The Relationship between Age and Facial Asymmetry

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Background: Facial symmetry is a fundamental goal of plastic surgery, yet some asymmetry is inherent in any face. Three-dimensional photogrammetry allows for rapid, reproducible, and quantitative facial measurements. With this tool, the authors investigated the relationship between age and facial symmetry.

Methods: The authors imaged normal subjects using three-dimensional photogrammetry. Facial symmetry was calculated by identifying the plane of maximum symmetry and the root-mean-square deviation. Regression analysis was used to assess the relationship between age and symmetry. Subgroup analyses were performed among facial thirds.

Results: The authors imaged 191 volunteers with an average age of 26.7 ± 22.2 years (range, 0.3 to 88 years). Root-mean-square deviation of facial symmetry clustered between 0.4 and 1.3 mm (mean, 0.8 ± 0.2 mm). The authors found a significant positive correlation between increasing age and asymmetry ($p < 0.001$; $r = 0.66$). The upper, middle, and lower facial third's average root-mean-square deviations were 0.5 ± 0.2 mm (range, 0.2 to 1.2 mm), 0.6 ± 0.2 mm (range, 0.2 to 1.4 mm), and 0.6 ± 0.2 mm (range, 0.2 to 1.2 mm), respectively. Asymmetry also increased with age across all facial thirds ($p < 0.001$).

Conclusions: Facial asymmetry increases with age in each facial third, with a greater asymmetry and increase in asymmetry in the lower two-thirds. Contributing factors may include asymmetric skeletal remodeling along with differential deflation and descent of the soft tissues. The observed correlation between increasing facial asymmetry and age may be a useful guide in plastic surgery to produce age-matched features. (*Plast. Reconstr. Surg.* 142: 1145, 2018.)

acial symmetry is a fundamental goal of plastic surgery and is commonly regarded as a key component of human attractiveness.[1–4] Artificially generated, perfectly symmetric faces, however, appear unnatural. Although facial symmetry is thought to reflect genetic and molecular development, it may be perturbed by environmental factors, nutrition, illness, and behavior (e.g., facial habits causing unilateral skeletal and muscular development).[1,3,5] Some degree of facial asymmetry is attractive and inherent in any face, but in excess, it is unnatural and unattractive and correlates with a decline in well-being.[3,6,7]

Historically, facial asymmetry was measured by direct anthropometry, which is time-consuming and difficult in the pediatric population.[8,9] Anthropometry has been criticized because of unreliability in standard identification of landmarks, inability to accurately identify asymmetries in areas with few landmarks, and questionable validity of

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the selected symmetry planes.[2] In addition, anthropometry is restricted to the measurement of linear distances and angles. Recently, three-dimensional photogrammetry has been used as a tool for the rapid and reliable collection of quantitative cephalometric measurements, including the analysis of volumes and complex surface topography.[10,11] It has also proven to be a precise, accurate, and reproducible method of assessing facial dimensions.[6,12–17] With its rapid image capture and lack of radiation, it is both practical and reliable for imaging across age groups.[12,18] Here, we used three-dimensional photogrammetry to quantitatively explore the relationship between facial asymmetry and age in a cohort of normal volunteers across a broad age range.

PATIENTS AND METHODS

After institutional review board approval, 191 volunteers had photogrammetric images obtained of their faces. We confirm adherence to the tenets of the Declaration of Helsinki. All facial surface scans were captured using the Canfield Vectra stereo photogrammetry system (Canfield Imaging Systems, Fairfield, N.J.) with their faces in repose. Subject exclusion criteria included any history of facial operation, facial trauma, or craniofacial diagnoses. Demographic data including sex, race, and age were collected at the time of imaging.

