The effect of smiling on facial asymmetry in adults: a 3D evaluation

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Background/aims: Mild resting facial asymmetry exists in clinically symmetrical faces, but the effect of smiling on the magnitude of overall facial asymmetry in adults has not been assessed. The aim of the present study was to use stereophotogrammetry to quantify the effect of smiling on overall facial asymmetry in Caucasian adults who presented with Class I incisor relationships and no history of orthodontic treatment.

Methods: Twenty male and 20 female Caucasians aged 18–30 years with no history of orthodontic treatment, a clinically symmetrical face and a Class I incisor relationship had 3D stereophotogrammetric images captured at rest and on natural and maximal smile (T1). The images were repeated 2–4 weeks later (T2) to assess expression reproducibility. Overall facial asymmetry scores were produced from 27 landmarks using partial Ordinary Procrustes Analysis (OPA) and assessed by an Analysis of Covariance (ANCOVA) model. A random sample of the images was re-examined two months later to calculate intra-observer landmark reproducibility.

Results: Mean landmark error was low (0.41 ± 0.07 mm). Mean overall facial asymmetry scores were not significantly gender different ($p = 0.5300$); therefore, the male and female data were pooled. Mean overall facial asymmetry scores for maximal (0.91 ± 0.16) and natural smile (0.88 ± 0.18) were higher than at rest (0.80 ± 0.17) ($p < 0.0001$) and were reproducible across (T1–T2) sessions ($p = 0.3204$).

Conclusions/implications: Overall 3D facial asymmetry scores for the sampled Caucasian adults with clinically symmetrical faces increased in magnitude from rest to natural and to maximal smile. Clinicians should assess overall facial asymmetry at rest and on natural and maximal smile at baseline, during treatment and as part of a core outcome assessment, particularly for cases with unilateral posterior crossbite, unilateral cleft lip and palate or skeletal asymmetry.

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Introduction

Resting facial asymmetry exists in clinically symmetrical faces.[1] Mild facial asymmetry is considered inconsequential but asymmetry of the nose and lip[2] or a chin point asymmetry of 5–10 mm has been regarded as an impediment to facial aesthetics.[3]

Static facial asymmetry has been assessed using facial photographs, facial plaster casts and postero-anterior (PA) cephalograms. The reported studies have included children referred for orthodontic treatment[4] and orthodontically-untreated adolescents and adults.[5,6] Facial asymmetry assessment has invariably used the mid-sagittal plane based on a variety of landmarks[3] or with 3D technology and geometric morphometrics.[5,6,7] Using stereophotogrammetry, a three-dimensional evaluation of facial asymmetry can be undertaken using statistical shape analysis of a combination of midline and bilateral landmarks.[7] This has been shown to be a valid and more robust approach compared with using a mid-sagittal facial plane.[8]

Asymmetry of individual expressions has been assessed, while overall facial asymmetry on natural and maximal smiling in adults remains to be examined.[9,10] Gender and age have been noted to have a limited influence on total facial motion.[11] Coulson et al.[12] assessed the displacement of landmarks for a series of facial expressions, including maximal but not natural smile, in an adult group. A significantly greater displacement was found on the left side. The type of malocclusion and ethnicity were not specified and it was unclear if the patients had received orthodontic treatment.

There is a continuing increase in the number of adults requesting orthodontic and surgical-orthodontic treatment.[13] Although data exist for facial symmetry at rest for adolescents,[6] limited information exists regarding overall facial symmetry for adults.[14] Further data are required to determine the effect of smiling on the magnitude of overall facial asymmetry.

The aim of the present study was to use stereophotogrammetry to quantify the effect of smiling on overall facial asymmetry in Caucasian adults who presented with Class I incisor relationships and with no history of orthodontic treatment.

Null hypothesis

In adults with Class I incisor relationships and no history of orthodontic treatment, the null hypothesis would state that there is no difference in the magnitude of overall facial asymmetry between expressions, genders or between sessions.

Methods

A sample size of 30 (15 males and 15 females) was determined to have a power of 80% to detect differences of the order of 0.5 mm between similar expressions at $p = 0.05$. In order to account for sample size attrition, 40 volunteers (20 males and 20 females) were recruited. Following approval from the local research ethics committee, volunteers provided consent after perusing an information leaflet. On completion of a questionnaire and clinical examination, the eligibility of each volunteer was confirmed by one assessor according to the following criteria: Caucasian; aged 18–30 years; a Class I incisor relationship with overbite/overjet of 2–4 mm; an Index of Orthodontic Treatment Need Aesthetic Component score grade of 1–4.

