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Original article

Regional facial asymmetries and attractiveness of the face

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Summary

Objective: Facial attractiveness is an important factor in our social interactions. It is still not entirely clear which factors influence the attractiveness of a face and facial asymmetry appears to play a certain role. The aim of the present study was to assess the association between facial attractiveness and regional facial asymmetries evaluated on three-dimensional (3D) images.
Methods: 3D facial images of 59 (23 male, 36 female) young adult patients (age 16–25 years) before orthodontic treatment were evaluated for asymmetry. The same 3D images were presented to 12 lay judges who rated the attractiveness of each subject on a 100 mm visual analogue scale. Reliability of the method was assessed with Bland–Altman plots and Cronbach's alpha coefficient.
Results: All subjects showed a certain amount of asymmetry in all regions of the face; most asymmetry was found in the chin and cheek areas and less in the lip, nose and forehead areas. No statistically significant differences in regional facial asymmetries were found between male and female subjects ($P > 0.05$). Regression analyses demonstrated that the judgement of facial attractiveness was not influenced by absolute regional facial asymmetries when gender, facial width-to-height ratio and type of malocclusion were controlled ($P > 0.05$).
Limitations: A potential limitation of the study could be that other biologic and cultural factors influencing the perception of facial attractiveness were not controlled for.
Conclusions: A small amount of asymmetry was present in all subjects assessed in this study, and asymmetry of this magnitude may not influence the assessment of facial attractiveness.

Introduction

Facial attractiveness is an important factor in our daily social interactions (1, 2). One of the features that could influence facial attractiveness is facial asymmetry. The effect of facial asymmetry has been studied extensively with conflicting results. Although there is general agreement that gross facial asymmetries substantially decrease attractiveness of the face, an unresolved question is to what degree naturally occurring, subtle facial asymmetries affect facial aesthetics. By comparing attractiveness ratings of natural asymmetric faces with the scores assigned to digitally symmetrised (e.g. by aligning a hemi-face with its mirror reflection), some researches found the degree of facial symmetry to be an essential factor in the perception of attractiveness (3–5). But many other authors found that symmetric faces were judged less attractive (2, 6–8) or that facial attractiveness was independent of symmetry (9). A clarification of the relationship between attractiveness of the face and slight facial asymmetries seems particularly relevant for clinicians dealing with dentofacial problems—their patients usually use an improvement of facial aesthetics as a main criterion of therapeutical success. If slight facial asymmetries *do not* affect the perception of facial attractiveness, including them on the list of treatment goals may not be necessary.

To date most studies investigating facial asymmetry and its influence on facial attractiveness have used two-dimensional (2D) photographs. A 2D representation of a three-dimensional (3D) object is not likely to give us all the information we need to have for our judgement. Therefore the use of a 3D image could be decisive in establishing correlation between facial attractiveness and asymmetry. Nowadays 3D evaluation techniques are available and have been shown to represent 3D structures very accurately. 3D stereophotogrammetry is a preferred technique for soft tissue analysis (10–12).

Therefore, the aims of the present study were to assess the amount of regional facial asymmetry found in a sample of young adult orthodontic patients and to investigate correlations between regional facial asymmetry and attractiveness.

Material and methods

The ethics committee of the Canton of Bern, which follows the guidelines of the Declaration of Helsinki, approved the study protocol and the informed consent form (Ref.-Nr. KEK-BE: 388/2014).

The patients' database of the Department of Orthodontics and Dentofacial Orthopedics, University of Bern, Bern, Switzerland housing approximately 900 3D facial images taken from 2009 to October 2013 with a 3dMD stereophotogrammetry machine (3dMD faceTM System, 3dMD LLC, Atlanta, Georgia, USA) was searched