In a method we have described previously, we measured facial symmetry by calculating the root-mean-square deviation difference between the original facial image and one reflected about the sagittal plane of maximal symmetry.[6] The plane of maximal symmetry was generated by minimizing the differences between the original and reflected faces. In other words, after reflecting the facial surface, two images were "best fit" and then the distances between the two three-dimensional surfaces were calculated and averaged to give a single numerical value of the mean difference. This best fit of native and reflected faces avoids the errors inherent in manually identifying a plane for reflection. A greater root-mean-square deviation, or distance between the native and reflected faces, means a greater facial asymmetry, whereas a root-mean-square deviation of 0 would represent perfect symmetry. Root-mean-square deviation, measured in millimeters, is defined as follows:

$$x_{rms} = \sqrt{\frac{1}{N}\sum_{i=1}^{N}x_i^2} = \sqrt{\frac{x_1^2 + x_2^2 + \ldots + x_N^2}{N}}.$$

This method has a proven high interobserver reliability and ability to discriminate subtle levels of asymmetry.[6,19] The area selected for analysis of the full face included the forehead, buccal, orbital, nasal, and mandibular areas, and excluding the hairline, otic, and cervical areas (Fig. 1). In addition, images were divided into horizontal facial thirds according to the three-section canon using the trichion, glabella, subnasale, and menton as landmarks.[20] The upper facial third consists of the forehead area between the trichion and the glabella, excluding the hairline; the middle consists of the area between the glabella and the subnasale, including the ocular and nasal regions and excluding the otic area; and the lower third consists of the area between the subnasale and the menton, including the buccal and mandibular areas and excluding the cervical area.

Statistical Analysis

All analyses were performed using Stata SE Version 12.1 (StataCorp, College Station, Texas). Univariate analyses were calculated to evaluate the potential relationship between root-mean-square deviation and race, sex, and age. One-way analysis of variance was used to assess root-mean-square deviation and race. The t test was used to assess root-mean-square deviation and sex. Simple linear regression was used to assess root-mean-square deviation and age. R-square values were computed to examine the amount of variance explained by the predictor variable, age. All calculated p values were two-tailed and considered significant for values of $p < 0.05$.

RESULTS

We obtained three-dimensional facial images of a cohort of 191 volunteers with an average age of 26.7 ± 22.2 years (range, 0.3 to 88 years). Full patient demographics are shown in Table 1, with an age breakdown histogram shown in Figure 2. Root-mean-square deviation calculations of right to left facial asymmetry in the volunteer population clustered between 0.4 and 1.3 mm (average, 0.8 ± 0.2 mm), consistent with our previous analysis of facial asymmetry in the normative population.[6] Regression analysis demonstrated a statistically significant positive correlation between increasing age and facial asymmetry ($p < 0.001$; $r = 0.66$) (Fig. 3). This translated to a predictable increase in root-mean-square deviation by 0.06 mm for each decade of life. We found no significant relationship between sex or race and asymmetry (Table 2).

