

The role of the golden proportion in the evaluation of facial esthetics

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ABSTRACT

Objective: To demonstrate if one or more golden relationships between different measurements of the human face exist.

Materials and Methods: To make our measurements, we used three-dimensional (3D) stereophotogrammetry, which has proved to be the “gold standard” in the field of facial anthropometry. We obtained 3D stereophotogrammetric facial acquisitions of 400 healthy young adult subjects, then had them scored by an Evaluation Jury. Each subject received an esthetic evaluation ranging from 0 to 40. Individuals with a score larger than 28 were considered *very attractive* (VA), and individuals with a score lower than 12 were considered *not attractive* (NA). Fifteen subjects per group were chosen by chance, with a final total group of 60 subjects: 15 VA males, 15 NA males, 15 VA females, and 15 NA females. For each subject, a set of facial distances was obtained from the stereophotogrammetric facial reconstruction, and 10 ratios were computed. The effects of sex and attractiveness were tested by analysis of variance. Additionally, Student's *t*-tests verified if the ratios were statistically different from the golden ratio.

Results: For nine ratios, no significant effects of sex or attractiveness were found. Only the eye-mouth distance/height of the mandible ratio was significantly influenced by sex ($P = .035$) and attractiveness ($P = .032$). Seven out of 10 ratios were statistically different from the hypothetical value of 1.618, and only three of them were similar to the golden ratio.

Conclusions: Ratios between 3D facial distances were not related to attractiveness. Most of the facial ratios were different from the golden ratio. (*Angle Orthod.* 2013;83:801–808.)

KEY WORDS: Face; 3D; Esthetics

INTRODUCTION

The attempt to reduce to a mathematical formula, to simplify proportions through geometric concepts of absolute beauty and balance of forms, is as old as human civilization itself. The so-called “esthetic canons” have always been sought after, theorized, tested, applied, discussed, and again rejected within each discipline of knowledge.

The human body has been the crossroads of many points of view regarding the proportions of its different parts, arousing the interest of anatomists, scientists, and dentists, but also of artists and esthetes. The face, in particular, is the most expressive part of the human body, responsible for visual evaluation and recognition.^{1,2}

In 1509 Luca Pacioli published, in his “De Divina Proportione,” illustrated by Leonardo da Vinci, the first canons on the proportions of the face, making extensive reference to the golden section as an example of harmony and balance between the different parts.³

As theorized by the classical Greek scientists and artists, the golden section, ie, the size ratio between

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two quantities for which the largest stays at the smallest as the sum of both stays at the largest, has been applied in several fields, including architecture and art.³ Even the analysis of several natural structures, belonging to the mineral and vegetable world, has shown that this ratio has been applied by Nature herself even before Man.

In medical literature, several studies have focused on establishing whether there were mathematical relationships, in particular golden proportions, between different measurements of the human body and face.^{3,4}

These investigations were made using tools that require physical contact (eg, calipers) or using two-dimensional photographs and radiographs. The results are variable, depending on the applied method and the analyzed sample, but generally show a weak correlation between attractiveness and golden proportions.^{3,5-9}

In particular, faces considered attractive should possess a general harmony among the various measurements, with ratios approaching the golden proportions. Indeed, esthetic criteria have been defined in almost all cultures,² but the actual existence of codified facial ratios in attractive subjects is still a matter of debate. Scientific studies on the quantitative bases of human facial attractiveness are, therefore, still in progress.²

The purpose of the current investigation is to demonstrate if one or more golden relationships between different measurements of the human face exist. To make our measurements, we will use three-dimensional (3D) stereophotogrammetry, which has proved to be the "gold standard" in the field of facial anthropometry.^{10,11} We will further investigate if the golden ratio is differently represented in subjects considered to be more harmonious, proportionate, and, therefore, more attractive, than in those judged to be less so.