Volunteers were excluded if there was a history of: congenital facial deformity; gross facial asymmetry; muscular disorders or palsy; trauma, burns, paralysis, scars, botulinum toxin injections and dermal fillers, skin disease or surgery of the facial region. Volunteers who had undergone orthodontic treatment and those with anything other than the specified Class I incisor relationship were also excluded.

An experienced 3D imaging technician captured all of the 3D stereophotogrammetric images using two pairs of Canon EOS 1000D cameras (Canon, Reigate, UK) positioned 85 cm apart and linked with two Bowens Esprit 500DX digital flashes (Bowens, Colchester, UK). The photographic system was connected to a Dell Dimension 8400 computer (Dell, TX, USA) with Di3DCapture software (Di4D, Glasgow, UK). The system was re-calibrated weekly or at each session, whichever occurred sooner.

The subjects removed all makeup, earrings and facial jewellery to standardise the images and donned disposable hairbands in order to provide maximal facial exposure. The subjects were seated and orientated in natural head position (NHP) by looking directly into their own eyes reflected in a mirror. The images were then taken at rest and on natural and maximal smiling according to verbal cues (Table I).[15]

Table I. Verbal cues.

Position	Cues
Rest	Instruct subject to 'say Mississippi', 'Swallow and say "N"'. Check the subject's position twice to be sure the incisor display represents the true rest position of the lips (with posterior teeth slightly apart).
Natural smile	'Bite together lightly, smile and say "Cheese"'. Check that the smile is full and natural.
Maximal smile	'Bite teeth tightly together and smile maximally'

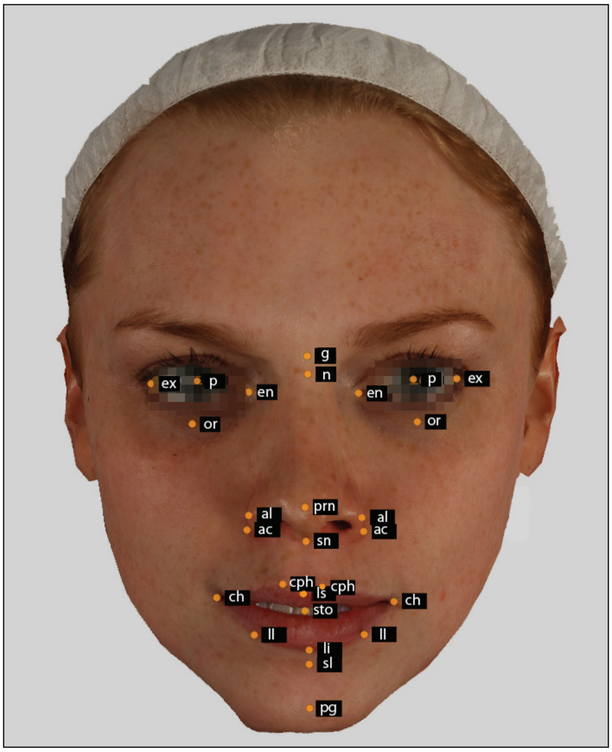

Figure 1. Facial landmarks

The facial expressions were practised until the subject felt comfortable in achieving the required expression prior to image capture (T1). Any poor quality or distorted images were immediately discarded and a new image taken. To assess expression reproducibility, each subject returned 2–4 weeks later for a repeat capture session (T2).

By using the rest image at T1, each subject was confirmed to have a clinically symmetrical face by a panel of ten orthodontic assessors. The assessments were repeated two weeks later to eliminate memory bias. One operator identified 27 landmarks on each image (Figure 1, Table II) to produce x-, y-, and z- co-ordinate data. The landmark configuration was scaled to a common size and reflected around an arbitrary plane to produce a mirror image or reflected landmark configuration. The reflected image was aligned with the original configuration using a partial Ordinary Procrustes Analysis (OPA). The landmark configurations were initially scaled to the same size and arranged so that the centroids were in a 'best fit' orientation such that the squared differences between the landmarks were minimised.[16] A symmetrical landmark configuration was therefore created. The original landmark configuration was subsequently superimposed on the symmetrical landmark configuration using OPA. Thereafter, the mean squared Euclidean distances between the pairs of landmarks in the original configurations and their

Table II. Facial landmark definitions.

