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Three-Dimensional Anthropometric Database of Attractive Caucasian Women: Standards and Comparisons

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Abstract: The aim of this paper is to develop a database to determine a new biomorphometric standard of attractiveness. Sampling was carried out using noninvasive three-dimensional relief methods to measure the soft tissues of the face. These anthropometric measurements were analyzed to verify the existence of any canons with respect to shape, size, and measurement proportions which proved to be significant with regard to the aesthetics of the face. Finally, the anthropometric parameters obtained were compared with findings described in the international literature.

The study sample was made up competitors in the Miss Italy 2010 and 2009 beauty contest. The three-dimensional (3D) scanning of soft tissue surfaces allowed 3D digital models of the faces and the spatial 3D coordinates of 25 anthropometric landmarks to be obtained and used to calculate linear and angular measurements. A paired Student *t* test for the analysis of the means allowed 3 key questions in the study of biomorphometric parameters of the face to be addressed through comparison with the data available in the literature.

The question of statistical evidence for the samples analyzed being members of the populations samples reported in literature was also addressed.

The critical analysis of the data helped to identify the anthropometric measurements of the upper, middle, and lower thirds of the face, variations in which have a major influence on the attractiveness of the face. These changes involve facial width, height, and depth. Changes in measurements of length, angles, and proportions found in the sample considered were also analyzed.

Key Words: 3D anthropometric measurements, attractiveness, face, photogrammetry, standards

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More and more patients feel the need to undergo surgical, orthodontic, and/or prosthetic treatments, not only for the restoration of good health and function of the cranio-maxillo-facial structures, but also to improve facial aesthetics and quality of life. Therefore for the maxillofacial surgeon, the orthodontist, the prosthetist it is essential to have diagnostic tools that enable them to make more detailed morphological analysis and to compare individual patient's data with updated date base, related to the patient's ethnicity. To respond to these needs, our scientific research work was started in 2010 and involved a team of doctors, orthodontists, and engineers to study the anthropometric measures of attractive young women of the same ethnic group to create a new update data base.

During the diagnostic and monitoring phase of orthodontic treatments[1] and maxillofacial surgery,[2] direct measurements of facial characteristics of the patient are performed. Historically, measurements of craniofacial structures are commonly used by most orthodontists and maxillofacial surgeons. First, specific landmarks are identified and derived from two-dimensional (2D) radiographs;[3] further craniofacial components, including measurements of distances, angles, and proportions are then calculated.[4,5] These measurements allowed us to produce diagnostic methods of analysis and anthropometric classification of craniofacial structures which will be referred to as cephalometric analysis.

Over the last few decades, extensive samples of 2D facial databases which include anthropometric characteristics have been recorded. These different populations have been analyzed on the basis of ethnicity, age, and gender, in both normal subjects[6] and subjects affected by pathological conditions.[7–9]

The advent of three-dimensional (3D) radiographic technologies (CT and cone beam CT) has made it necessary to revise traditional methods of cephalometric analysis and adapt them to 3D information about reference points in space (landmarks), resulting in the need to create new dimensional databases.[10,11]

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Historically, the surfaces of the soft tissues of the face (facial surface anthropometry) have received less attention. The difficulties of identifying and measuring these landmarks and soft tissue deformability are major challenges. Despite these methodological difficulties, over the years there has been an increasing need to be able to measure and analyze these structures accurately and reliably,[12,13] as they are immediately caught and play an important role in the visual impact of the facial aesthetics of the patient.[14]

Few studies[15–19] relating to these topics are reported in the literature prior to 2000.

The need for less invasive diagnostic procedures,[20] combined with the availability of X-ray-free systems with the advent of 3D technologies such as laser scanning, structured light,[21] stereophotogrammetry,[22] and multi-image photogrammetry, has provided researchers and specialists with new, powerful, computerized 3D methods to detect and analyze anthropometric facial features, with a largely positive impact on diagnostics and monitoring of treatments.

A growing number of researchers conduct anthropometric studies on samples of populations that reflect different anthropometric characteristics based on ethnic origin,[23] geographical place of origin,[24–26] age,[27] gender,[28] facial attractiveness,[29] or the presence of certain diseases,[7] to create new anthropometric databases of facial characteristics.

Groups of universities have developed these databases and made them readily available on the Internet.[30,31]

METHODS

Aims of the Study

In this research, specific equipment and a precise investigation protocol previously described by the authors[32,33] were applied to scan and analyze the faces of a sample of young Italian women finalists in a national beauty contest (Miss Italia 2010), referred to in this paper as "attractive 2010," and to compare it with other similar samples found in the literature.

First step: analysis of the 2 main anthropometric facial measurements (height and width).

