex structure of facial morphology can be evaluated three dimensionally.[9] In light of this information, the present study aimed to examine the social smile symmetry on three-dimensional (3D) stereophotogrammetric images. The hypothesis of the study is that social smile is

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Figure 1. Submandible (Sm) and right-left tragus (Tr) and trichion (Tri) points and planes intersecting these points were used to designate these meshes. Facial mesh production for (A) test position (reference image) and (B) social smile (test image).

not symmetric in three planes of space, considering the different morphological points on the face.

MATERIALS AND METHODS

Participants

This prospective study was conducted with the approval of the Gülhane Military Medical Academy Ethics Committee, and the study participants completed consent forms. The study sample was selected randomly and included 30 white patients aged between 13 and 25 years who had met the inclusion criteria. The mean age of the participants was 17.2 $\pm$ 3.6 years and included 14 females (mean age: 16.7 years, range: 14.2–22.5 years) and 16 males (mean age: 17.7, range: 13.4–25.8 years). The inclusion criteria of the study were as follows: no clinically evident facial asymmetry, no facial defects or trauma, no muscular or neural disorders, no history of facial surgery or orthodontic treatment, and presence of Angle Class I molar dental relationship.

Acquisition of 3D Stereophotogrammetric Images

3D surface images of each participant were acquired by a trained technician using a five-point 3D stereophotogrammetric camera setup, the 3dMD Flex system (3dMD, Atlanta, Ga). Prior to attaining smile records, the rest position records of the participants were acquired. The rest position was achieved in natural head position, and the lips were in a relaxed position in front of the mirror.[10] Social smiles of the participants were acquired by the same investigator, who gave the command "Give me a nice big smile like the people in the photographs" to the participants.[11]

Data Organization and Processing

The 3D images were transferred into Rapidform (Inus Technology, Seoul, Korea) software for processing. Facial meshes were obtained by establishing two planes and removing the areas falling outside the crossing site of these planes (Figure 1). The rest position was considered as the reference image, and the social smile image was aligned on this image using the iterative closest point algorithm (ICP) or best-fit alignment method (Figure 2). This method has been used widely for alignment of different 3D surface meshes.[9] Following the initial alignment, the meshes were trimmed together for the second time and the alignment was repeated. After these alignment procedures, the forehead was selected, and the final alignment was performed on this selected area. The aligned images were transferred into 3-matic (Materialise, Leuven, Belgium) software for the measurement process, and landmark identification was made for each image (Figure 3). The same morphological points on 3D facial images were marked by the same investigator both on the rest position images and the social smile images (Figure 4). Differences between the same points established on both images using 3D analyses were determined for right and left points in X

Figure 2. Alignment of reference and test images.

(transversal), Y (sagittal), and Z (vertical) planes (Figure 5).

Statistical Analysis

All statistics of the parameters were analyzed using the Statistical Package for Social Sciences software (SPSS), version 20 (IBM, Chicago, Ill). To evaluate the reliability of the method, the images of 10 randomly selected patients were realigned 1 month later by the same investigator, and the 3D deviation analyses were repeated. The intraexaminer reliability was evaluated using an intraclass correlation coefficient (ICC). Descriptive statistics of the deviation of morphological points in the three planes of space and spatial distance

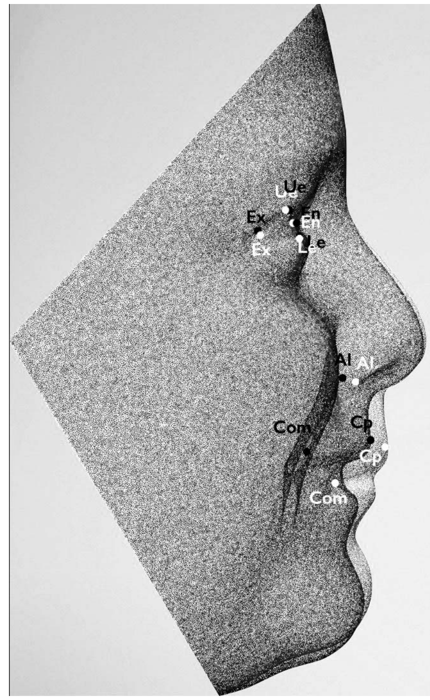

Figure 4. 3D deviation of same morphological points after aligning the meshes on the forehead.

