Original Article

The perception of facial asymmetry using 3-dimensional simulated images

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ABSTRACT

Objective: To investigate the perception of facial asymmetry in young adults to identify the amounts of chin asymmetry that can be regarded as normal and may benefit from correction.

Materials and Methods: Three-dimensional (3D) images of 56 individuals of mixed ethnicity were obtained and used to produce average 3D images of male and female faces. Distortion was then applied to these average faces using a 3D graphics package to simulate different amounts of chin point asymmetry. Five observer groups (lay individuals, dental students, dental care professionals, dental practitioners, and orthodontists) assessed timed presentations of 3D images, rating them as ''normal,'' ''acceptable,'' or ''would benefit from correction.'' Time-to-event analysis was used to assess the level of chin asymmetry perceived as normal and beneficial for correction for each group.

Results: The factors influencing the perception of facial asymmetry were the degree of asymmetry and the observer group. Direction of the asymmetry and gender of the assessed individual did not affect the perception of asymmetry, except in the 4- to 6-mm distortion range. The gender of the observer had no influence on perception. There were statistically significant differences in the amounts of asymmetry that the laypeople and orthodontists considered to be normal (5.6 $\pm$ 2.7 mm and 3.6 $\pm$ 1.5 mm, respectively; $P < .001$) and felt would benefit from surgical correction (11.8 $\pm$ 4.0 mm and 9.7 $\pm$ 3.0 mm, respectively; $P = .001$).

Conclusions: Perception of asymmetry is affected by the amount of asymmetry and the observer group, with orthodontists being more critical. (*Angle Orthod.* 0000;00:000–000.)

KEY WORDS: Facial asymmetry; Three-dimensional images; Perception

INTRODUCTION

Asymmetry is ''a lack of equality of equivalence between parts or aspects of something.''[1] Mild asymmetry of the body occurs in all individuals. In relation to the face, symmetry and balance relate to correspondences in the size, shape, and arrangement of the facial features on both sides of the midsagittal plane.[2]

Severe facial asymmetry can be a manifestation of a number of craniofacial syndromes, trauma, pathologies, or abnormal growth. It can have important psychological, functional, and esthetic implications for patients, with the potential to affect their self-esteem and quality of life.[3,4]

For patients contemplating surgical correction, it would be beneficial to understand how others perceive asymmetry to allow comparisons and determine levels of severity. It has been suggested that gender, culture, and race may influence perception.[5,6] A recent study on the threshold of visual perception found that a minimum of 3 mm of facial asymmetry was needed for the layperson to notice it in digitally manipulated images.[7]

The aims of this study were to assess to what extent facial asymmetry is detected and which values are outside a perceived ''normal'' range, if any. The

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objectives of this study were to determine, for each category of observers, (1) the range of chin point deviations regarded as ''normal,'' (2) the deviation perceived to be outside the normal range but still esthetically acceptable, (3) the level of deviation thought to warrant surgical correction, and (4) whether there were any differences in the perception of asymmetry between various observer groups (lay individuals, dental students, dental care professionals, general dental professionals, and orthodontists).

The two null hypotheses considered here were: (1) there is no difference between the level of asymmetry perceived to be ''abnormal'' by laypeople and by various levels of dentally trained individuals, and (2) there is no difference between the level at which asymmetry is first noted by the observer and the level of asymmetry that is considered to require correction.

MATERIALS AND METHODS

Ethical approval for this study was obtained from the Birmingham University Research and Ethics Committee (ERN_11_0117).

Average Face Synthesis

''Averaged'' male and female faces were used as templates to which simulated chin point deviations were applied. ''Average'' faces were used rather than real-life proband faces to help prevent distractions caused by unique features that might be present in an individual.

To construct average faces, three-dimensional (3D) images from volunteers using a 3D camera were used. In total, 56 individuals of mixed race, recruited from the University of Birmingham Dental School, were photographed (24 men with an average age of 27.5 $\pm$ 4.7 years and 32 women with an average age of 26.6 $\pm$ 4.6 years). The inclusion criteria for the volunteers were age between 18 and 35 years, no facial hair, and no craniofacial anomalies or history of head and neck trauma.