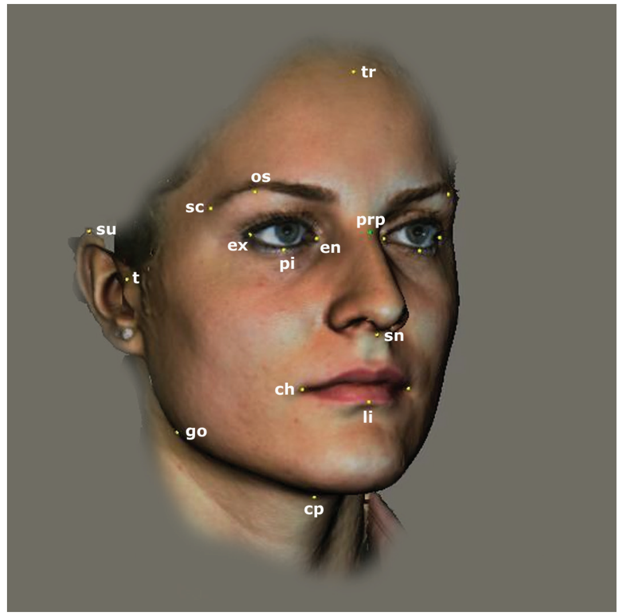

Figure 1. Soft-tissue landmarks (see Table 1 for definitions).

Table 1. Definitions of landmarks and planes.

Landmarks		
tr	Trichion	The point located just below the hairline in the midline of the forehead
os	Orbitale superius	The highest point on the lower border of each eyebrow
sc	distal end of supercilium	The point at the distal end of each eyebrow
su	Superaurale	The highest point of the free margin of the auricle
prp	Pupil reconstructed point	The point located at the midline of the nose and the bipupillary line
ex	Exocanthion	The soft tissue point located at the outer commissure of each eye fissure
en	Endocanthion	The soft tissue point located at the inner commissure of each eye fissure
pi	Palpebrale inferius	The lowest point in the midposition of the free margin of each lower eyelid
t	Tragion	The point located at the most concave point of the insertion of the upper margin of the tragus
sn	Subnasale	The midpoint on the nasolabial soft tissue contour between the columella crest and the upper lip
ch	Cheilion	The point located at each labial commissure
li	Labiale inferius	The midpoint of the vermilion line of the lower lip
go	Gonion	The most lateral point on the soft tissue contour of each mandibular angle located at the intersection of the tangent lines
cp	collum point	The deepest point at the transition between horizontal and vertical contour of the neck
Planes		
nhp	Natural head position	Superaurale-Exocanthion horizontally aligned
hp*	Horizontal plane	6.6° below cantion-superaurale, in natural headposition, through prp
vp*	Vertical plane	Perpendicular to the horizontal plane, along the horizontal direction of nhp
mp*	Median plane	Perpendicular to the cephalometric reference planes horizontal (x) and vertical (y)
p1	Eyebrows	os R - os L, perpendicular to vertical plane
p2	Eyelids	pi R - pi L, perpendicular to vertical plane
p3	Lower mouth	Through li, parallel to horizontal plane
p4	Mouth corners	ch R - ch L, perpendicular to vertical plane
p5	Outer eyebrows	sc R - sc L, perpendicular to p6 (subnasale)
p6	Subnasale	Through sn, parallel to horizontal plane
p7	Top plane hairline	tr -t L and t R, plane on the forehead just below the hairline
p8	Vertical left	en L - ch L, perpendicular to vertical plane
p9	Vertical right	en R - ch R, perpendicular to vertical plane
p10	Neck plane	Through neck point, parallel to horizontal plane
p11	Posterior plane	tr - go R and go L

*Defined by Maxilim software.

for 3D photographs of patients meeting the following inclusion criteria: untreated orthodontically in the past, Caucasian, and at the age from 16 to 25 years. Initially 120 3D images were selected but 35 had to be excluded later because patients had craniofacial syndromes, excessive facial hair or the image quality was poor. Another 7 patients refused consent and 19 photos could not be analysed due to software problems (corrupt files). Finally 59 3D images of 23 male and 36 female patients were used in the study.

Two types of assessment were performed: 1. evaluation of regional facial asymmetries and 2. evaluation of facial attractiveness.