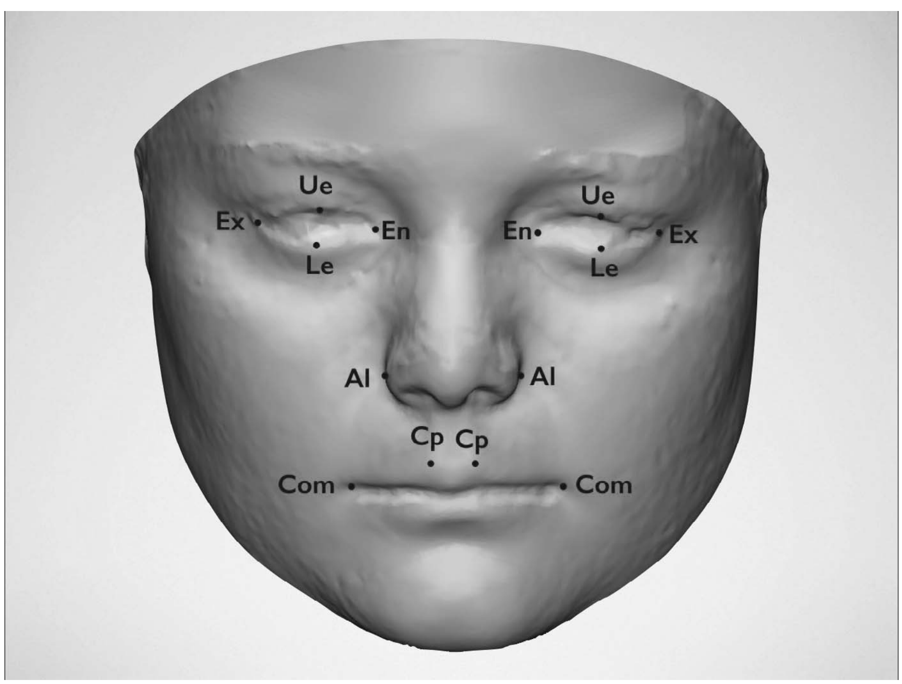

Figure 3. Reference landmarks. En (endocanthion): The point at the inner commissure of the eye fissure. Ex (exocanthion): The point at the outer commissure of the eye fissure. Ue (upper eye): The highest point in the midportion of the free margin of each upper eyelid. Le (lower eye): The lowest point in the midportion of the free margin of each lower eyelid. Al (alare): Most lateral point on alar contour. Com (commissure): Point at labial commissure. Cp (crista philtri): Lateral point on elevated margin of the philtrum above the vermilion line.