The 3D images were recorded at the Clinical Illustration Unit, within the Birmingham Dental School and Hospital using a static 3dMD camera (3dMD, Atlanta, Ga). The average faces were constructed using a set of subroutines designed for Rapidform 2006 (INUS Technology, Seoul, Korea).[8]

Deformation Simulation

The average faces were processed by one of us (FM) to simulate chin point deviations using the Maya software package (Autodesk Inc, San Francisco, CA, USA). Because the average face was represented by data points only (without skin texture), a skin map was overlaid onto it prior to manipulation using two-dimensional facial color wraps to produce more realistic results for the assessment. Deviations of the chin point were applied, from 0 to 20 mm in 2-mm increments, to both the right and the left, using pogonion as a reference point (Figures 1 and 2). The images were shown in a fixed random sequence in a timed Power Point presentation (Microsoft, Redmond, Wash). Each image was shown for 14 seconds, projected as an animation rotating in real time from the frontal view to the right and left profile views. This allowed the viewer to perceive temporally the 3D nature of the images instead of only 2D projections. There was a 2-second break between each of the images.

Asymmetry Perception

The images were rated by five groups of 40 observers: laypeople, dental students, dental care professionals, general dental practitioners, and orthodontists.

Each observer completed a consent form and indicated their gender and the group to which they belonged. The students consisted of fourth- and fifth-year dental undergraduates (ie, they had some clinical experience). Dental care professionals included dental nurses and technicians. The general dental practitioners consisted of qualified dentists with no additional registered qualifications in a dental specialty, while the orthodontists were orthodontic registrars, specialists, and consultants. The lay group included individuals with no formal dental training. The observers categorized each image during the time it was on the screen as (a) normal; (b) slightly abnormal, but socially ''acceptable'' and not requiring correction; or (c) abnormal and would benefit from correction.

Statistical Analysis

A sample size calculation was performed based on 80% sensitivity, with the aim of discriminating between groups at the 0.8 and 0.5 levels. The layperson category was chosen as the base group and all other groups were compared to this. The minimum sample size to satisfy the test requirements was 39 observers per group.

Because the data were categorical, analysis was based on comparison of proportions. Time-to-event analysis was used to define the ranges of asymmetry that could be classified as ''normal,'' ''socially acceptable,'' or ''in need of correction.'' From these results, a general linear model analysis was performed, with post hoc Tukey tests.

RESULTS

The proportions of observer responses in category (a) (no abnormality) are shown in Figure 3. The