The first step was to consider the 2 main anthropometric facial measurements (facial height and width) and the relationship between them, to investigate whether a uniform distribution of the sample can be observed by grouping the individuals into classes based on the following variables: facial height (Tr-Sn-Me), facial width (T_l-T_r) and the ratio of these 2 measurements ((Tr-Sn-Me)/(T_l-T_r)).

A further aim of this study was to verify whether statistical evidence of a scale factor relationship between facial height and facial width, based upon the measurements taken within this sample, could be demonstrated.

Second step: comparison with the data available in the literature.

With regard to anthropometric facial parameters, it was necessary to address 3 key questions:

- In studies found in the literature, do the samples analyzed (attractive women) and reference samples ("normal" women) belong—based on statistical evidence—to the same population, or are the differences such as to suggest a population of "attractive" subjects that is different from the population of "normal" subjects?
- Do the Miss Italia 2010 sample (66 women, "attractive 2010") and the "normal" reference samples adopted by other researchers in the literature belong—based on statistical evidence—to the same population, or are the differences such as to suggest that the "attractive 2010" population is different from the populations of "normal" reference samples?

FIGURE 1. Photogrammetric facial scanner and scanned subject.

- Do the sample analyzed in the Miss Italia 2010 contest ("attractive 2010") and the samples of attractive women analyzed by other researchers belong—based on statistical evidence—to the same population, or are the differences such as to suggest that the "attractive 2010" population is different from the populations of "attractive" women in other samples?

Taking of the Sample

A 5-camera photogrammetric facial scanner (Fig. 1) was used, applying the method and the scanning protocol for facial samples described and referenced in (32, 33).

The study sample ("attractive 2010") consisted of 60 contestants and 4 finalists in the Miss Italia 2010 beauty contest, and the first- and second-placed contestants in the Miss Italia 2009 contest. Facial data was acquired using close range stereophotogrammetry following a specific, standardized protocol, described in detail in (33, 34).

Data and Measurement Processing

A single skilled operator identified and marked 25 anatomical landmarks on the faces of all the individuals in the sample. Identification of the landmarks reported in Table 1 and shown in Figure 2 was completed by a direct method based on visual inspection and palpation, with the exception of points Ex_r, Ex_l, En_r, En_l, Ey_r, and Ey_l, which were marked afterward on photographs, and not directly on the face; for each point the precision of the measurement for coordinates x, y, and z and the precision of the vector length for the linear measurements were calculated.

The 3D reconstruction of virtual faces enabled us to conduct our qualitative and quantitative analysis, to measure the surfaces and to

TABLE 1. Landmarks Extracted Using Photogrammetric Elaboration

Points on the Middle Line	Coupled Points
Tr—Trichion	Os—Orbitale superius
G—Glabella	Ft—Frontotemporale
N—Nasion	T—Tragion
Prn—Pronasale	Ac—Nasal alar crest
Sn—Subnasale	Chp—Crista philtri
Ls—Labiale superius	Ch—Cheilion
Sto—Stomion	AGo—Antegonionale
Li—Labiale inferius	
Sl—Sublabiale	
Pg—Pogonion	
Me—Menton	

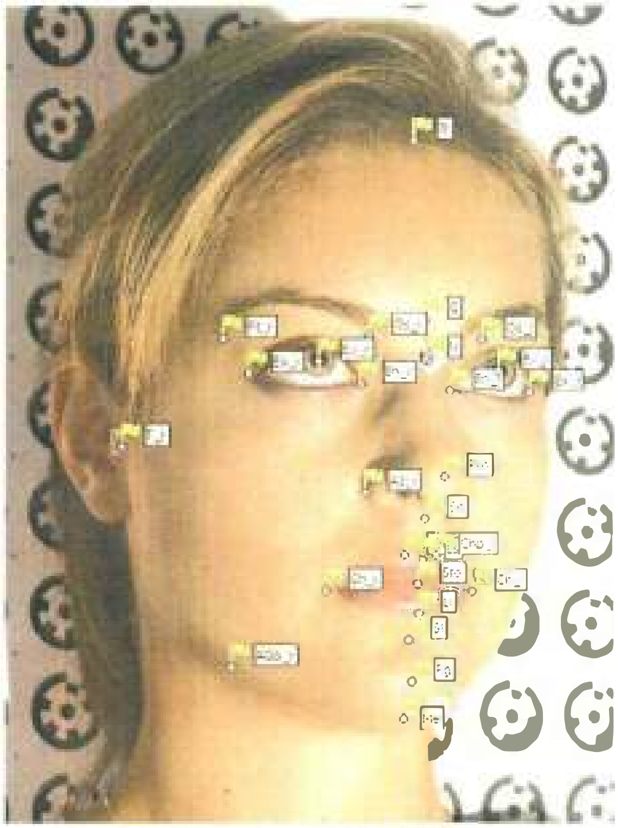

FIGURE 2. Identification of the 25 anatomical landmarks on the faces of the individuals.

extract and calculate all of the important facial anthropometric features.