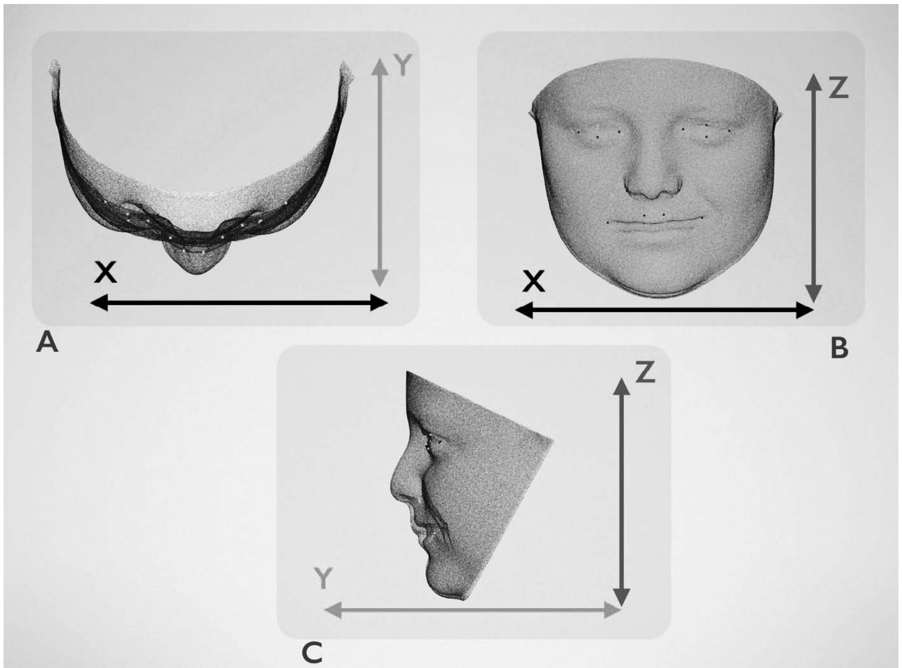

Figure 5. Reference planes. (A) Top view; (B) Frontal view; and (C) Sagittal view.

(D) were calculated. Spatial distance was calculated automatically by software using the Euclidian distance formula. Smile symmetry was evaluated using the paired-sample *t*-test with a significance level of $P \leq .05$, and Bland-Altman limits of agreement were calculated in terms of mean $\pm$ 1.96 standard deviation (SD)" for their planes of space and spatial distances separately.[12] The agreement between right and left sides for spatial distance was shown using Bland-Altman Plots.

RESULTS

At the time of the measurements that were repeated 1 month later by the same investigator, the ICC varied between 0.897 and 0.944. The highest difference related to spatial distance (D) in right and left symmetric points was –0.56 mm between the right and left commissure (Com). The difference was not significant, and the Bland-Altman upper and lower limits were –3.85 mm and 2.71 mm, respectively. The lowest difference was in the upper eye (Ue) point. The change observed in all left and right symmetric morphological points for combined movement was not significant ($P > .05$) (Table 1).

The highest difference for the transverse plane was found in the Com, similar to what was observed for the spatial distance (mean: 0.50 mm, 95% confidence interval [CI], –2.62, 1.02 mm). The Bland-Altman upper and lower limits for that difference ($P = .354$) were –3.11 and 3.52 mm, respectively. The mean difference in other points and the Bland-Altman limits are presented in Table 2, (Figure 6).

The differences between the changes in the left and right points in the sagittal plane were not significant ($P > .05$). The lowest and highest differences between the means were 0.01 mm (95% CI, –0.62, 0.64 mm) in alare (Al) points (Table 3).

Table 1. Comparison of Spatial Deviation Between Right and Left Morphological Points[a]

Variable (D, Distance)	Right		Left		Mean Difference (95% CI)	Limits of Agreement (Upper, Lower)	*t*	*P*
	Mean	SD	Mean	SD				
En	1.59	0.61	1.67	0.47	−0.08 (−0.40, 0.23)	1.60, −1.77	−1.421	.166
Ex	1.69	0.89	1.95	0.61	−0.26 (−0.65, 0.12)	1.74, −2.27	−0.525	.606
Ue	1.59	0.37	1.63	0.54	−0.04 (−0.27, 0.19)	1.19, −1.26	−0.335	.740
Le	1.88	0.49	2.03	0.66	−0.15 (−0.47, 0.17)	1.54, −1.84	−0.962	.344
Al	3.25	1.63	3.66	1.41	−0.41 (−0.85, 0.04)	1.94, −2.76	−1.871	.072
Com	10.50	2.43	11.07	1.69	−0.56 (−1.19, 0.06)	2.71, −3.85	−1.854	.074
Cp	4.96	1.65	5.16	1.70	−0.19 (−0.49, 0.11)	1.41, −1.79	−1.295	.205

[a] SD indicates standard deviation; CI, confidence interval. *P*-value represents the results of paired-sample *t*-test. Upper and lower limits are the mean difference ±1.96 SD of the difference in the Bland-Altman Plot.