MATERIALS AND METHODS

Sample Selection

The sample used for this study was taken from a population of approximately 600 subjects who underwent a stereophotogrammetric acquisition during the last 2 years in our laboratory. The procedure is not invasive and not dangerous, and it does not provoke pain or discomfort in the subjects.¹² A written, informed consent was obtained from all subjects, and all images were analyzed in accordance with current Italian law about personal data and privacy. Institutional Review Board approval was obtained.

A first selection was made according to the following inclusion criteria:

- Age between 19 and 35 years
- White origin
- No current or previous facial surgical treatments

- No previous facial trauma compromising its symmetry or proportions
- No orthodontic treatments in progress
- Presence of all anterior teeth from premolar to premolar, both superiorly and inferiorly
- Absence of beard and moustache for male subjects, which affects the stereophotogrammetric acquisition.

A group of 400 subjects was obtained. A second selection was made by an Evaluation Jury, which brought the sample to 60 subjects: 30 males and 30 females.¹³

Evaluation Jury

To select, within the available population, subjects with a greater or lesser facial esthetic attractiveness, a jury of four persons—two dentists and two pregraduate students (one man and one woman for each category)—was used.

Each judge assigned an esthetic judgment to each of the 400 subjects using a visual analogue scale that ranged from 0 to 10, corresponding to the level of esthetic attractiveness of the face (0, not at all attractive face; 10, very attractive face).^{3,11,14} Each subject received an esthetic evaluation ranging from 0 to 40 (10 degrees of evaluation \times four judges). Individuals with score ≥ 28 were considered *very attractive* (VA) and individuals with a score ≤ 12 were considered *not attractive* (NA). In order to make numerically homogeneous groups, 15 subjects per group were chosen by chance, with a final total group of 60 subjects: 15 VA males, 15 NA males, 15 VA females, and 15 NA females.

Acquisition of Three-Dimensional Facial Images

For each subject, soft issue facial morphology was acquired using a three-dimensional stereophotogrammetry imaging system (Vectra-3D; Canfield Scientific Inc, Fairfield, NJ). The system consists of two pods, each including three cameras (two black and white, one color) and a projector. After a three-dimensional metric calibration, the system records synchronized pairs of two-dimensional images of the subjects. Using dedicated software, three-dimensional facial reconstructions are obtained. The images can subsequently be processed, analyzed, manipulated, and measured. The reproducibility of stereophotogrammetric technology is well documented.^{11,12,15,16}

Before each acquisition, a set of 50 soft tissue landmarks were marked on the face with black liquid eye liner for further analysis.¹⁵ Marking the face before the acquisition allows for capturing the position of landmarks that need palpation, whose acquisition on a digital surface is questionable.

Among the standard 50 landmarks, a subset of 14 landmarks was selected (Figure 1), and 13 facial distances were obtained. The landmarks were chosen in accord with previous investigations dealing with facial attractiveness.^{7,11}

Besides the traditional landmarks, used to obtain the vertical measurements on the face (Tr, N, Sn, St, Me), we also chose landmarks for horizontal measurements (FTr, FTl), for the position of the eyes (Oc), and for the proportions of the nose (Alr-All) and mouth (Chl-Chr).

All landmarks except Oc (Oculare) were defined according to Farkas.¹⁷ Oc, deriving more from the artistic than from the scientific world, was located at the intersection of the bipupillar line with the sagittal axis of the head, with the subject in natural head position.¹⁴

Data Analysis

Using the three-dimensional coordinates of the 14 landmarks, for each subject the following measurements (unit: mm) were made: Tr-Me, physiognomical height of the face; Tr-Sn, height of the upper face; N-Me, morphological height of the face; Sn-Me, height of the lower face; St-Me, height of the mandible; N-Sn,