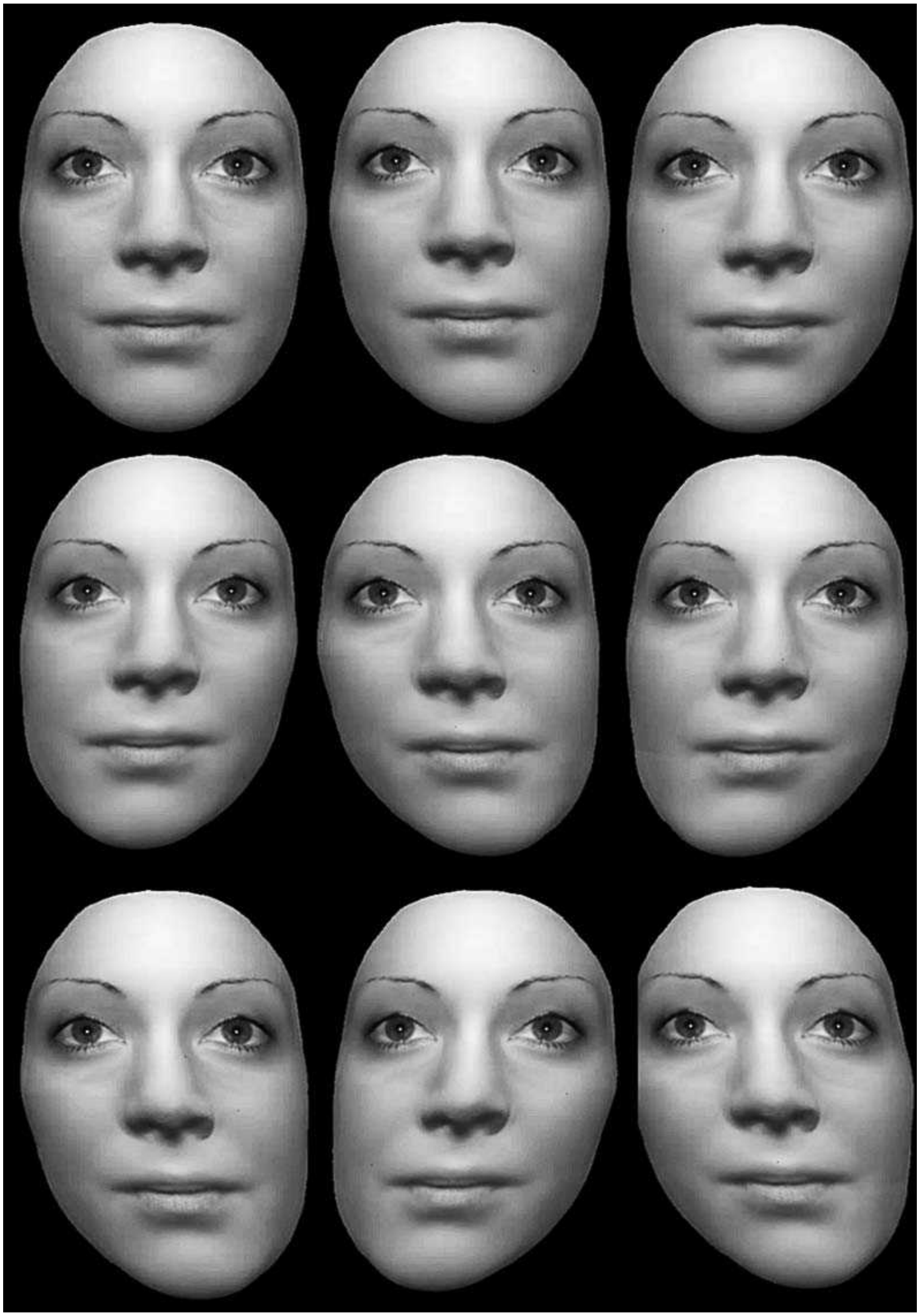

Figure 1. Examples of female averaged faces with various levels of asymmetry (from top left: 0 mm, 6 mm, 8 mm, 10 mm, 12 mm, 14 mm, 16 mm, 18 mm, 20 mm).

proportions of responses for each level of asymmetry followed similar trends.

Unsurprisingly, the lay group (group 1) was less likely to detect low levels of asymmetry, while the orthodontists (group 5) noticed this much earlier. The other groups perceived asymmetry at levels between those judged by the lay and orthodontist observers. For the subsequent analyses, only the lay and orthodontist groups were considered, as these appeared to represent the upper and lower bounds of asymmetry perception.