To assess regional facial asymmetry a modified method described by Verhoeven *et al.* (12) was used. In summary, the 3D images were imported into Maxilim® software (Medicim NV, Mechelen, Belgium) and an asymmetry analysis was performed with the following steps:

- positioning the face horizontally
- positioning the face vertically
- removal of confounding regions such as ears, hair and neck
- identification of 22 soft tissue landmarks (Figure 1 and Table 1)
- construction of 15 planes (Figure 2 and Table 1)
- creation of a mirror model of the face (Figure 3)

The planes were designed to divide the 3D facial image into specified areas. In this way five facial regions were defined to be compared for asymmetry (Figure 4).

A mirrored 3D photograph was created using the following steps: 1. Construction of a transversal plane through left and right exocanthion (ExL and ExR) and pupil reconstructed point (prp, the centre point between the left and right eyes on the midline of the

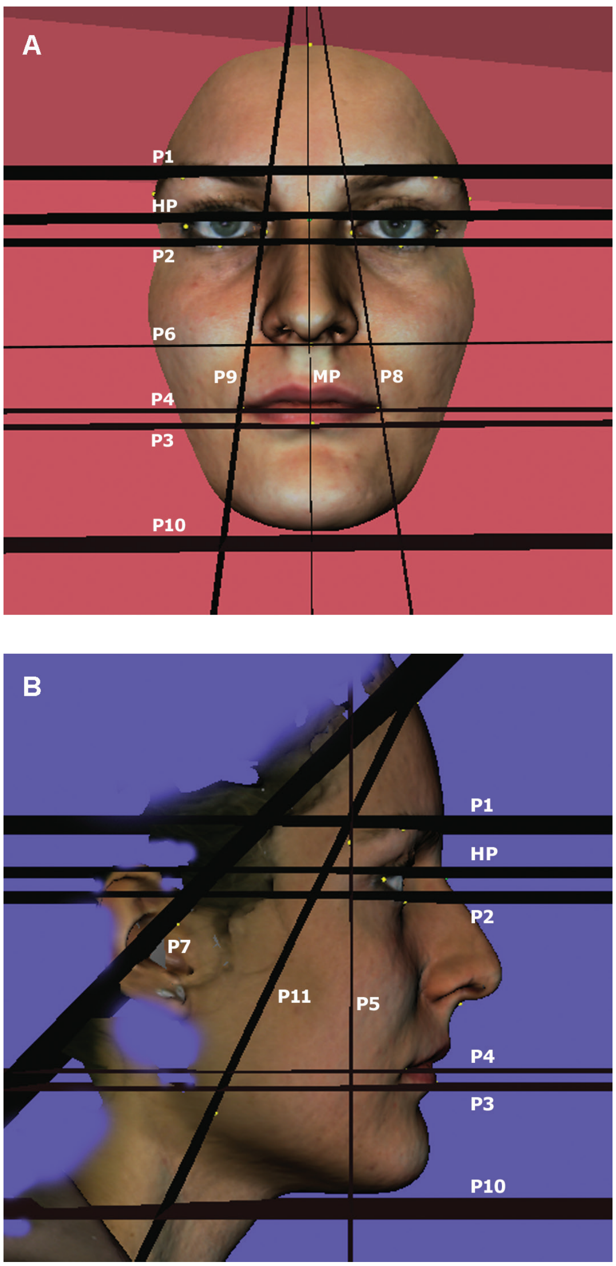

Figure 2. (A) Constructed planes, frontal view. (B) Constructed planes, lateral view (see Table 1 for definitions).