To assess facial attractiveness, 13 linear and 9 angular measurements were considered, as shown in Table 2.

The paired Student *t* test analysis was used to answer the 3 key questions formulated above to approach the study of biomorphometric facial parameters, by means of comparisons with the data available in the literature (in the literature, samples were reported for each measurement: average, standard deviation, and sample size).

Tables 3–6 report the average, minimum and maximum, and standard deviation for each linear and angular measurement calculated for the sample analyzed here.

RESULTS

From the sample analyzed, 58 linear measurements, 22 angular measurements, 4 linear relationships between measurements and 1 percentage ratio between linear measurements were obtained, a total of 5610 data items, as shown in Tables 3–6.

The minimum linear measurement, 0.14 mm, was the "lower lip to E-line distance" measurement Li-(Prn-Pg); the maximum linear measurement, 140 mm, was the "middle facial width" measurement T_r-T_l. The tables for each linear measurement show the average, minimum and maximum measurement uncertainty (accuracy) values, the standard deviation, and the variation range.

Analysis of this very large amount of data enabled the main anthropometric parameters influencing facial attractiveness of the upper, middle, and lower thirds of the face to be identified. These parameters express variations in the measurements in the 3 spatial planes, and involve facial width, and height. In the sample, changes in measurements of length, angles, and proportions were also analyzed, to verify the existence of any canons with respect to shape, size, and measurement proportions which proved to be significant with regard to the aesthetics of the face.

Measurements between points Ex_r-Ex_l, En_r-En_l, Ey_r-Ey_l, and T_r-T_l show higher uncertainty values among the linear transverse measurements.

With regard to the landmarks T_r and T_l, this problem may be caused principally by 2 factors: they may not be clearly visible due to the scanner being partially masked by the hair, and the anatomical points are classified and recognized only by a pair of cameras, which are located ipsilaterally in relation to the points.

For the landmarks Ex_r-Ex_l, En_r-En_l, Ey_r-Ey_l, the cause of uncertainty may be due to the fact that they were marked on the photographs and not directly on the face.

Analysis of the vertical linear measurements along the midline shows a much smaller uncertainty value (average 0.15, minimum 0.09, maximum 0.21 mm). Figure 3 shows the average, minimum, and maximum values measured on the sample, as well as the standard deviation, for linear measurements, and Figure 4 for angular measurement. The analysis of linear measurements obtained shows very different values between individuals, probably as a function of changes in morphology and facial type of the finalists analyzed.

TABLE 2. Linear and Angular Measurements Considered When Evaluating Facial Attractiveness

Liner Measurement	Meaning	Angular Measurement	Meaning
N-Pg	Facial line	N-Sn-Pg	Facial convexity excluding the nose
N-M (T_r-T_l)	Nasion—midpoint of Tragi	Sl-N-Sn	Maxillary prominence
Pg-M(T_r-T_l)	Pogonion—midpoint of Tragi	Prn-Sn-Ls	Nasolabial
Pg-M (Ago_l-Ago_r)	Mandibular corpus length	(Sn-Ls)^(Sl-Pg)	Interlabial
Ago_l-Ago_r	Lower facial width	N-Prn-Pg	Nasion-Pronasal_Pogonion
N-Sn	Anterior upper facial 2 Third height	T_l-Prn-T_r	Left Tragi-Pronasal_Right Tragi
Ch_r-Ch_l	Oral length	T_l-Pg-T_r	Left Tragi-Pogonion_Right Tragi
Ex_r-Ex_l	Upper facial width	T_l-N-T_r	Left Tragi-Nasion_Right Tragi
Sn-Pg	Anterior lower facial height		
T_r-T_l	Middle facial width		
Ls-(Prn-Pg)	Upper lip to E-line distance		
Li-(Prn-Pg)	Lower lip to E-line distance		
Ls-Li	Vermillon height		

TABLE 3. Linear Measurements (mm)