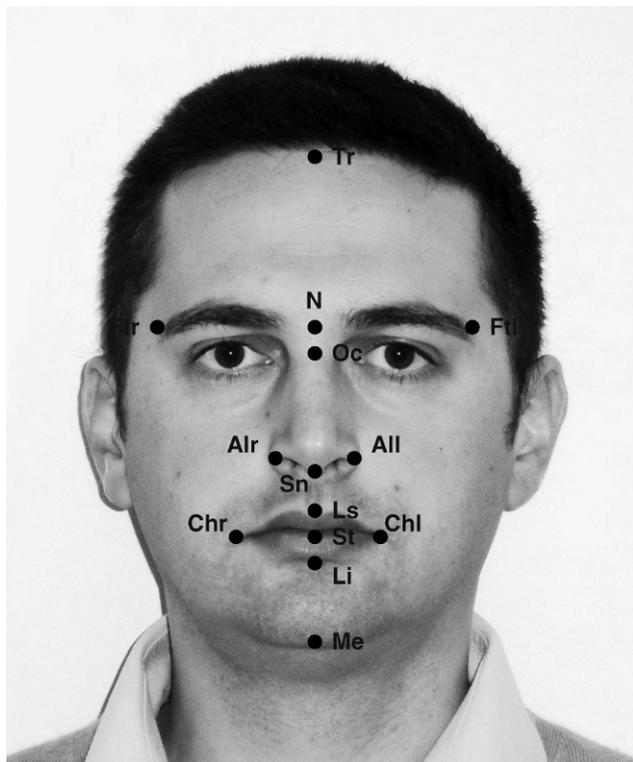


Figure 1. The landmarks considered in this study. On the midline: Tr indicates Trichion; N, Nasion; Oc, Oculare; Sn, Subnasale; Ls, Labialis Superior; St, Stomion; Li, Labialis Inferior; Me, Menton. Paired, right and left: Ft indicates Frontotemporale; Al, Alare; Ch, Cheilion.

nose height; Ftr-Ftl, forehead width; Tr-Oc, forehead-eye distance; Oc-Me, eye-chin distance; Oc-St, eye-mouth distance; Alr-All, nose width; St-Ch, hemi-mouth width; Ls-Li, mouth height.¹⁷ Subsequently, 10 ratios (seven parallel, three rectangular) were obtained from these distances (Table 1).

Descriptive statistics (mean and standard deviation) were obtained separately for sex and for attractiveness group (VA or NA). The influence of the factors *sex* and *attractiveness* was analyzed on the 10 ratios using two-way factorial analyses of variance. Additionally, we tested if the mean ratios obtained in the VA and NA groups, pooled for sex, were statistically different from the golden ratio 1.618, using a Student's *t*-test for paired samples.

Normality of data and homoscedasticity of the variances were tested for all 10 ratios; in all occasions, the hypotheses were respected. All tests were made using the Minitab software (Minitab Inc, State College, PA). For all analyses, $P \leq .05$ was considered significant.

RESULTS

Table 2 reports the mean values of the 10 ratios computed in the four groups. For all ratios, the analyses of variance found no significant effects of sex or attractiveness, or of their interaction (Table 3). Only ratio 8 (R8; eye-mouth distance/height of the mandible) was marginally significant ($P = .052$ for the factor *sex*). At a closer analysis, three outliers were found: 1.91, 2.46, and 1.73, compared to an average value of 1.40. These three outliers were omitted, and the analysis rerun, obtaining two significant F values for the main factors.

The visualization of the obtained data in a radar chart may help, although at a glance, to note the substantial overlap between the more and less attractive subjects separately for each sex (Figures 2 and 3).

To assess if the mean values of the 10 ratios were similar to the golden ratio 1.618, a *t*-test for paired samples was performed. Considering the results of the analyses of variance, we pooled all the subjects for ratios R1–R7, R9, and R10, while data for R8 were analyzed separately for VA and NA males and females. Seven out of 10 ratios (considering that the four R8 ratios had similar results) were statistically different from the hypothetical value of 1.618, and only three of them were similar to the golden ratio (Table 4). No relationship between the kind of ratio (rectangular or parallel) and its similarity to the golden ratio was observed.