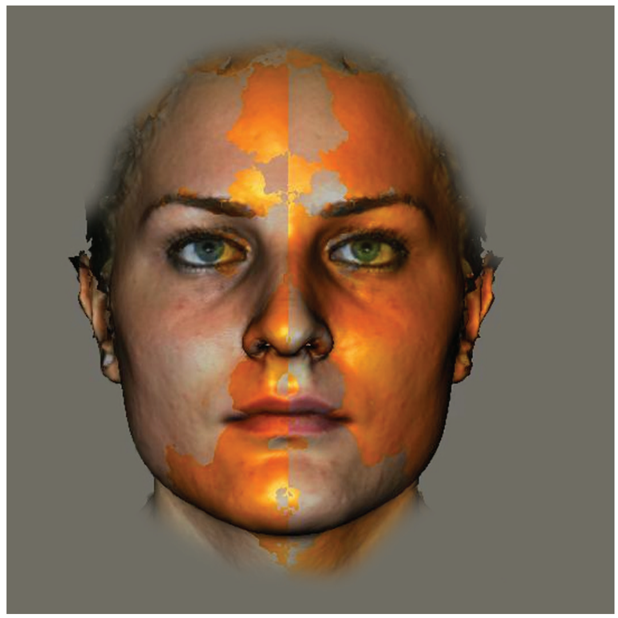

Figure 3. Mirror model (the mirrored surface is orange, description in text).

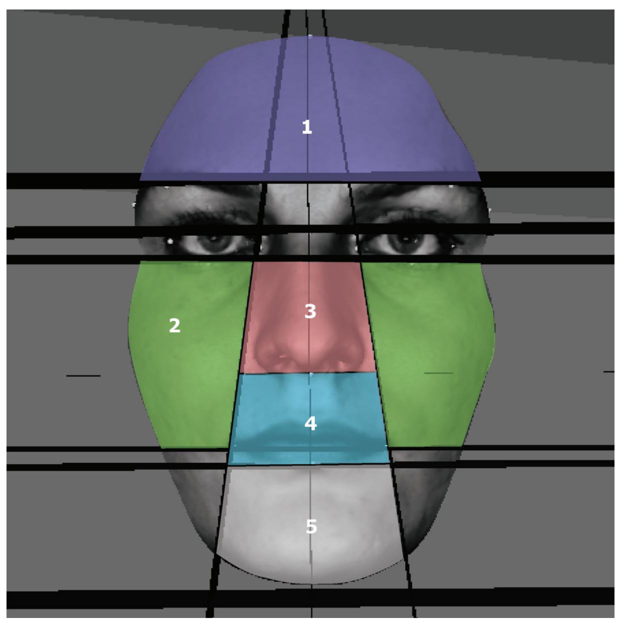

Figure 4. Regions for asymmetry analysis (1 = Forehead, 2 = Cheek, 3 = Nose, 4 = Lip, 5 = Chin).

nose), 2. Construction of a coronal plane perpendicular to the transversal plane and through both exocanthi, and 3. construction of a sagittal plane passing through prp and Subnasale (Sn). The sagittal plane was then used to create a mirrored photograph (Figure 3).

The original and the mirrored 3D photographs were matched using a complex surface registration algorithm (Iterative Closest Point Algorithm). The registration procedure was performed after selecting the forehead, upper nasal dorsum and zygoma area on both the original and the mirrored 3D photograph. Using the surface registration tool in Maxilim® software the selected regions of the original and mirrored 3D photographs were matched.

After computing the best match between the original and the mirrored 3D photograph a distance map was calculated. This distance map illustrates the absolute distance between corresponding points on both 3D images of the face. This way, asymmetry can be measured directly. After importing the distance map into Mathlab® software (7.4.0 (R2007a) Mathworks, Natick, Massachusetts, USA), the absolute mean and the 95th percentiles of the asymmetry could be calculated in millimetres for individual facial regions. This absolute mean is a number, which indicates the absolute mean difference between the original and mirrored image and is expressed in millimetres. The distance map is a visual representation of the difference between the surface of the original and the mirrored image.

Kramer *et al.* (13) showed a high consistency between measurements of facial width and height on either 2D, 3D and direct facial anthropometry. Therefore, the printouts of the 3D images in frontal view with the pupils horizontally aligned were used to measure the width (the horizontal distance between left and right zygion) and height (hairline to bottom of the chin) of the face, and width-to-height ratio (WHR) was calculated for each face (Figure 5). In order to determine the reliability of the WHR measurements, 20 randomly selected photographs were remeasured by the same researcher.