The subgroup analysis by horizontal facial thirds demonstrated a significant increase in asymmetry with aging across all thirds ($p < 0.001$)
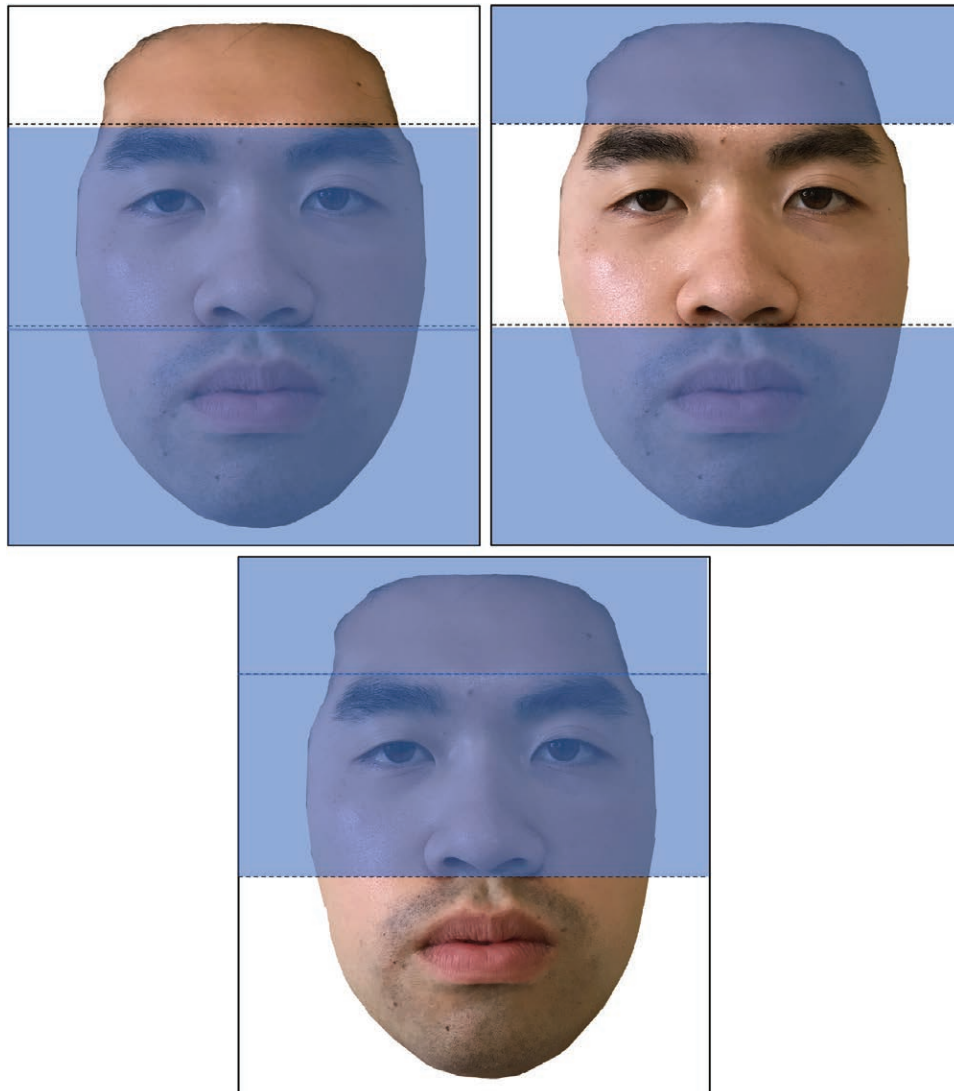
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Fig. 1. (*Above*, *left*) Facial area of analysis and demonstration of facial thirds. Upper third: Area between the trichion and glabella including the forehead above the eyebrows. (*Above*, *right*) Middle third: Area between the glabella and subnasale including the ocular and nasal areas and excluding the otic area. (*Below*) Lower third: Area between the subnasale and menton including the buccal and mandibular areas and excluding the cervical area.

(Figs. 4 through 6). The mean root-mean-square deviation of the upper facial third was 0.5 ± 0.2 mm (range, 0.2 to 1.2 mm). The mean root-mean-square deviation of the middle facial third was 0.6 ± 0.2 mm (range, 0.2 to 1.4 mm). The mean root-mean-square deviation of the lower facial third was 0.6 ± 0.2 mm (range, 0.2 to 1.2 mm). The upper third overall had a smaller degree of asymmetry ($p < 0.001$) and changed less with aging when compared to the other facial regions. The asymmetries measured in the middle and lower thirds were not significantly different from each other ($p = 0.090$) (Table 3).

DISCUSSION

In this cohort study, through the use of three-dimensional photogrammetry we were able to quantitatively demonstrate a positive linear correlation between aging and facial asymmetry. This relationship translates to a predictable increase in root-mean-square deviation by 0.06 mm for each decade of life, which is a small but significant increase over time. In a previous study, we demonstrated that facial asymmetry measurements with this technique, in a normative population, cluster around 0.8 ± 0.2 mm, with noticeable asymmetry occurring with root-mean-square deviation values

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Table 1. Demographics of 191 Normative Volunteers