	Landmark	Description
g	Glabella	Most prominent midline between the eyebrows
n	Soft tissue nasion	Point in the midline of both the nasal root and nasofrontal suture
ex	Exocanthion	point on the commissure of eye fissure (right and left)
p	Mid pupil	Centre point of the pupil (right and left)
or	Orbitale	Lowest point on the lower margin of orbit (right and left)
en	Endocanthion	Innermost point on the commissure of eye fissure (right and left)
prn	Pronasale	Most protruded point of the apex nasi
sn	Subnasale	Midpoint of angle where lower nasal septum and lips meet
ac	Alar crest point	Most lateral point in the curved base line of the ala (right and left)
al	Alare	Most lateral point on the alar contour (right and left)
ch	Cheilion	Outermost point of lip commissure (right and left)
cph	Christa philtri	Point on elevated margin of the philtrum just above vermillion line (right and left)
ls	Labiale superius	Midpoint on the upper vermillion border
li	Labiale inferius	Lower border of lower lip
ll	Lower lip	Midway between cheilion and labiale inferius (right and left)
sto	Stomion	Crossing of the vertical facial midline and the horizontal labial fissure
sl	Sublabiale	Upper border of chin, mentolabial ridge
pg	Pogonion	Most anterior midpoint on the chin

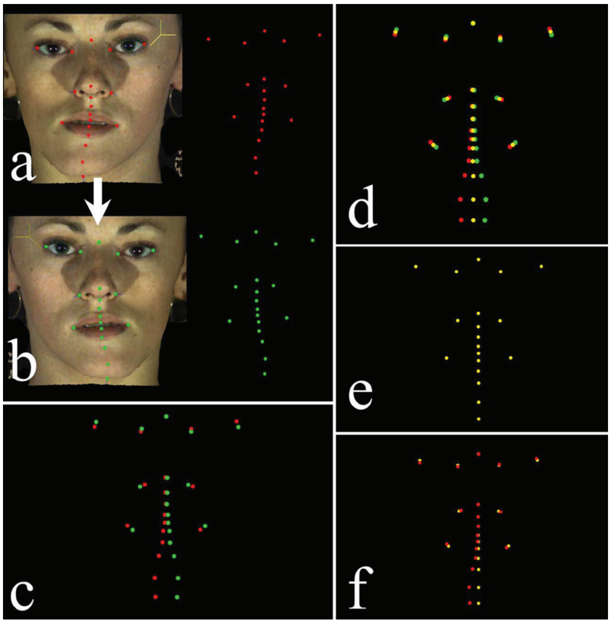

Figure 2. 3D facial asymmetry analysis based on landmarks. The original landmark configuration is shown in red (a). The mirrored configuration is shown in green (b). Both configurations are superimposed using partial Ordinary Procrustes Analysis (c) and the individual symmetrical landmark configuration is created and shown in yellow (d and e). Another superimposition is made between the original configuration and the individual symmetrical configuration (f), followed by calculating the squared Euclidean distances between pairs of homologous landmarks. (Reproduced from Hajeer MY, Ayoub AF, Millett DT. Three-dimensional assessment of facial soft-tissue asymmetry before and after orthognathic surgery. Br J Oral Maxillofac Surg 2004;42:396-404. With permission from Elsevier Ltd.)

individual symmetrical configurations were calculated and used to determine an overall facial asymmetry score in which zero indicated perfect symmetry (Figure 2).[8]

Statistical analysis

Intra-observer landmark reproducibility was calculated by re-identifying landmarks in a random 10% sample of the images two months after initial capture. The mean distance between homologous landmarks was re-determined.

Facial asymmetry scores were analysed using an Analysis of Covariance (ANCOVA) model for a repeated measures design. Expression (Rest, Natural Smile or Maximal Smile) and Session (T1 or T2) were included as fixed effects. All two-way interactions and the three-way interaction between these factors were included. Gender was included as a fixed effect and the subject was included as a random effect. A variance component variance-covariance structure was selected, based on the Akaike Information Criteria (which are used for the selection of an appropriate statistical model). Residual analyses were then performed to confirm the suitability of the ANCOVA model. All statistical analyses were performed in SAS® Version 9.2 (SAS, NC, USA).

Table III. Summary statistics of overall facial asymmetry scores by expression and session.

Expression		N	Mean	SD
At rest	Session			
	T1	40	0.80	0.18
	T2	40	0.80	0.17
	Total	80	0.80	0.17
Natural smile	Session			
	T1	40	0.88	0.16
	T2	40	0.88	0.20
	Total	80	0.88	0.18
Maximal smile	Session			
	T1	40	0.89	0.16
	T2	40	0.92	0.16
	Total	80	0.91	0.16
Total	Session			
	T1	120	0.85	0.17
	T2	120	0.87	0.19
	Total	240	0.86	0.18

Results

The mean age of male and female volunteers was 22.7 (SD 3.3) and 21.1 (SD 2.1) years, respectively, and there was a mean of 15.0 days between capture sessions.

The mean overall landmark error was 0.41 ± 0.07 mm.