DISCUSSION

Most of the previous studies about facial attractiveness were performed using two-dimensional photographs,^{3,18}

Table 1. Ratios analysed in the current study.

| Numerator | Denominator | | | | | | | |
|---|---------------------------------------|---|--|-------------------------------------|-------------------------------|---------------------------|------------------------------------|---------------------------|
| | Tr-Sn: height of the upper face | N-Me: morphological height of the face | Sn-Me: height of the lower face | St-Me: height of the mandible | Ftr-Ftl: forehead width | Alr-All: nose width | Tr-Oc: forehead-eye distance | St-Ch: mouth height |
| Tr-Me: Physiognomical height of the face | R1 | R2 | | | R6§ | | | |
| Tr-Sn: Height of the upper face | | | R3 | | | | | |
| Sn-Me: Height of the lower face | | | | R4 | | | | |
| N-Sn: Nose height | | | | R5 | | R9§ | | |
| Oc-Me: Eye-chin distance | | | | | | | R7 | |
| Oc-St: Eye-mouth distance | | | | R8 | | | | |
| Ls-Li: Hemi-mouth width | | | | | | | | R10§ |

§ denotes a rectangular ratio

Table 2. Descriptive Statistics of the 10 Ratios Computed in the Four Groups^a

| | Females | | | | Males | | | |
|-----|-----------------|------|----------------|------|-----------------|------|----------------|------|
| | Very Attractive | | Not Attractive | | Very Attractive | | Not Attractive | |
| | Mean | SD | Mean | SD | Mean | SD | Mean | SD |
| R1 | 1.53 | 0.05 | 1.57 | 0.06 | 1.57 | 0.05 | 1.56 | 0.06 |
| R2 | 1.52 | 0.07 | 1.47 | 0.04 | 1.47 | 0.06 | 1.52 | 0.07 |
| R3 | 1.79 | 0.15 | 1.63 | 0.14 | 1.61 | 0.12 | 1.65 | 0.18 |
| R4 | 1.44 | 0.10 | 1.45 | 0.06 | 1.43 | 0.05 | 1.42 | 0.08 |
| R5 | 1.17 | 0.09 | 1.14 | 0.12 | 1.09 | 0.13 | 1.07 | 0.18 |
| R6 | 1.53 | 0.08 | 1.58 | 0.13 | 1.57 | 0.11 | 1.63 | 0.12 |
| R7 | 1.57 | 0.18 | 1.66 | 0.18 | 1.72 | 0.20 | 1.63 | 0.15 |
| R8 | 1.46 | 0.15 | 1.37 | 0.15 | 1.36 | 0.12 | 1.33 | 0.16 |
| R9 | 1.66 | 0.19 | 1.64 | 0.20 | 1.59 | 0.15 | 1.60 | 0.28 |
| R10 | 1.69 | 0.33 | 1.55 | 0.24 | 1.68 | 0.24 | 1.65 | 0.43 |

^a SD indicates standard deviation; for descriptions of ratios R1–R10, see Table 1.

Table 3. Two-way Factorial Analysis of Variance, Effects of Sex and Attractiveness on Facial Ratios^a

| | Sex | Attractiveness | Sex × Attractiveness |
|------------------------|--------------|----------------|----------------------|
| R1 | 1.71 (.197) | 0.34 (.56) | 1.26 (.266) |
| R2 | 0.06 (.805) | 0.01 (.938) | 3.16 (.081) |
| R3 | 3.33 (.073) | 0.88 (.352) | 2.32 (.133) |
| R4 | 0.49 (.488) | 0.00 (.986) | 0.13 (.717) |
| R5 | 3.28 (.075) | 0.40 (.529) | 0.02 (.880) |
| R6 | 0.86 (.358) | 3.06 (.086) | 0.77 (.385) |
| R7 | 0.87 (.354) | 0.79 (.377) | 0.59 (.447) |
| R8 | 3.96 (.052) | 0.31 (.582) | 0.01 (.939) |
| R8' – outliers removed | 4.66 (.035)* | 4.84 (.032)* | 0.01 (.923) |
| R9 | 1.94 (.169) | 0.07 (.791) | 0.01 (.930) |
| R10 | 0.02 (.891) | 0.34 (.560) | 0.47 (.494) |

^a Data represent $F_{1,56}$ (P) for all factors and interactions except R8', which are represented by $F_{1,53}$ (P) for all occasions. For descriptions of ratios R1–R10, see Table 1.