Table 2. Comparison of Deviation in Transversal Plane Between Right and Left Morphological Points[a]

Variable (X Distance)	Right Mean	Right SD	Left Mean	Left SD	Mean Difference (95% CI)	Limits of Agreement (Upper, Lower)	*t*	*P*
En	1.06	0.69	0.96	0.77	0.10 (−0.75, 0.95)	2.56, −2.36	0.263	.798
Ex	1.06	0.94	1.58	1.03	−0.52 (−1.42, 0.38)	2.12, −3.15	−1.271	.233
Ue	0.76	0.63	0.70	0.80	0.06 (−0.72, 0.83)	2.32, −2.20	0.167	.871
Le	0.74	0.56	0.80	0.85	−0.07 (−0.73, 0.60)	1.88, −2.01	−0.221	.829
Al	1.56	0.76	1.87	0.91	−0.31 (−1.02, 0.40)	1.77, −2.39	−0.966	.357
Com	4.00	2.24	4.80	1.32	−0.50 (−1.62, 1.02)	3.52, −3.11	−0.972	.354
Cp	1.24	0.62	1.93	1.39	−0.68 (−1.77, 0.41)	2.52, −3.87	−1.385	.196

[a] SD indicates standard deviation; CI, confidence interval. *P*-value represents the results of paired-sample *t*-test. Upper and lower limits are the mean difference ±1.96 SD of the difference in the Bland-Altman Plot.

Similarly, the difference between the changes in the left and right points in the vertical plane were not significant ($P > .05$). However, the highest deviation difference between left and right points was observed in the Com (mean: 0.31 mm; 95% CI, −0.84, 1.47 mm). The upper and lower limits obtained in the Com point were −3.07 and 3.70 mm, respectively (Table 4).

DISCUSSION

The present study evaluated the symmetry of the social smile in all three planes of space using 3D stereophotogrammetric images. The social smile is regarded as a reproducible smile in the literature.[13] But in addition to reproducibility, social smile symmetry is also important for clinical decisions in orthodontic treatment planning, developmental modifications, and orthognathic surgical treatments.[7] The characteristics of facial mimicry, such as the smile, rest, and speech, are among the fields that are focused on by several medical disciplines. To the best of our knowledge, there have been limited 3D clinical studies published on the symmetry of the social smile.

Many studies in the literature evaluated the smile esthetics using frontal facial or mouth area images.[14] According to Sarver and Ackerman,[15] only vertical and transverse smile characteristics can be evaluated on frontal images. Therefore, analyses made on images acquired from a different aspect are required to include the potential changes in oblique and sagittal directions in the treatment planning. In the present study, the changes during the smile could be examined three-dimensionally using 3D stereophotogrammetric images in combination with advanced engineering software.

It is ascertained from the literature that facial functions are evaluated using different methods, such as markers,[16] photographs,[17] and videos.[11] Gross et al.[18] reported that 2D methods can reflect only 43% of the facial expressions, and, therefore, it would be more appropriate to use 3D methods. With 3D stereophotogrammetry, the image can be acquired quickly (in less than 1.5 ms), and for this reason, movement-related distortions can be prevented. Furthermore, the measurements on 3D stereophotogrammetric images have been observed to be accurate and reliable compared to direct anthropometry and 2D photogrammetry.[19] The surface-based alignment algorithm (Iterative Closest Point Algorithm) or the best-fit alignment method used for aligning 3D images is considered a reliable method and is reported[9] to have an alignment error varying from 0.39 to 0.52 mm. The forehead, which is not expected to change, appears to be the region most commonly preferred for alignment in the studies on facial 3D images.[10,20] Similarly, the alignment was performed on the forehead in this study. Literature contains multiple opinions on the tissue midsagittal plane to be taken as a reference.[21] With the method used in the present study, the movement of the same points marked on different images could be analyzed, and therefore the need for a facial tissue midsagittal plane was eliminated. It has been reported