Characteristics	Value (%)
No.	191
Age at imaging, yr	
Mean ± SD	26.7 ± 22.2
Range	0.3–88.0
Sex	
Male	88 (46)
Female	103 (54)
Ethnicity	
Caucasian	122 (64)
Hispanic	29 (15)
Black	19 (10)
Asian	13 (7)
Other	8 (4)

of greater than 1.3 mm.[6] Subdivision into horizontal thirds also showed that asymmetry increases significantly within each region of the face with aging ($p < 0.001$). The rate of increasing asymmetry was significantly higher in the middle and lower thirds when compared to the upper third. This finding suggests that middle and lower facial features contribute more to overall asymmetry over time, which is consistent with the literature.[3,4,9] One theory suggests that a higher degree of asymmetry in the lower face is caused by longer mandibular growth periods and the relative increased mobility of the area compared with the upper face and midface.[3]
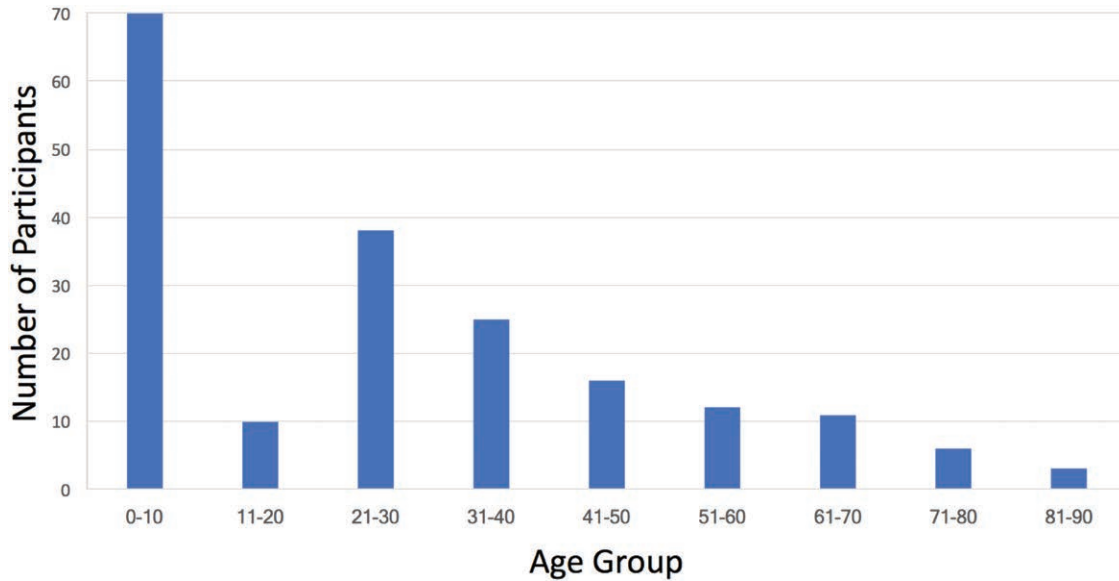

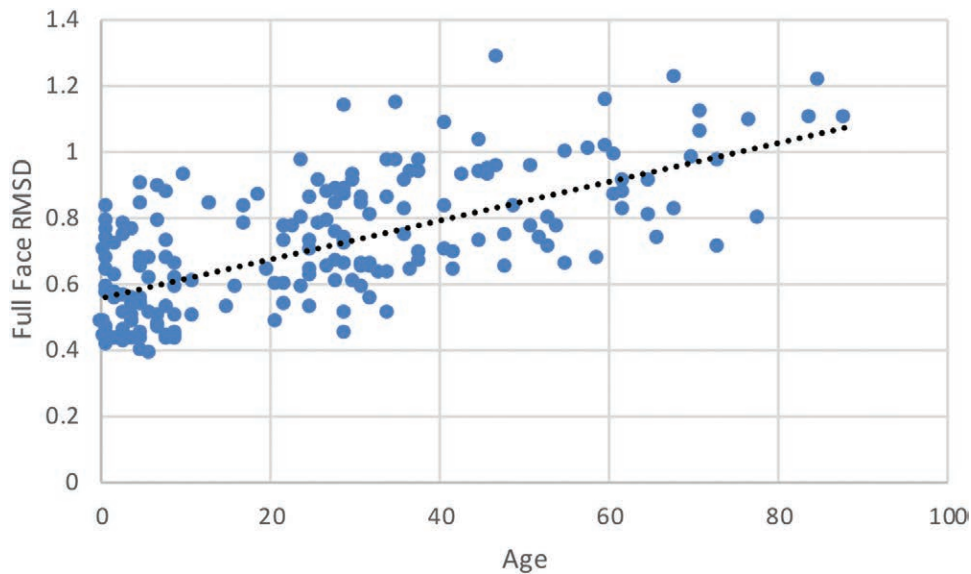**Fig. 2.** Histogram of patient ages by decade.