* Denotes significance at $P < .05$.

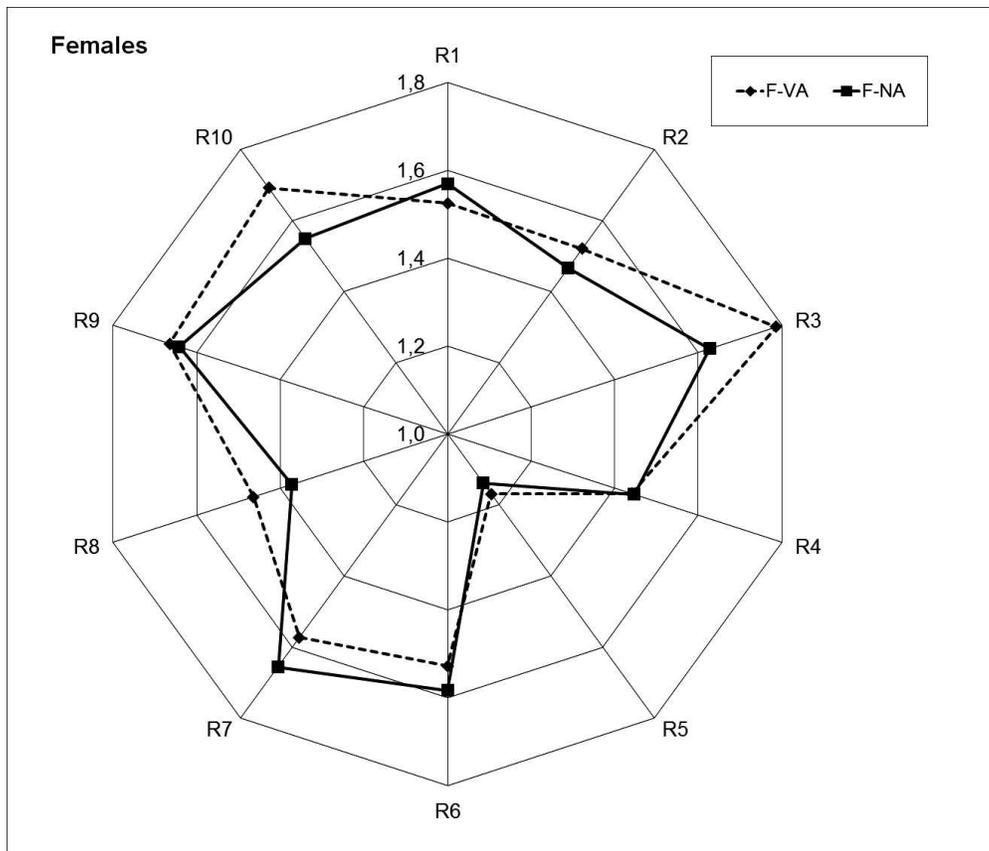


Figure 2. Mean values of the 10 analyzed ratios in VA and NA females.

x-rays,¹⁹ or direct anthropometry.⁸ The majority of these investigations found a weak correlation between facial characteristics and attractiveness that varies depending on the examined distances and ratios, the chosen facial view (ie, front or side), and the analyzed sample.^{2,19} In contrast, the technique used in the present study is three-dimensional and allows for the calculation of the distances between two facial landmarks, taking into account their natural position on different planes.¹¹

Three-dimensional analysis of facial morphology in more or less attractive subjects has been done in previous studies.^{20–22} The authors analyzed different facial features (distances, angles, volumes, areas, and ratios), defining some characteristics of facial attractiveness typical for age and sex. Among the others, a large forehead, a wide face (especially in the middle third), a small nose, a large mouth, and a flat profile are the main facial characteristics that seem to be correlated with a better esthetic perception. In no case has the relationship between facial ratios and the golden ratio been investigated in three dimensions.

