A 10-year longitudinal evaluation was performed of the morphology of soft tissue facial profiles of 14 healthy adults (8 female and 6 male; mean age at the second evaluation, 34 years). Standardized left-side photographs were taken of each subject, and facial profiles were traced between trichion and cervical point. The line joining the 2 landmarks was set as the baseline, and each outline was automatically digitized and mathematically reconstructed by a 20-harmonic elliptic Fourier series expansion. Shape modifications were quantified by calculating the morphologic distance between the Fourier reconstruction of each facial profile in the 2 examinations. The area enclosed in each facial outline was automatically computed, and the difference between the soft tissue areas obtained in the 2 examinations was calculated. On average, significant longitudinal differences were found in both men and women for shape differences (P < 0.05), while size variations were significant only in men. While the 10-year increase in size was significantly (P < 0.01) larger in men than in women, no sex-related differences were found for shape modifications. Between the third and the fourth decades of life, both men and women experience some modifications in their facial soft tissues. While shape changes in both sexes, size changes are particularly evident in men and less manifest in women, who show greater variability in the amount of change that takes place. 

(Craniofacial hard and soft tissues modify their dimensions, shape, and arrangement even after biologic maturity is reached.\(^1\)\(^3\)\(^\)\(^4\)\(^\)\(^,\)\(^5\) Often the modifications induced by actual "aging" cannot be completely distinguished from those produced by growth and development.\(^6\)\(^\)\(^,\)\(^7\) The third decade of life is often seen as a period that is free from detectable modifications in facial morphology; the typical "adult" appearance has been established (in the late teens, sometimes earlier in females than in males).\(^1\)\(^8\) and aging has not yet begun. However, facial and oral structures undergo continuous modification. As expected, the changes occur at a slower rate than that seen during the first 2 decades of life.\(^3\)\(^-\)\(^7\) In particular, facial dimensions continue to increase even after young adulthood. For instance, in a longitudinal study, Gualdi-Russo\(^8\) found that in subjects between 21 and 60 years of age, some facial dimensions (bizygomatic diameter, facial height, nose length, ear length) increased significantly over a 10-year interval. Age-related differences were more significant in men than in women. Longitudinal growth changes in soft and hard tissue facial profiles measured by Formby et al\(^1\)\(^9\) between 18 and 42 years of age were also greater in men than in women. Similar age-related changes in cross-sectional facial and ear dimensions were reported by Ferrario et al.\(^7\)
Ten years ago, the authors analyzed a group of healthy young adults in their twenties. Among other assessments, a quantitative analysis of their soft tissue facial profiles was performed. The study focused on the shape (size-independent) characteristics of the profiles as quantified by Fourier analysis, a method that allows mathematical evaluation of complex biologic forms. Recently, a group of these subjects returned to our laboratory for a longitudinal evaluation. The present report examined the quantitative modifications in the morphology of their soft tissue facial profiles after a 10-year span.

### Materials and methods

#### Sample

In 1989, a group of 45 men and 38 women, all Caucasians aged 20 to 27 years with sound dentitions, was analyzed in our laboratory. Those with a previous history of craniofacial trauma, congenital anomalies, surgery, or orthodontics were not included in the sample. Ten years later, the subjects were recalled for a longitudinal evaluation. Of the respondents, 8 women and 6 men who still met the inclusion criteria and who still had a sound dentition were
analyzed (Table 1). On average, women were older than men \((P < 0.023)\), as assessed by Student’s \(t\) test for independent samples.

All assessments were noninvasive and performed with procedures currently not known to involve any present or future biologic damage. For both data collections, subjects were informed about all the adopted procedures and gave their consent to the investigation. The study protocol was approved by the local ethics committee.

Data collection

For both data collections, a standardized procedure described by Ferrario et al\(^\text{[9,10]}\) was followed. In brief, left-side photographs were taken while the subjects stood 2.5 m away from the camera and looked straight ahead. Each subject was asked to assume and maintain a natural head and body position. The camera was mounted on a tripod and leveled, with the optical axis of the lens horizontal and the film plane vertical. The films were developed and printed with a final magnification fixed at \(\times 0.62\).