A panel of 12 judges (6 females, 6 males; mean age = 24.9 years, range 19–32 years) was asked to rate attractiveness of all 3D facial images using a 100 mm visual analogue scale (VAS) where 0 corresponded with unattractive and 100 with very attractive. Each judge was calibrated on how to manipulate 3D images on the computer screen. Each 3D photo was then shown individually to the judges and the judges were able to manipulate the 3D images at will. After the score was assigned, the next image was shown. This took approximately 20 seconds per image. Two weeks later the same panel of judges was asked to repeat the assessment procedure on 25 randomly selected 3D images.

Reliability of assessments of facial asymmetry and WHR were done with Bland–Altman plots (Figure 6). Cronbach's alpha reliability coefficient was calculated for the judgement of aesthetics between all raters to check for adequacy of inter-rater coherence. If ratings were sufficiently coherent, the mean scores of all judges were used in further analysis.

Regression models were computed to investigate associations between aesthetic score (dependent variable) and absolute regional facial asymmetries, WHR, gender and Angle classification (independent variables).

Results

Reliability of the evaluation of facial asymmetry and WHR were good (Figure 6). Cronbach's alpha coefficient was 0.891, which indicated good coherence among the 12 raters. Therefore, the average scores of all observers were used in the analyses.

A certain degree of regional facial asymmetries was found in all regions of the face (Table 2). Generally a higher amount of asymmetry was found in the lower and middle third of the face, especially in the chin and cheek area (absolute mean asymmetry was 1.17 and 1.62 mm, respectively), and less in the lip, nose and forehead areas (from 0.73 to 0.99 mm).

No statistically significant differences were found in regional facial asymmetries between female and male patients although

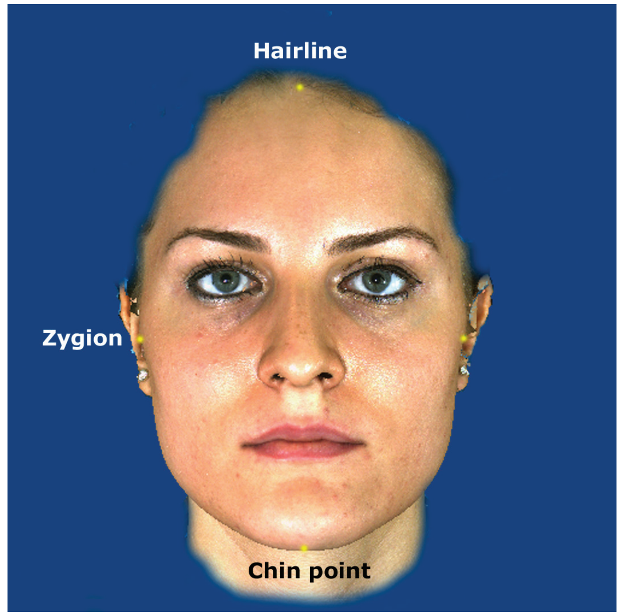

Figure 5. Facial width-to-height ratio calculated by dividing measured width by height.