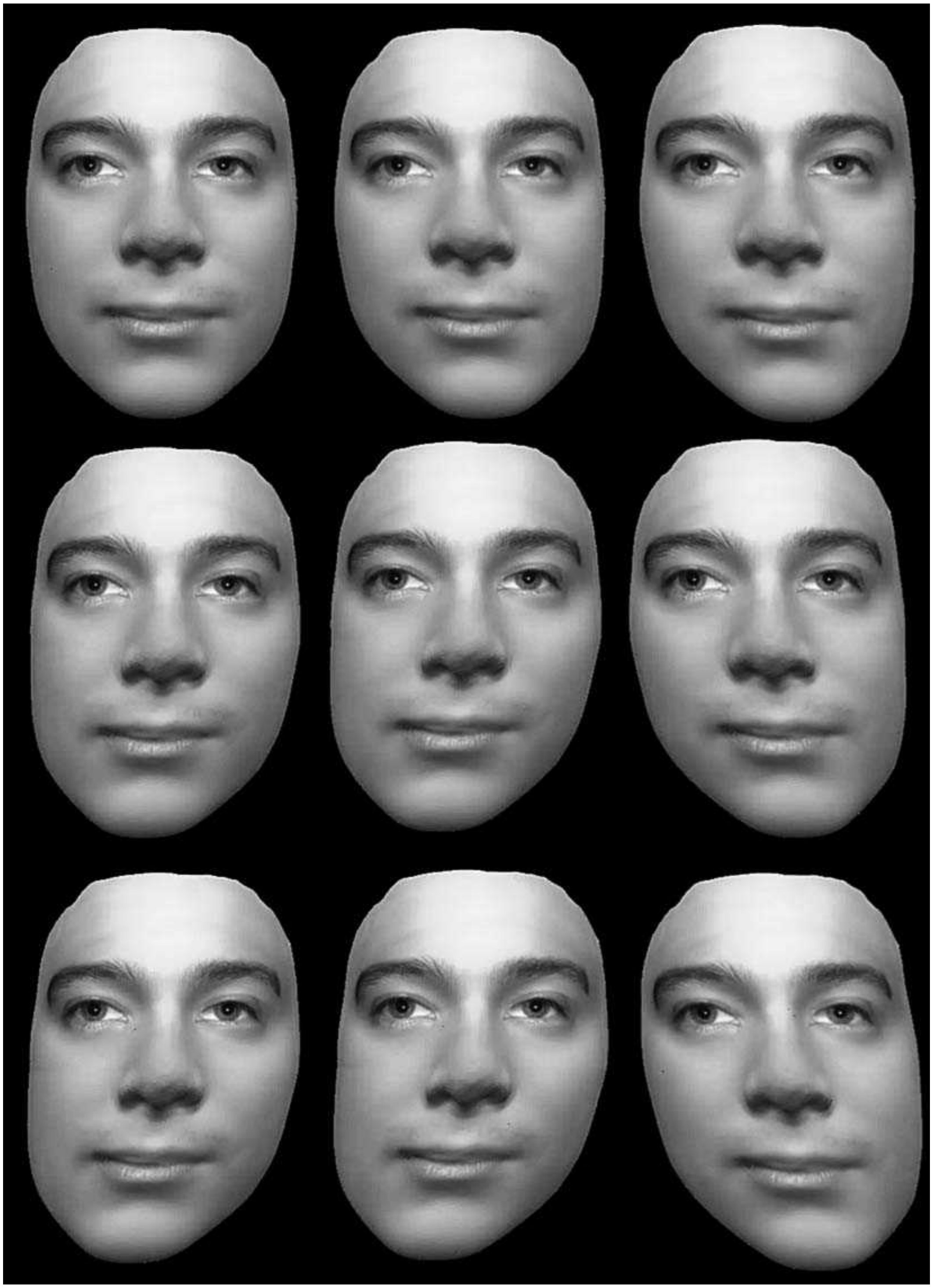

Figure 2. Examples of male averaged faces with various levels of asymmetry (from top left: 0 mm, 6 mm, 8 mm, 10 mm, 12 mm, 14 mm, 16 mm, 18 mm, 20 mm).

Reliability Analysis

A preliminary test was carried out to assess intraobserver variability, with six observers completing the ratings at two separate sessions at least 1 week apart. The Cohen's kappa values ranged from 0.44 ("moderate agreement") to 0.78 ("substantial agreement). The average kappa value was 0.60 $\pm$ 0.10 ("substantial agreement").[9]

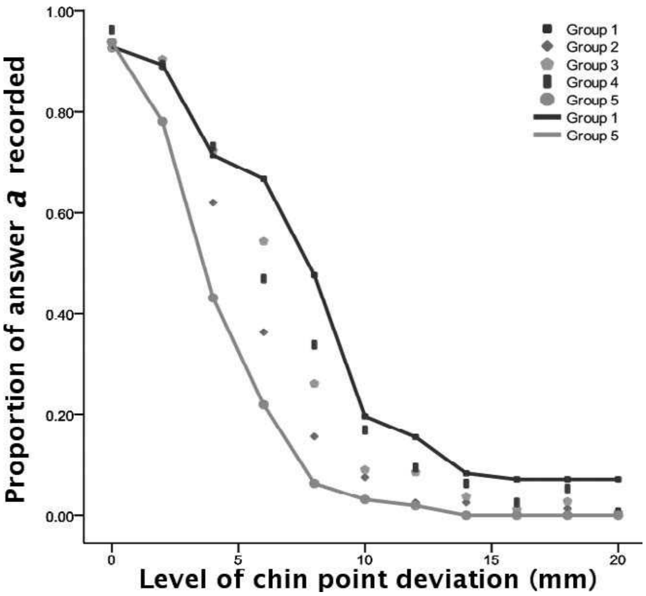

Figure 3. Proportion of option (a) (''normal'') selected for each asymmetry level for each group. Group 1 corresponds to the layperson group; group 2, dental students; group, 3 dental care professionals; group 4, general dental practitioners; and group 5, orthodontists. Group 1 and group 5 can be seen to represent the upper and lower bounds for the perception of chin point asymmetry, with the laypeople needing greater levels of asymmetry to be present before they perceive it than the orthodontist group.