The results of the current investigation show that neither sex nor the degrees of attractiveness of the face have any relationship with the examined facial ratios, at least for a jury of dental professionals.¹¹ The

only significant values, shown by ratio R8, emerged only after the elimination of outliers, and moreover were fairly weak.

The obtained results are thus substantially in accordance with a good part of the previous literature. Less categorical, but still aligned, are the results of Mommaerts and Moerenhout,²³ who reported that the ratio between the lower third and the total height of the face was 45% in women and 48% in men, similar to the 50% found in the faces of the statues of classical antiquity.

Similar conclusions were obtained in the orthodontic field, where in addition to the relationship between distances, some angles were investigated. In a group of adolescents, Kiekens et al.^{7,14} found a low relationship between two-dimensional ratios and angles, and facial esthetics. Figures 2 and 3 show that the mean values of several facial ratios are actually close to the golden ratio, although the statistical tests found that only three of them were truly “golden” (R7, R9, and R10). Almost unexpectedly, two of these ratios are not relative to the whole face, but involve two substructures: R9 is the relationship between nasal height and width, and R10 is the ratio between the height and the width of the hemi-mouth. From two structures, one

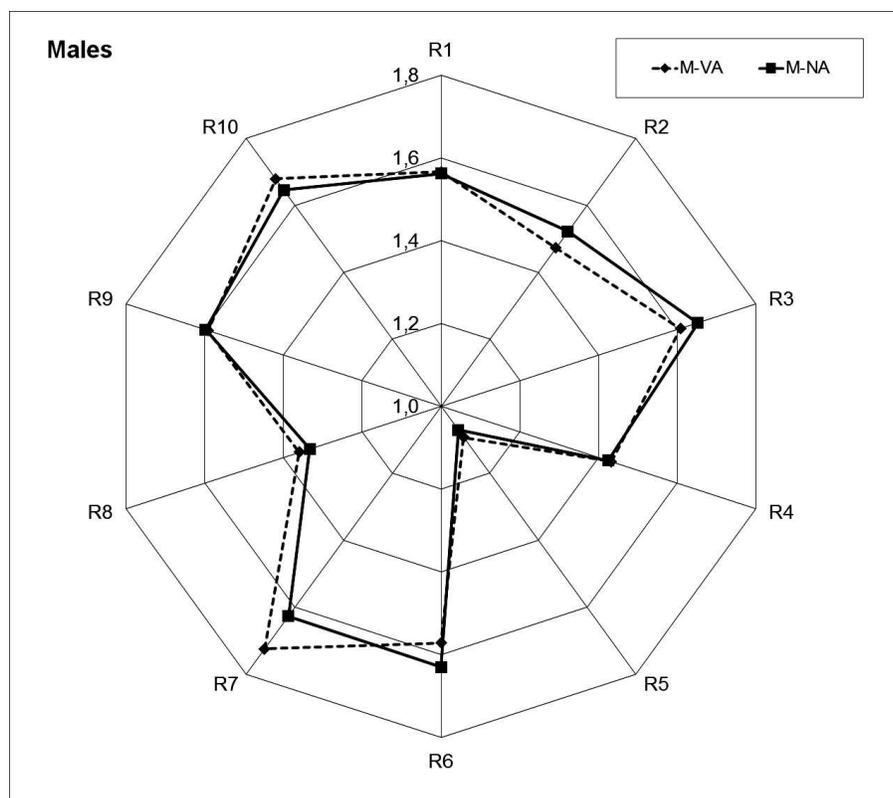


Figure 3. Mean values of the 10 analyzed ratios in VA and NA males.