Fig. 3. Relationship between age and full face symmetry. Facial asymmetry plotted against age demonstrates a positive linear relationship. *RMSD*, root-mean-square deviation.

Table 2. Univariate Analyses Comparing Demographic Data to Facial Asymmetry as Measured by Root-Mean-Square Deviation

Characteristic	p^*
Age	<0.0001
Sex	0.44
Race	0.24

*Calculated using simple linear regression for age, the t test for sex, and one-way analysis of variance for ethnicity.

The underlying mechanism of facial aging remains open to debate, and changes in both the hard and soft tissues are thought to contribute. Some theories focus on facial aging primarily relating to an asymmetric descent of soft tissue, whereas others propose that deflation of soft-tissue volume with aging merely exposes inherent underlying asymmetry in the craniofacial skeleton.[21] Coleman and Grover described changes of
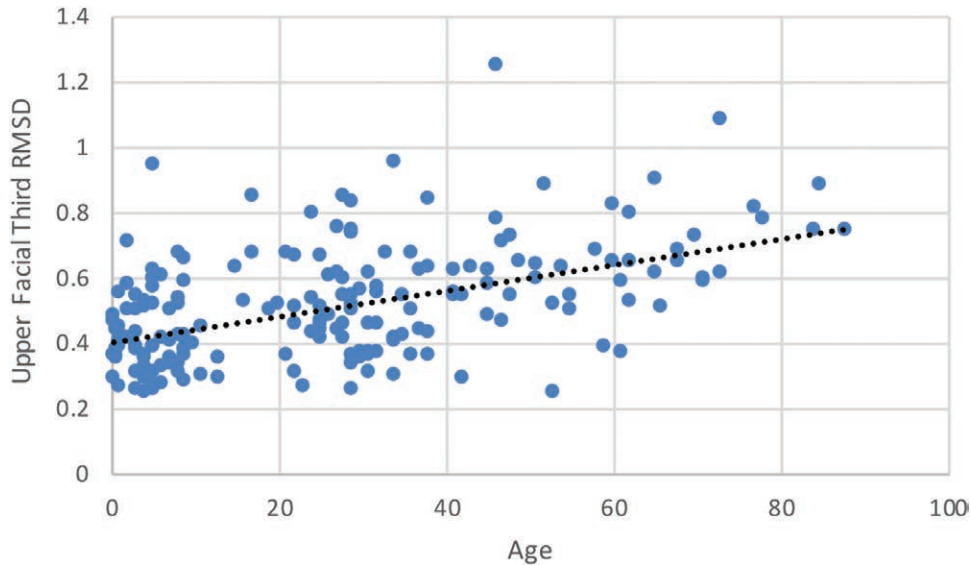