Table 3. Comparison of Deviation in Sagittal Plane Between Right and Left Morphological Points[a]

Variable (Y Distance)	Right Mean	Right SD	Left Mean	Left SD	Mean Difference (95% CI)	Limits of Agreement (Upper, Lower)	*t*	*P*
En	0.50	0.32	0.91	0.42	−0.41 (−0.17, 0.65)	0.30, −1.11	−3.748	.321
Ex	1.61	1.58	1.52	1.07	0.09 (−0.44, 0.63)	1.64, −1.46	0.395	.701
Ue	0.57	0.30	0.85	0.78	−0.28 (−0.21, 0.77)	1.14, −1.70	−1.268	.233
Le	1.09	0.73	1.17	0.79	−0.07 (−0.37, 0.52)	1.22, −1.36	−0.365	.723
Al	1.52	0.81	1.51	1.24	0.01 (−0.62, 0.64)	1.85, −1.83	0.035	.973
Com	6.55	1.85	6.69	1.63	−0.14 (−0.76, 1.03)	2.47, −2.74	−0.337	.743
Cp	2.21	1.09	2.33	1.15	−0.12 (−0.21, 0.45)	0.85, −1.09	−0.800	.442

[a] SD indicates standard deviation; CI, confidence interval. *P*-value represents the results of paired-sample *t*-test. Upper and lower limits are the mean difference ±1.96 SD of the difference in the Bland-Altman Plot.

Table 4. Comparison of Deviation in Vertical Plane Between Right and Left Morphological Points[a]

Variable	Right		Left		Mean Difference	Limits of Agreement		
(Z Distance)	Mean	SD	Mean	SD	(95% CI)	(Upper, Lower)	*t*	*P*
En	0.98	0.55	0.78	0.54	0.20 (−0.31, 0.71)	1.69, −1.30	0.861	.409
Ex	1.05	0.68	1.00	0.87	0.05 (−0.57, 0.69)	1.89, −1.77	0.207	.841
Ue	0.89	0.71	0.79	0.67	0.09 (−0.38, 0.57)	1.48, −1.29	0.448	.664
Le	0.97	0.83	0.88	0.77	0.09 (−0.61, 0.80)	2.14, −1.96	0.297	.773
Al	2.83	2.35	2.76	2.01	0.07 (−1.02, 1.16)	3.25, −3.11	0.145	.888
Com	6.59	2.64	6.28	2.66	0.31 (−0.84, 1.47)	3.10, −3.07	0.603	.560
Cp	4.10	1.75	3.97	2.06	0.14 (−0.24, 0.51)	1.23, −0.96	0.807	.439

[a] SD indicates standard deviation; CI, confidence interval. *P*-value represents the results of paired-sample *t*-test. Upper and lower limits are the mean difference ±1.96 SD of the difference in the Bland-Altman Plot.

that there may be an operator-related margin of error in landmark identification; however, different researchers reported that such a margin of error was low.[20]