substantially cartilaginous (nose) and the other consisting of only soft tissues (mouth), one would expect the highest variability in the intersubjects ratios. On the contrary, they appear to maintain the same proportions, better than other hard tissue indicators. On this point literature is not unanimous, especially because nasal and mouth morphology are dependent on many ethnic variables that should be taken into account.²⁴

Table 4. Student's *t*-Test for Paired Samples, Difference Between Actual Facial Ratios and the Golden Ratio^a

| Variable | <i>P</i> |
|-----------|----------|
| R1 | < .001* |
| R2 | < .001* |
| R3 | < .001* |
| R4 | < .001* |
| R5 | < .001* |
| R6 | .002* |
| R7 | .524 |
| R9 | .579 |
| R10 | .471 |
| R8 – F VA | .002* |
| R8 – F NA | .001* |
| R8 – M VA | .001* |
| R8 – M NA | .003* |

^a F VA indicates very attractive (female); F NA, not attractive (female); M VA, very attractive (male); M NA, not attractive (male). For descriptions of ratios R1–R10, see Table 1.

* Denotes significance at *P* < .05.

The current results, therefore, apply to people of white origin; analyses on other ethnic groups may possibly supply different findings.

The last golden ratio, R7 (eyes-chin distance/forehead-eyes distance) is quite symbolic, since it has historically been represented by both classical and Renaissance art in the world.¹ It is the ratio that, in essence, puts the eye line exactly at a “golden” distance from the forehead and chin. Finding it in a scientific context gives justice to the esthetic and artistic history from which it comes. Unfortunately, we cannot say the same for the remaining ratios, which have only proximity with the golden ratio, but without being statistically significant.

Though it would be fascinating to find a formula, a “perfect proportion,” able to infuse automatically into its possessor the quality of the esthetic appeal, once again we must admit to be very far from having found it. Although the results of the present study do more to undermine rather than support some of these formulas, there are, overall, undoubtedly many aspects of innovation in our investigation.

The use of 3D stereophotogrammetry allowed us to collect a large amount of data: there were 60 subjects sampled in the study, but they were selected from about 600 in the Laboratory database. With a very high filtering from the starting population, we got a highly

representative sample, which could never be obtained easily by other methods.

Indeed, while two-dimensional studies of facial attractiveness commonly use standardized images (printed in full color, of standard size, with frontal or profile views), the use of 3D photographs could be advantageous for several aspects.¹¹ The 3D images give the examiner the freedom to analyze the whole face, with both panoramic views, and the possibility to spin and zoom the image.

Additionally, the method permits the use of surface as well as caliper-type measurements, thus providing a more comprehensive analysis. Furthermore, patient positioning for image capture is less demanding than that for conventional photography, as the image can be oriented on the screen prior to digitization.¹¹

Unlike the previous investigations on the topic, which employed two-dimensional techniques (radiographs and photos), we can now employ these 3D techniques, the reliability of which is comparable to in vivo measurements, resulting at the same time in much easier detection, management, storing, and retrieving of data.^{11,19} Moreover, unlike x-rays, they do not have the problem of ionizing radiation, and the acquisitions are perfectly harmless for the subjects. In the forthcoming years, there will be an increasing use of these techniques, not only in the anthropometric but also in the clinical field.

It is conceivable that, by increasing the parameters considered in this study (eg, number of indicators, number and kind of judges on the jury, the comparison between different ethnic groups, etc), ie, by increasing the power of the test, we may arrive at even more certain conclusions. Stereophotogrammetry makes all of this possible.

CONCLUSIONS

- In the analyzed young, white adults, ratios between 3D facial distances were not related to attractiveness as assessed by a panel of dental professionals. Most of the facial ratios were different from the golden ratio.

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