The overall facial asymmetry scores for each expression and session are shown in Table III. There was no statistically significant difference between genders (p = 0.5300) (Table IV) and therefore the male and female data were pooled for further analysis. There were no statistically significant differences in mean overall facial asymmetry scores between sessions (p = 0.8547), therefore facial asymmetry was reproducible for all expressions.

Overall facial asymmetry was greater for maximal (0.91 ± 0.16mm) than for natural smile (0.88 ± 0.18mm),

Table IV. Analysis of covariance for overall facial asymmetry scores.

Effect	Numerator degrees of freedom	Denominator degrees of freedom	F value	*p*-value
Gender	1	429	0.40	0.5300
Session	1	429	0.03	0.8547
Expression	2	429	50.40	< 0.0001
Expression and Session combined	2	429	1.14	0.3204

which in turn was greater than the mean overall facial asymmetry score at rest (0.80 ± 0.17mm). There was a statistically significant difference in the mean overall facial asymmetry scores between expressions ($p < 0.0001$), which was consistent across sessions (T1–T2) ($p = 0.3204$).

Discussion

In the present study of young Caucasian adults, overall facial asymmetry was quantified at rest, and on natural and maximal smiling. Overall facial asymmetry was more marked for maximal than for natural smile, which in turn was of a greater magnitude than the mean overall facial asymmetry score at rest. The null hypothesis was therefore rejected. No statistically significant gender differences were detected in mean overall facial asymmetry scores for each facial expression. The reproducibility of each expression was high.

Due to heterogeneity arising from age,[5,6,12] ethnicity,[5,7] orthodontic treatment status,[4] occlusal characteristics,[4-6,7] and the method of assessment[4-7,12] reported in previous studies, it was not possible to compare the present findings with those of earlier work.

Although an increase in overall facial asymmetry during the natural and maximal smile may be due to a neuromuscular deficit, subjects with hard and soft-tissue contributors to functional asymmetry were excluded. Despite this, it was found that subjects with clinically symmetric faces still exhibited an increase in overall asymmetry on smiling.

A gender difference in overall facial asymmetry scores for rest position was not found, which agreed with the results of previous studies.[5-7] A clinical examination using the Ferrario et al.[5] protocol was undertaken to assess the participants, and all subjects were confirmed to have clinically symmetrical faces by a panel of ten assessors. Forty subjects were recruited to account for possible sample size attrition. All returned for the second data capture session, resulting in a power of 90%. The sample size was therefore comparable with a cross-sectional 3D analysis of the symmetry of facial expressions[12] and a recent longitudinal 3D study of facial asymmetry in adolescents.[6]

Three-dimensional stereophotogrammetry was used and standardised prompts[15] employed to elicit each facial expression. The data were captured at the same time point of the expression for each volunteer. Landmarks were placed on the digital image rather than on the face before scanning, which allowed points to be re-identified if needed. Although the imaging and landmark identification procedures could be affected by systematic error, the mean landmark error was low – 0.41 ± 0.70 mm. This is below the threshold level of 2 mm proposed as acceptable by Weinberg et al.[17] Facial expressions were highly reproducible across sessions ($p = 0.8547$) and this was in accordance with Sawyer et al.,[18] who found rest position to be reproducible.

The method used to calculate overall facial asymmetry scores eliminated the need for a predetermined mid-sagittal plane to be used and created an individualised plane for each image,[8] which minimised confounding. To eliminate the effect of size from the facial asymmetry assessment,[8] images were scaled to determine an overall facial asymmetry score. This also overcame the shortcomings associated with subjective assessment.

Adults increasingly seek orthodontic and surgical-orthodontic treatment[13] and have concerns about facial and dental asymmetry.[19] While asymmetry of the natural and maximal smile should be assessed for all patients,[20] the present results suggest that overall facial asymmetry should be assessed in the fourth dimension during facial expressions. It is suggested that a future study should assess facial asymmetry in patients scheduled for orthodontic or surgical-orthodontic treatment.

Clinicians are advised to be aware that in clinically symmetrical faces, overall facial asymmetry increases from rest to natural and maximal smile. For cases presenting with a unilateral posterior crossbite, unilateral cleft lip and palate or skeletal asymmetry, the magnitude of this change is likely to be greater at baseline and should be monitored during treatment. With the current focus on the development of Core Outcome Measures (COMET) for clinical practice,[21] the normative Caucasian data from the present study could be used for comparison.

Conclusion

The 3D facial asymmetry scores for Caucasian adults with clinically symmetrical faces increased in magnitude from rest to natural and to maximal smile and should be considered during treatment planning.

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