The Impact of Deformation Direction on Perception of Asymmetry

Figure 4 shows the proportions of answers in the (a) category from the lay and orthodontist groups combined at each asymmetry level, between the right and left sides. The deviations were perceived similarly, regardless of whether they were on the right or left, especially at the upper and lower ends of the spectrum. However, for the midrange values, some variability was observed. The confidence intervals for these proportions revealed that, at 4 mm, chin deviation direction may have a small but significant influence on the perception of asymmetry.

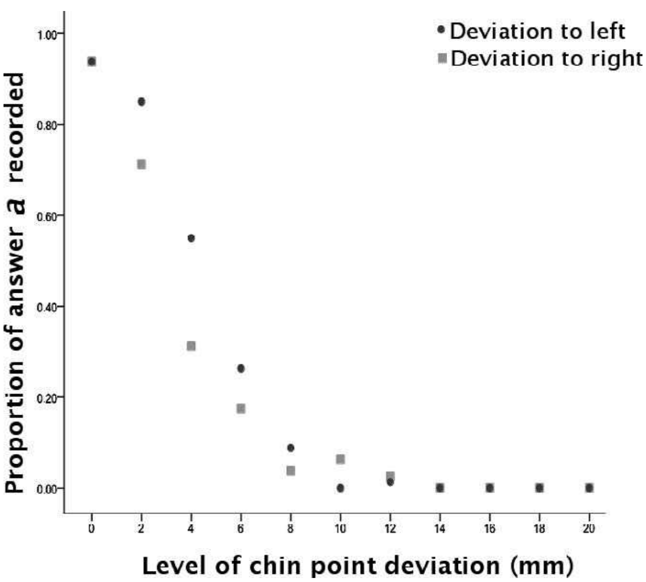

Figure 4. The proportions of option (a) for both the orthodontist and laypeople groups combined for each increment of deviation to both the right and left are shown. There is close correspondence between the responses at each increment, with the exception of the 4-mm level.

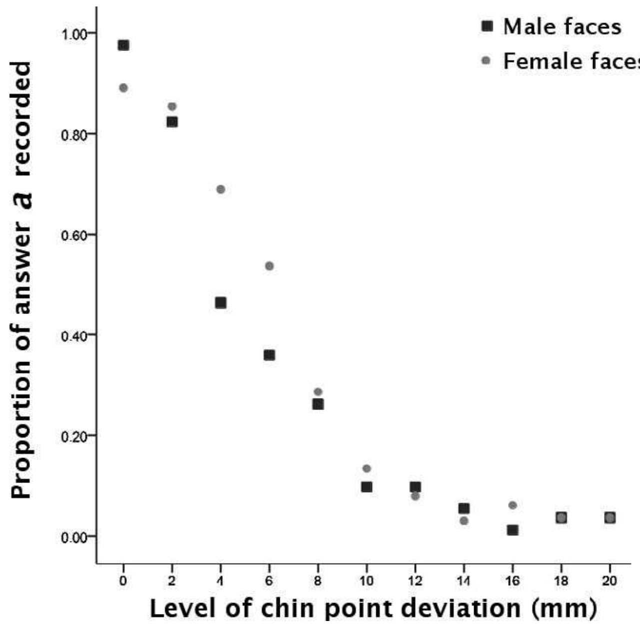

Figure 5. Differences in the ratings of the male and female faces. The graph indicates the proportion of option a (''normal'') recorded for each level of asymmetry for the female faces and male faces. There are similar responses for the genders and increased variation at the 4 and 6 mm levels.