It is an expected result that the highest amount of movement occurs in the lower middle face and around the mouth during the social smile.[22] The greatest spatial distance occurred in the Com points during the smile in the present study. The movement was observed to be greater in the Y and Z planes, as such in similar 3D studies.[23] Okamoto et al.[24] observed that the right and left commisure points showed statistically significant asymmetry in the social smile and that there was a laterality toward the left regarding the hemiface size. Additionally, asymmetric smiles can occur in neural pathologies and insufficient muscular tonus in the hemiface.[25] The laterality observed in the Com in individuals with a symmetric face is a controversial topic. It is reported that the right hemisphere of the brain is more dominant and that the left side of the face is more expressive than the right during the smile.[26] Sawyer et al.[23] investigated different smile types three-dimensionally and reported that there was a maximum 10° directional difference between the right and left morphological points at a range of 0 to 6 mm, and they almost moved symmetrically. Based on the findings of the present study, the difference (95% CI) between the amounts of movement in the right and left Com during the smile varied within an insignificant range. Although the movement amount in the Com was greater in the sagittal and vertical planes, the highest asymmetry was observed in the transversal (X) plane (mean: –0.68, 95% CI: –1.77, 0.41), whereas the lowest asymmetry was in the sagittal (Y) plane (mean: –0.14, 95% CI –0.76, 1.03). The Bland-Altman limits of agreement for difference between right and left points in the transversal plane increased up to 3.50 mm. The limits of the difference between the amount of spatial distance (D) and the amount of movements in sagittal (Y) and vertical (Z) planes was observed to be 3.85 mm at the highest. It is reported that the levator labii superioris and zygomaticus major muscles are responsible for the vertical component of social smile, while the buccinator and risorious muscles are responsible for the horizontal component.[27] The asymmetry that was observed differently in three planes in the present study is believed to result from different muscular activations. Yang et al.[28] reported that sagittal and oblique smile profiles became important, specifically in orthognathic surgery. These differences in the Com points in the present study may be considered clinically important for diagnosis and treatment planning. Asymmetry during smiling could be considered clinically as dental occlusal cant or maxillary skeletal asymmetry. Clarifying the main problem of the patient is crucial to determining the appropriate treatment. Batwa et al.[29] reported that lip asymmetry of >2.5 mm had a relative impact on smile esthetics. However, there are limited studies on the extent to which the asymmetry can be visually perceived in which planes in clinical terms.

Movement in the Com is followed by amount of movements in the christa philtrum (mean; right: 4.96 mm, left: 5.16 mm) and alar base (mean; right: 3.25 mm, left: 3.66 mm). The anatomic relationship of the nose with the muscles that affect smile function is a cause of potential changes in this region. The 95% CI of the mean difference between the movements both in the spatial and different planes in right and left Al points is not considered clinically significant. However, the Bland-Altman limits of the deviation difference between right and left points can be up to 3 mm in the vertical plane, differently from other planes. Although it is not likely to observe such a difference in clinical practice, it is important to know the potential differences in quantitative assessments. Around the eye, which is another important anatomic region, slight pouching under the eyes is observed, along with the activation of the orbicularis oculi muscle during the smile.[30] The changes in the eye region during the smile were evaluated at four different points on the face designated for symmetry. When the differences in right and left movements in different planes were examined, the range was not the same for the right and left deviations. It was established that the deviation difference between the right and left sides in this region could be up to approximately 3 mm in some