To reduce measurement error, all facial profiles (both the first [10 years ago] and the second [current] evaluations) were traced and digitized by a single operator as follows. Facial profiles were traced between 2 standardized landmarks: trichion\(^\text{17}\) and cervical point (the junction between the neck and the throat).\(^\text{18,19}\) The line joining the 2 landmarks was set as the baseline (Figs 1a and 1b). The tracings were then digitized using a scanner interfaced to a personal computer, and the facial outline was obtained by means of a computerized program (Morphological Analyzer, CUBE srl).\(^\text{14,16}\) For each outline, the \(x\) and \(y\) coordinates of approximately 250 points were obtained, with the \(y\)-axis coinciding with baseline.

**Fourier analysis of facial profiles**

For each facial profile, the \(x,y\) coordinates of the points were encoded with a numeric code (or chain code), which provided a description of the profile and allowed the calculation of the relevant elliptic Fourier coefficients.\(^\text{12,20}\) The elliptic Fourier series expansions for the \(x\) and \(y\) projections of the contour are defined as:

\[
x(t) = A_0 + \sum_{n=1}^{20} a_n \cos \left(\frac{2\pi nt}{T}\right) + b_n \sin \left(\frac{2\pi nt}{T}\right)
\]

\[
y(t) = C_0 + \sum_{n=1}^{20} c_n \cos \left(\frac{2\pi nt}{T}\right) + d_n \sin \left(\frac{2\pi nt}{T}\right)
\]

where \(A_0\) and \(C_0\) are the coordinates of the harmonic centroid; \(a_n, b_n, c_n, d_n\) are the 4 coefficients of the \(n\)th elliptic harmonic; and \(0 < t < T\), where \(T\) is the basic period of the chain code.\(^\text{20}\)

The elliptic Fourier series were normalized with respect to the rotation, translation, and size of the contour. Standardization for rotation was performed by aligning the semimajor axis of the first harmonic on the abscissa; for translation by ignoring the \(A_0\) and \(C_0\) terms; and for size by dividing each coefficient by the magnitude of the first semimajor axis.\(^\text{20}\) Fourier series were truncated at the twentieth harmonic, because the higher-degree coefficients and relevant amplitudes were negligible (Fig 2).
Shape analysis. A “morphologic distance” (MD), i.e., a measurement of differences in shape between each facial profile in the 2 examinations, was computed using the Fourier coefficients calculated for each outline (all 4 a, b, c, d coefficients of the first 20 elliptic harmonics). The MD measures the Euclidean distance in a 20-dimensional space (the first 20 harmonics) between 2 plots characterized by their Fourier coefficients, which are used similar to Cartesian coordinates in standard metric measurements. The MD equals 0 when the profiles are identical and when they have been sampled with the same lattice coarseness and orientation. For easier reading, all MDs were multiplied by 100. The MD quantifies the difference between 2 outlines (in the present investigation, between the 2 profiles obtained 10 years apart) with a single, comprehensive number that incorporates all the morphologic characteristics of the analyzed structures.

Size analysis. Before size standardization, the area enclosed in each facial outline (between the soft tissue profile and the baseline; Fig 1) was computed automatically. For each subject, the difference between the soft tissue areas calculated in the 2 examinations was computed.

Statistical calculations

Descriptive statistics of the shape (MD) and size (differential area) indices calculated between the 2 examinations were computed separately for men and women. The significance of the longitudinal modifications was assessed by paired Student’s t tests, while the significance of sex-related differences was quantified with Student’s t tests for independent samples. In all cases, 2-tailed tests were used, with a level of significance set at 5%.

Results

All the facial profiles used for the present study were reconstructed well by elliptic Fourier series, and in all cases, the 20-harmonic truncation produced outlines that were easily superimposed on the original tracings. Table 1 reports the results of the size (area) and shape (MD) analysis of the 10-year longitudinal modifications in soft tissue profiles. Overall, size variations in women were very variable, ranging from ± 1.7 mm² (no appreciable changes, F-BL, F-OM, and F-GC) to 9.1 mm² (F-CL). More homogeneity was found for size variations in men, all of whom experienced an increase in soft tissue profile area.

On average, significant longitudinal differences (P < 0.05) were found in both men and women for shape, while size variations were significant only in men. Indeed, while the 10-year increase in size was significantly (P < 0.01) larger in men than in women, no sex-related differences were found for the modification in shape.