The Impact of Patient Gender on the Perception of Facial Asymmetry

The results for option (a) from the orthodontist and lay groups were also used to test for differences in perception according to the gender of the manipulated faces. Figure 5 shows that the responses for each level of deviation were similar in the assessment of male and female faces. As previously observed, the midrange is where more variable responses were recorded. The confidence limits of responses for the male and female images (Figure 6) showed that, with the exception of 0, 4, 6, and 16 mm, there were no statistically significant differences. At 0 and 16 mm of deviation, the confidence limits were close to zero, indicating weaker effects than at 4 and 6 mm.

The Impact of Observer Gender on Perception of Facial Asymmetry

The proportions of option (a) recorded by male or female observers in the orthodontic and layperson

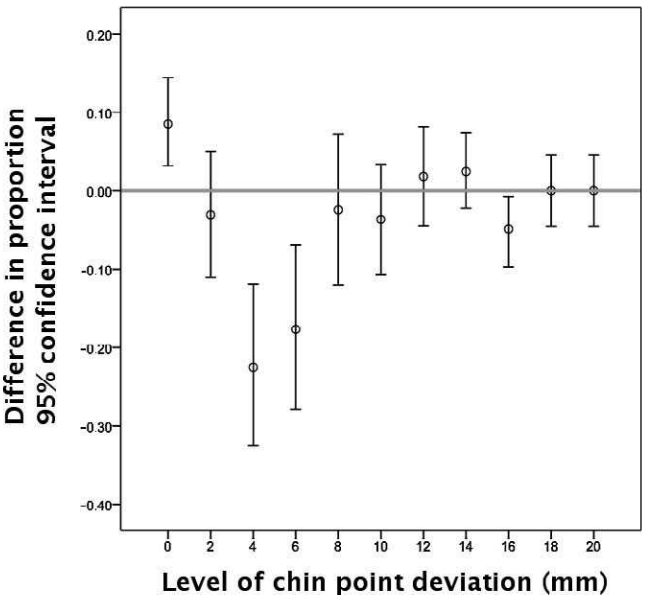

Figure 6. Differences in proportions with respect to the impact of male and female faces on perception. The vertical lines indicate the upper and lower limits of the confidence interval, while the circles represent the mean for that level of asymmetry. For most levels of asymmetry, a statistically significant difference could not be found, with the exception of 0, 4, 6, and 16 mm. At those levels the vertical lines do not cross the x-axis, indicating that a difference, small for 0 and 16 mm and larger for 4 and 6 mm, may exist for these degrees of asymmetry.

groups combined were not significantly different at the levels of asymmetry investigated.

Assessment of ''Normal'' and ''Acceptable'' Ranges

The lowest level of asymmetry at which the first change from option (a) to option (b) occurred was recorded for each observer. Similarly, the level at which the first change from option (b) to option (c) occurred was recorded to determine the level at which correction was deemed appropriate. The time-to-event results were analyzed according to group, and then comparisons were carried out to assess any differences between groups.

Using the time-to-event results, the mean values were calculated for each group (Table 1) to find the upper limit of the ''normal'' range. For the layperson group, the upper limit of ''normal'' was 5.6 $\pm$ 2.7 mm, whereas for the orthodontist group, the upper limit was 3.6 $\pm$ 1.5 mm. For the other observer groups assessed, the ranges were greater than that of the orthodontist group but narrower than that of the layperson group. A general linear model analysis showed that the observer group was a statistically significant ($P < .001$) factor with respect to the perception of chin point asymmetry for the range of deviations that were considered to be within normal.

Post hoc Tukey's tests (Table 2) showed that the orthodontic group differed significantly ($P < .05$) from all other groups except the general dental practitioner group when the normal range values were compared. There was also a significant difference between the layperson group and the general dental practitioner group for the range of normality ($P < .05$).

Perceived Asymmetry Deemed Appropriate for Correction

The mean values for the first change from option (b) to option (c) in the observer groups are shown in Table 3. Again, the orthodontist group had the lowest threshold for correction of asymmetry (9.7 $\pm$ 3.0 mm), and the laypeople group allowed the largest acceptable level of asymmetry (11.8 $\pm$ 4.0 mm). The general linear model analysis confirmed that these differences were statistically significant ($P < .05$) (Table 4).

The differences between groups, assessed with the post hoc Tukey's test, confirmed that significant differences ($P < .05$) existed between the orthodontists and the other groups, with the exception of the dental care professionals.