Fig. 4. Relationship between age and upper facial third symmetry. Asymmetry of the upper facial third increases with age, with a mean root-mean-square deviation (*RMSD*) of 0.51 ± 0.17 mm (range, 0.24 to 1.2 mm).
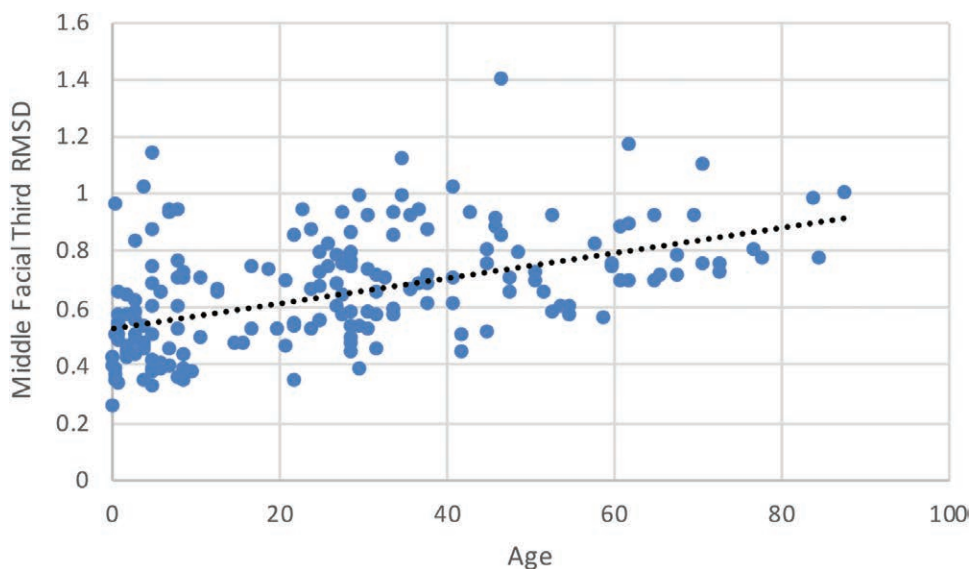

Fig. 5. Relationship between age and middle facial third symmetry. Asymmetry of the middle facial third increases with age, with a mean root-mean-square deviation (*RMSD*) of 0.64 ± 0.20 mm (range, 0.24 to 1.4 mm).
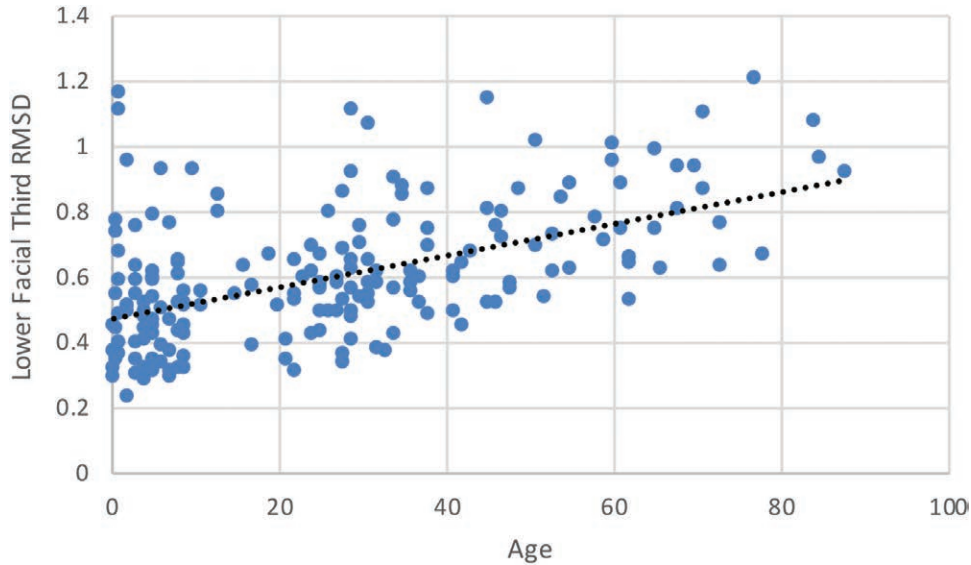
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Fig. 6. Relationship between age and the lower facial third symmetry. Asymmetry of the lower facial third increases with age, with a mean root-mean-square deviation (*RMSD*) of 0.60 ± 0.21 mm (range, 0.23 to 1.2 mm).