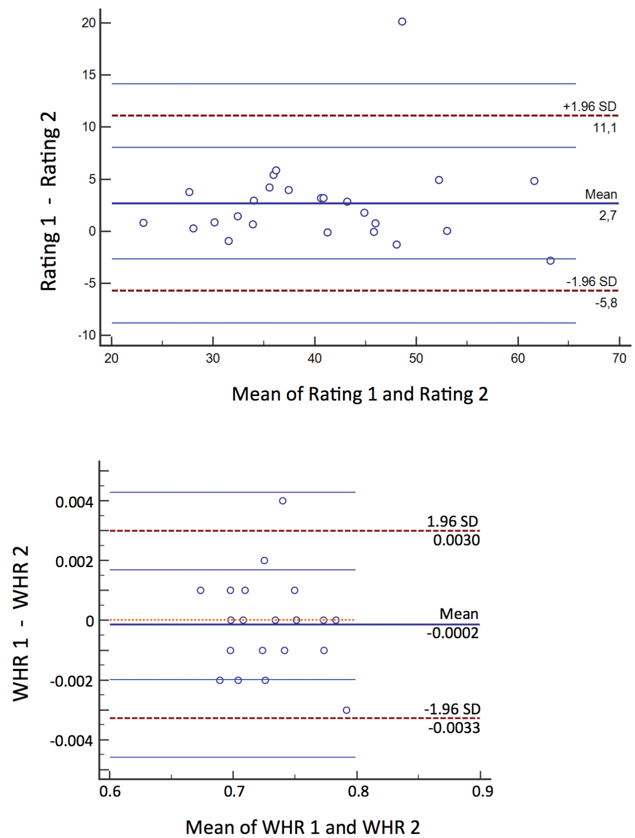

Figure 6. Bland–Altman plots demonstrating the reliability of assessment of facial asymmetry and width-to-height ratio (WHR).

Table 2. Mean absolute asymmetry of various facial regions expressed in mm.

	Mean	SD	10% percentile	25% percentile	50% percentile	75% percentile	90% percentile
Chin	1.17	0.98	0.44	0.98	1.66	2.57	3.16
Lip	0.73	0.61	0.25	0.62	1.10	1.55	1.75
Nose	0.75	0.59	0.29	0.67	1.12	1.49	1.70
Cheek	1.62	0.75	1.07	1.58	2.13	2.66	2.91
Forehead	0.99	0.70	0.41	0.93	1.48	1.92	2.17

Table 3. Comparison of regional asymmetries in males and females with independent *t*-tests.

	Male (n = 23)		Female (n = 36)		
Facial region	Mean	SD	Mean	SD	*P*-value
Chin	1.221	0.814	1.142	0.637	0.683
Lip	1.135	0.540	1.078	0.594	0.713
Nose	0.753	0.396	0.737	0.353	0.867
Cheek	1.733	1.253	1.547	0.984	0.526
Forehead	1.108	0.689	0.922	0.518	0.244

Table 4. Regression model with mean aesthetic score as dependent variable and regional facial asymmetries, gender, Angle classification and width-to-height ratio as independent variables.

Facial region	Effect of region asymmetry	*P*	95% CI lower limit	95% CI upper limit
Chin	−0.68	0.816	−6.48	5.12
Lip	−7.59	0.085	−16.25	1.07
Nose	5.94	0.233	−2.33	9.37
Cheek	3.52	0.233	−2.33	9.37
Forehead	−4.95	0.223	−13.01	3.12
Gender (M = 1, F = 2)	4.35	0.200	−2.38	5.95
Angle class (1, 2, 3)	1.01	0.685	−3.94	5.95
Width-height ratio	−40.45	0.524	−167.05	86.15
R-squared	0.129			
Adj R-squared	−0.013			

CI, confidence interval.

females seemed to be slightly less asymmetric in the cheek and forehead regions (Table 3). Regression analysis demonstrated that the judgement of facial attractiveness was not influenced by absolute regional facial asymmetries when gender, WHR and type of malocclusion (Angle class) were controlled (Table 4).

Discussion

The classical concept of a symmetric human face with a vertical line running through the nose, philtrum and chin thus dividing the face into two identical mirrored halves, as seen on drawings of Leonardo da Vinci or Albrecht Dürer, is very rarely, if ever, found in nature. Even in an apparently symmetric face a certain degree of asymmetry can be found in various regions (14–19). It is not clear how these asymmetries influence facial aesthetics. Therefore, the objective of our study was to examine to what degree regional facial asymmetries affect the attractiveness of the face in general.

The protocol used for assessment of regional facial asymmetries on 3D facial images has been previously validated by Verhoeven *et al.* (12). 3D stereophotogrammetry using the 3dMDface™ system has been shown to have a very small system error (less than 0.5 mm). Moreover it is non-invasive and has a fast acquisition time (1.5 milliseconds), which reduces the risk of movement artefacts (20, 21). A sample size of 12 lay judges was chosen according to Kiekens *et al.* (22) who stated that a panel of at least seven randomly selected laymen and/or orthodontists was sufficient to obtain reliable results in the aesthetic evaluation of faces using photographs and a VAS scale.