DISCUSSION

Previous studies of facial and dental asymmetry revealed that perception can be affected by variables associated with the observer (eg, profession) as well as the patient (eg, location of asymmetry).[10,11] Perception of asymmetry is important to clinicians involved in assessment and treatment, to the patients themselves, and to the governing bodies that are responsible for resource allocation. Cunningham et al.[12] performed a cost-utility analysis of patients undergoing orthognathic treatment in a cohort of 21 patients, with estimations of treatment costs based on a single United Kingdom trust. They found that the average cost for treatment involving single-jaw surgery was almost £2700 and for

Table 1. Range of Asymmetry Regarded as Normal by Each Observer Group

Observer Group	Mean Chin Point Deviation, mm	Standard Deviation, mm	Perceived Normal Range, mm
Laypeople	5.60	2.68	0–5.60
Dental students	5.13	2.06	0–5.13
Dental care professionals	5.06	2.36	0–5.06
General dental practitioners	4.40	1.60	0–4.40
Orthodontists	3.60	1.54	0–3.60

Table 2. Multiple Comparisons (Tukey Tests) of Facial Asymmetry Perception Between the Observer Groups for the "Normal" Range of Asymmetry

Group A	Group B	Mean Difference Between A and B	Standard. Error	Significance*	95% Confidence Interval	
					Lower Bound	Upper Bound
Laypeople	Dental students	0.47	0.32	.56	−0.40	1.33
	Dental care professionals	0.53	0.33	.48	−0.37	1.43
	General dental practitioners	1.20	0.33	.003*	0.30	2.10
	Orthodontists	2.00	0.33	<.001*	1.10	2.90
Dental students	Laypeople	0.47	0.32	.56	−1.33	0.35
	Dental care professionals	−0.07	0.32	1.00	−0.81	0.94
	General dental practitioners	0.73	0.32	.16	−0.15	1.60
	Orthodontists	1.53	0.32	<.001*	0.65	2.40
Dental care professionals	Laypeople	−0.53	0.33	.48	−1.43	0.37
	Dental students	−0.65	0.32	1.00	−0.94	0.81
	General dental practitioners	0.66	0.33	.27	−0.25	1.57
	Orthodontists	1.46	0.33	<.001*	0.55	2.37
General dental practitioners	Laypeople	−1.20	0.33	.003*	−2.10	−0.30
	Dental students	−0.73	0.32	.16	−1.60	0.15
	Dental care professionals	−0.66	0.33	.27	−1.57	0.25
	Orthodontists	0.80	0.33	.12	−0.11	1.71
Orthodontists	Laypeople	−2.00	0.33	<.001*	−2.90	−1.10
	Dental students	−1.53	0.32	<.001*	−2.40	−0.65
	Dental care professionals	−1.46	0.33	<.001*	−2.37	−0.55
	General dental practitioners	−0.80	0.33	.12	−1.71	0.11

* Statistically significant ($P < .05$).

bimaxillary surgery it was approximately £3600. These figures do not include disruptions to work/study, necessary travel to/from appointments, or, more importantly, additional potential risks from surgery, general anesthesia, and orthodontic treatment. With consideration of all these factors, it is important to determine whether these asymmetries are naturally acceptable or even detectable by most individuals to allow a fair assessment of potential risks and benefits.

There is no gold standard method for the assessment of realistic asymmetry at varying levels of deviation without compromise, such as digital manipulation. Recently, Meyer-Marcotty et al.[11] investigated asymmetry using a digitally altered 3D male proband face. Their single face may be more realistic than the average faces used in this study; however, their images were in greyscale, which may have reduced the realism of the face. Another study used stylized 2D cartoons to represent an individual with asymmetry.[13] It can be argued that this method is the least realistic method of assessing the perception of asymmetry, as stylized cartoons are not representative of facial features in terms of form, proportions, texture, or color, especially in comparison with the methods used here.

Table 3. Mean Level of Chin Point Asymmetry at Which Surgical Correction Was Deemed Appropriate, as Perceived by the Observers

Observer Group	Mean Chin Point Deviation Threshold, mm	Standard Deviation, mm
Laypeople	11.79	4.04
Dental students	11.98	3.62
Dental care professionals	10.60	2.85
General dental practitioners	11.35	2.80
Orthodontists	9.73	2.98

Our study found that observers were less sensitive to asymmetry of the chin when discrepancies were small. In the midrange, the response approached a sigmoid curve, with greater intergroup variability, suggesting that other variables (such as the direction of asymmetry and the patient's gender) might come into play. In addition, we found that observer group played a significant role in the perception of facial asymmetry.