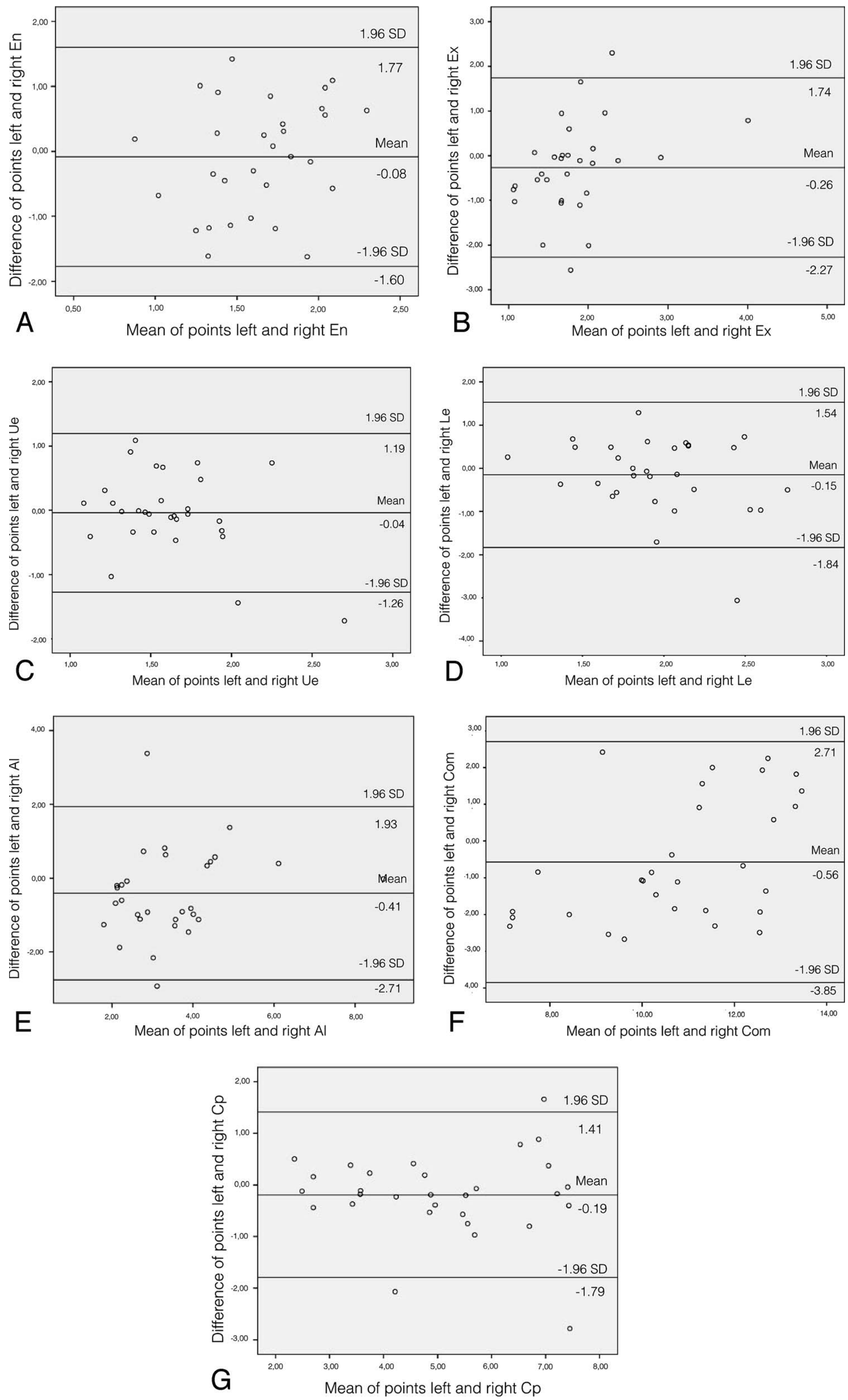

Figure 6. Bland-Altman Plots representing comparisons between left and right morphological points for spatial distance (D) amounts. The mean line represents the mean difference between the points, with the upper and lower lines representing the limits of agreement (±1.96 SD). (A) Endocanthion; (B) Exocanthion; (C) Upper eye; (D) Lower eye; (E) Alare; (F) Commissure; (G) Crista philtrum.

individuals. The Bland-Altman plots showed that the differences do not demonstrate a systematic distribution around zero, and there is no clear relationship between differences and means.

The present study did not evaluate symmetry on spontaneous smile images. Dynamic imaging methods such as video are required to acquire a proper spontaneous smile.[11] However, it is not possible to make an actual 3D assessment on the images acquired using a videographic method. It seems possible to acquire spontaneous smile using dynamic (four-dimensional) stereophotogrammetry, which has been recently developed, and to include this function in an actual 3D assessment. Further studies are required that would evaluate asymmetry of the spontaneous smile and compare it with the social smile in this manner. In addition, to investigate the possible effects of gender and age differences on the social smile symmetry, longitudinal studies with larger sample sizes are needed.

CONCLUSION

- The social smile shows various amounts of asymmetry in the X, Y, and Z planes. Asymmetry increases in some cases, specifically at the corners of the mouth, and should be taken into consideration during the clinical examination.

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