The amount of regional facial asymmetries found in this patient sample (Table 2) was higher than found by Kuijpers *et al.* (23). This could be explained by the fact that subjects at a different age were assessed—young adults in the current investigation and children in the study by Kuijpers *et al.* Maturation, particularly during puberty, tends to increase the asymmetry of the face (14, 24). Facial asymmetries in our sample were also greater than those described in a Chinese population (25). This disagreement could be due to the fact that Huang *et al.* evaluated only patients with Angle Class I malocclusions, while various malocclusions (Angle Class I, II and III) were present in the current sample and some patients scheduled for later orthognathic surgery were included. This might also be one of the reasons why some of these patients had not been treated orthodontically at an earlier age.

More asymmetry was found in the chin and cheek areas than in the nose, lip and forehead regions. A high prevalence of chin asymmetry and of facial areas further away from the midline have been described earlier (15–18, 26). According to Severt and Proffit (15) this tendency of increased asymmetry in the lower third of the face seems to be partly due to the fact that the mandible is a mobile structure compared to the maxilla which is more strongly connected to the adjacent anatomical structures with sutures.

In accordance with others (10, 14, 26) no statistically significant gender differences were found in this study (Table 3). This differs from the findings of Ferrario *et al.* (27) with an older patient sample and Claes *et al.* (17) with a similar age group. One possible explanation for this could be that orthodontic patients were assessed in the present study instead of a sample of a normal population. More female than male (36 f versus 23 m) patients are present in our sample, which is due to 3D images which had to be excluded from the asymmetry assessment because of excessive facial hair. Malocclusions were quite evenly distributed between males and females in our sample with some more Class I in males and more Class II in females.

In the current study, no association could be found between regional asymmetries and ratings of facial attractiveness. Regression analyses with the aesthetic score as dependent variable and regional facial asymmetries, gender, facial width-to-height ratio and Angle classification as independent variables demonstrated that facial asymmetries do not affect perception of attractiveness (Table 4). The present results agree with many previous studies (2, 6, 7, 19, 28, 29). Our findings seem to disagree with studies showing that facial asymmetry negatively affects perception of facial aesthetics (4, 30, 31). This could be an apparent disagreement because in the mentioned above publications facial aesthetics in normal faces, that is faces with asymmetries, was compared with attractiveness of symmetrised faces, that is faces, in which full symmetry was achieved with digital manipulation. In contrast, we analysed the influence of discreet regional asymmetries on attractiveness within a cohort of prospective orthodontic patients. It is likely that had we compared attractiveness of the faces of our subjects with their symmetrised images, a similar association between more symmetry and higher aesthetic scores would have been found. However, omitting a comparison with symmetrised faces and focusing on orthodontic patients allows for a conclusion useful for clinicians—because regional facial asymmetries play a limited role in perception of aesthetics, not all them have to be considered during treatment planning in patients, whose main goal is to enhance attractiveness of the face. We would like to emphasise, however, that this suggestion might not be applicable to orthognathic patients, in whom significant asymmetries can be noticed.

Potential limitations of this study are—1. we have selected orthodontic patients who might have had asymmetries above average; thus our results may not be generalisable to a population at large; 2. we used lay persons as raters; had we asked professional raters, for example orthodontists, maxillofacial surgeons, portrait painters or photographers (32), the results might be dissimilar because these raters might judge faces differently; 3. there is an imbalance between male and female subjects assessed in this study; 4. we did not control for other biological or cultural factors influencing the perception of facial attractiveness.

Conclusions

In conclusion, a small amount of asymmetry was present in all subject assessed in this study. However, asymmetries of this magnitude apparently did not influence the assessment of facial attractiveness. As small regional facial asymmetries seem to play a limited role in perception of aesthetics, not all of them need to be addressed necessarily during treatment planning.

It should be emphasised that further research is needed to investigate the threshold for regional facial asymmetry to have an effect on judgements of attractiveness, with stimuli that control for multiple factors affecting facial attractiveness.

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