A recent study by Meyer-Marcotty et al. suggested that the profession of the rater did not influence their opinion of the simulated asymmetry.[11] The observers rated images on a Likert scale of 1 to 6, but bias may have been introduced into the study by indicating that symmetry should be sought. The images used in that study were 3D manipulated images, similar to those used here; however, the face was shown as a grey 3D shell lacking skin colors and textures, which may have affected the results.

In another study, Meyer-Marcotty et al.[14] assessed the opinions of observers with regard to appearance, symmetry, and expression with 3D images of repaired adult unilateral cleft lip and palate patients compared with age- and sex-matched adults without the condition. They found that a greater level of asymmetry in the midface contributed to a more negative observer opinion toward the image. However, the study compared images

Table 4. Results of Multiple-Comparison (Tukey) Tests Between the Observer Groups for the Level of Facial Asymmetry Deemed Appropriate for Surgical Correction

Group A	Group B	Mean Difference Between A and B	Standard Error	Significance*	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Laypeople	Dental students	−0.19	0.50	1.00	−1.56	1.17
	Dental care professionals	1.19	0.52	.15	0.23	2.61
	General dental practitioners	0.44	0.52	.92	−0.98	1.86
	Orthodontists	2.06	0.52	.001*	0.64	3.48
Dental students	Laypeople	0.19	0.50	1.00	−1.17	1.56
	Dental care professionals	1.38	0.50	.05	−0.003	2.76
	General dental practitioners	0.63	0.50	.72	−0.75	2.01
	Orthodontists	2.25	0.50	<.001*	0.87	3.64
Dental care professionals	Laypeople	−1.19	0.52	.15	−2.60	0.23
	Dental students	−1.14	0.50	.05	−2.76	0.003
	General dental practitioners	−0.75	0.52	.61	−2.19	0.69
	Orthodontists	0.88	0.52	.45	−0.56	2.31
General dental practitioners	Laypeople	−0.44	0.52	.92	−1.86	0.98
	Dental students	−0.63	0.50	.72	−2.01	0.75
	Dental care professionals	0.75	0.52	.61	−0.69	2.19
	Orthodontists	1.63	0.52	.02*	0.19	3.06
Orthodontists	Laypeople	−2.06	0.52	.001*	−3.48	−0.64
	Dental students	−2.25	0.50	<.001*	−3.64	−0.87
	Dental care professionals	−0.88	0.52	.45	−2.31	0.56
	General dental practitioners	−1.63	0.52	.02*	−3.06	−0.19

* Statistically significant ($P < .05$).

from different individuals, and observers may have been biased by features other than those assessed. The authors attempted to account for this by using cropped greyscale images so that peripheral features did not influence observer opinion, but it is difficult to determine whether this was achieved.

More recently, Naini et al.[13] assessed the influence of chin point asymmetry on perceived attractiveness of individuals. The observer groups included orthognathic patients, clinicians, and laypeople. Their conclusions agreed with our study with respect to the perception of asymmetry increasing as the deviation increased. They concluded that deviations of less than 5 mm were not considered important and the desire for surgery was more likely when the deviations were above 10 mm; also, orthodontists were more critical of asymmetry than laypeople, and the gender of the observer did not affect the perception of asymmetry.

Although this investigation and similar studies give some indication of the perception of asymmetry, it must be remembered that the results were based on static images and may vary significantly when applied to clinical or real-world settings where facial movement, facial features, or patient personality may affect perception.

CONCLUSIONS

- Perception of asymmetry was influenced by the level of asymmetry and the profession of the observer.
- Perception of asymmetry was not affected by the gender of the individual with the asymmetry, the gender of the observer, or the direction of the asymmetry.
- The layperson group classified the upper limit of "normal" as 5.6 ± 2.7 mm.
- The layperson group considered that asymmetry greater than 11.8 ± 4.0 mm required correction.
- The orthodontists were most sensitive to asymmetry.

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