Discussion

Currently, one of the main components of the clinical analysis of patients with facial alterations and deformities, as well as of treatment planning and the final evaluation of results, is the quantitative
assessment of the dimensions, reciprocal spatial positions, and relative proportions of the facial soft tissue structures (eyes, nose, lips, chin, ears). In contemporary Western society, the number of older persons is increasing along with a demand for health care that was previously typical only of younger people. Some of these requests involve the face and are mainly cosmetic, where the surgeon is asked to correct the facial modifications typical of aging, thus reproducing a younger appearance. A deeper understanding of the aging process may suggest better surgical and medical techniques. The definition of quantitative models of facial growth, development, and aging is therefore an essential step toward this goal.

Evaluations of facial morphology can currently be performed in all 3 spatial dimensions, and technology supplies several instruments for the quantitative analysis of soft tissues. Unfortunately, this technology was not yet available 10 years ago. Moreover in orthodontics, facial profiles are still evaluated on 2-dimensional reproductions (radiographs and photographs). In the present study, therefore, the same kind of protocol (standardized photographs) used 10 years ago was followed.

Published longitudinal evaluations of the modifications in facial soft tissues between the second and the third decade of life are scarce and report mainly assessments of size variations. Gualdi-Russo performed a direct anthropometric study of 30 men and 22 women, who were measured twice: once between 21 and 30 years of age and again 10 years later. On average, in men significant increases were found for both facial and nose heights, while in women the changes did not reach statistical significance. Formby et al conducted a longitudinal study of the facial profiles of 24 men and 23 women, who were radiographed between 18 and 42 years of life. Highly significant increases in nose height, length, and depth, as well as in soft tissue thickness at the lips and pogonion, were found in men. Differences in women were less evident. No formal shape analysis was performed, but all angular measurements (an approximate assessment of facial shape) yielded non-significant variations.

Age-related modifications in facial morphology involve both size and shape, and an accurate assessment should separate these 2 components of form, because they mutually interact and size variations can mask shape modifications. While Euclidean measurements (distances, areas, volumes) sufficiently evaluate the dimensions (size) of craniofacial components, facial profile is a complex shape that cannot be reduced to Euclidean geometry and accurately described by conventional metric measurements. More precise analyses of the shape of biologic structures can be performed by Fourier series. This method mathematically describes the outline of objects and can quantitatively analyze their global shape characteristics, independent of their size, spatial orientation, or relationship to reference planes. Both classic Fourier series and elliptic Fourier analysis have already been successfully applied to the quantitative study of biologic forms in dentistry, as recently reviewed by Ferrario et al.

In the first investigation of the present subjects 10 years ago, the shape of facial profiles was reconstructed by using classic Fourier series. In the present study, both series of profiles were quantified by elliptic Fourier analysis, which is currently considered more suitable for the analysis of human forms. In brief, elliptic series allow an internal (self-consistent) orientation of structures for comparison: each form is rotated until the major axes of the first harmonic ellipses coincide. Such an internal orientation cannot be performed by classic Fourier analysis.

In the present study, significant longitudinal increases in the size of soft tissues were found in men only, while in women they did not reach statistical significance (P = 0.059, ie, not significant). It must be mentioned that the within-group variation was larger in women than in men. Moreover, the mean size variation was significantly larger in men than in women...
Childbearing has been reported as a factor influencing changes in women, but no relationship between the number of children born in the 10-year follow-up period and size variations was found. For instance, the 2 largest increases in size were found in a woman who had no children (F-CL, 9.1 mm²) and in a woman who had 2 children (F-DC, 8.7 mm²). Subject F-BL gave birth to 3 children, and her variations in size were negligible (0.3 mm²). In men, differences in facial size may depend on the landmarks selected for the quantitative analysis of soft tissue profile. In particular, hair distribution (and therefore the landmark trichion) is highly influenced by sex hormones, with a progressive loss of hair after the third decade of life. In both sexes, differences in facial shape were significantly different from 0 (the alternative statistical hypothesis: same facial shape in both examinations), and the changes that occurred were similar in both sexes. Unfortunately, no literature comparisons can be performed for this component of facial form. It should be mentioned that the women in the present sample were significantly older than the men (Table 1), but this factor does not appear to be very influential in a longitudinal analysis.

Conclusions

Between the third and fourth decades of life, both men and women experience some modifications in their facial soft tissues. While facial shape changes in both sexes, size increases are particularly evident in men and less manifest in women, who also show greater variability. However, the present sample was very small, and further investigations should assess a larger number of normal individuals of both sexes.

Acknowledgments

This study was made possible only by the kind collaboration of all the investigated women and men.

References