Table 3. Comparisons of Differences in Root-Mean-Square Deviations between Facial Thirds

Compared Facial Thirds	p^*	Third with Greater Asymmetry
Top and middle	<0.001	Middle
Top and bottom	<0.001	Bottom
Middle and bottom	0.090	Middle

*Calculated using the *t* test.

facial symmetry generally as the result of the combined effects of gravity, bone resorption, increased tissue rigidity, and redistribution of subcutaneous mass and fullness.[22] It is likely that differences in relaxing skin tension, musculoskeletal changes with stress and aging, and compartmentalized fat changes all contribute.[21,23]

Vleggaar and Fitzgerald suggest that gravity determines the direction of facial reshaping with aging, whereas tissue layers interdependently change, as the decreased craniofacial skeletal support causes the outer layers of soft tissue to descend, fold, and sag.[23] Lambros, however, proposed that losses and gains in tissue volume, rather than pure vertical descent, better described facial aging. Various skin landmarks, including the lid-cheek junction, orbicularis wrinkles, and moles, were found to be stable in position over time and instead became more pronounced.[24] Both of these hypotheses would support replacing the deep support structures with implants or using soft tissue volumizers, especially in the lower two-thirds of the face to improve facial asymmetry and restore youthful proportions.

The work of Rohrich and Pessa, and others, has contributed to clear delineation of facial fat compartments.[25] The compartments undergo changes and metabolism at different rates, thus contributing to asymmetry. In the youthful face, fat is ample and evenly distributed, allowing smooth transitions from one compartment to the next. Facial folds occur at transition points between fat compartments, and as each ages independently, compartments are revealed asymmetrically. Along with redistribution of fat caused by repeated contraction of facial mimetic muscles and craniofacial bony remodeling, these changes contribute to facial aging and therefore asymmetry. These findings support a site-specific approach to facial rejuvenation in terms of the aforementioned procedures.[26] Consistent with this and with our data, Wang et al. reported the area between the cheek bone prominence and the mental tubercle to form the area contributing most to youthful appearance. Volume loss in this area resulted in changes associated with aging, including compartmentalized volume loss, accentuated grooves, and concaved facial contour, and thus could be reversed by targeted volume restoration with autologous fat grafting.[27]

In our study, sex and race independently did not show any significant correlation with facial asymmetry. Although men did have greater average facial asymmetry and change in facial symmetry with age, these differences did not meet significance, which is consistent with the previous

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literature. In a recent study that focused specifically on adolescents, Djordjevic et al. found no significant difference in symmetry between facial thirds when controlling for sex.[2,21] Another study by Ferrario et al. also reported no age- or gender-related differences in facial symmetry, with a population limited to white subjects and an age range of 12 to 56 years.[28] The relationship between age and asymmetry may also begin to clarify the impact of social and environmental stressors on a person's health. Although this still needs further exploration, one study has found that fluctuating facial asymmetry in men aged 79 to 83 years has been found to be associated with cognitive decline.[29]

Limitations of our study include sample size, image quality of complex surfaces, and the one-time measurements of symmetry in a cohort. A larger sample size can help to further support the correlation between age and asymmetry. The ability of cameras to capture details of the face is constantly improving, and enhanced image quality may help better describe differences in asymmetry between specific regions of the face. A longitudinal study could identify specific factors in a given individual that contribute most to asymmetry.

CONCLUSIONS

Ultimately, we hope to contribute to a better understanding of how asymmetry evolves with time and use these data to improve outcomes in both reconstructive and aesthetic surgery. Future work will include following specific individuals over time to observe changes in facial symmetry, analysis of the effects of skeletal asymmetry on the soft tissue, and continued identification of factors contributing to asymmetry from both anatomical and physiologic standpoints.

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PATIENT CONSENT

Patient provided written consent for the use of patient's images.

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