Landmarks	Measure	Mean	Min	Max	Std. Dev.	Range	Asymmetry	Kurtosis
N-Pg	Facial line (Peck and Peck)	97.34	84.30	108.78	4.03	24.48	0.42	−0.61
N-P	Nasion—midpoint of facial line (Peck and Peck)	48.67	42.15	54.39	2.02	12.24	0.41	−0.68
P-Pg	Midpoint of facial line—Nasion (Peck and Peck)	48.67	42.15	54.39	2.02	12.24	0.38	−0.68
P-M (T_r-T_l)	Midpoint of facial line—midpoint of Tragi (Peck and Peck)	86.14	78.22	93.07	3.35	14.84	0.36	−0.67
N-Ls	Nasion—Ls upper lip (Peck and Peck)	62.34	52.92	68.76	3.10	15.84	0.39	−0.66
Ls-Prn	Ls upper lip—Pronasale (Peck and Peck)	27.13	21.24	33.28	2.73	12.05	0.35	−0.71
N-M (T_r-T_l)	Nasion—midpoint of Tragi (Peck and Peck)	88.03	79.14	95.16	3.52	16.02	0.32	−0.71
Prn-M (T_r-T_l)	Pronasale—midpoint of Tragi (Peck and Peck)	105.16	96.64	113.19	3.97	16.54	0.31	−0.74
Ls-M (T_r-T_l)	Upper lip—midpoint of Tragi (Peck and Peck)	98.14	89.89	105.33	3.48	15.44	0.36	−0.74
Pg-M (T_r-T_l)	Pogonion—midpoint of Tragi (Peck and Peck)	108.76	97.69	118.05	4.09	20.37	0.39	−0.75
Tr-Sn	Tragi—subnasal	113.76	99.32	131.25	6.69	31.93	0.44	−0.72
Tr-N	1° third facial height (Farkas, neoclassic)	63.74	48.51	79.17	6.25	30.66	0.49	−0.64
N-Sn	Anterior upper facial 2° third height (Farkas, neoclassic)	50.29	41.90	54.73	2.43	12.84	0.47	−0.67
Sn-Me	Anterior upper facial 3° third height (Farkas, neoclassic)	61.25	55.05	70.31	2.88	15.25	0.45	−0.71
Tr-N in Y	1° third facial height (Farkas, neoclassic)	61.92	46.37	77.52	5.90	31.15	0.44	−0.75
N-Sn in Y	Anterior upper facial 2° third height (Farkas, neoclassic)	49.70	41.79	54.59	2.44	12.79	0.43	−0.79
Sn-Me in Y	Anterior upper facial 3° third height (Farkas, neoclassic)	58.65	52.78	67.90	2.81	15.12	0.42	−0.82
Ex_r-En_r	Right eye (Farkas, neoclassic)	27.77	23.62	31.19	1.46	7.57	0.43	−0.84
Ex_l-En_l	Left eye (Farkas, neoclassic)	27.54	25.00	31.13	1.31	6.13	0.40	−0.86
En_r-En_l	Eye distance (Farkas, neoclassic)	30.51	25.10	34.66	2.03	9.57	0.38	−0.87
Ey_r-Ey_l	Eye pupillar distance (Farkas, neoclassic)	59.12	52.48	63.54	2.43	11.06	0.35	−0.89
Ch_r-Ch_l	Oral length (Farkas, neoclassic)	45.70	38.48	54.28	2.77	15.80	0.34	−0.92
Ac_r-Ac_l	Nasal width (Farkas, neoclassic)	31.61	27.83	36.74	1.88	8.91	0.32	−0.95
1.5*(Ac_r-Ac_l)	1.5 × nasal width (Farkas, neoclassic)	47.41	41.75	55.12	2.82	13.37	0.29	−0.97
Ex_r-N	Right Exocantium—Nasion	47.14	42.95	52.68	2.04	9.73	0.27	−0.99
N-Ex_l	Nasion_Left Exocantium	47.21	42.06	52.50	2.20	10.44	0.25	−1.02
Ex_r-Ex_l	Upper facial width	84.01	78.67	92.33	2.98	13.66	0.23	−1.05
AGo_l-AGo_r	Lower facial width	80.43	69.71	89.26	4.31	19.55	0.24	−1.07
Pg-M (AGo_l-AGo_r)	Mandibular corpus length	45.74	35.61	52.91	3.36	17.29	0.25	−1.10
N-Prn	Nasion-pronasale	43.35	36.18	48.91	2.55	12.73	0.23	−1.13
Prn-Pg	Pronasale-pogonion	63.24	56.05	72.82	3.36	16.77	0.20	−1.15
N-Sn	Anterior upper facial height	50.29	41.90	54.73	2.43	12.84	0.19	−1.18
Sn-Pg	Anterior lower facial height	48.14	42.50	56.47	2.65	13.96	0.17	−1.21
T_r-T_l	Middle facial width	131.52	123.71	140.04	4.19	16.33	0.15	−1.24
Sn-(T_r-T_l)	Middle facial depth	93.15	84.05	100.47	3.42	16.42	0.19	−1.20
Ch_l-Ch_r	Mouth width	45.70	38.48	54.28	2.77	15.80	0.22	−1.21
Ls-(Prn-Pg)	Upper lip to E-line distance	3.95	0.68	9.29	1.80	8.61	0.19	−1.24
Li-(Prn-Pg)	Lower lip to E-line distance	2.32	0.14	6.52	1.31	6.37	0.16	−1.24
Ls-Li	Vermillon height	17.97	12.01	23.22	2.29	11.21	0.13	−1.22
Sl-Pg	Sublabiale-Pogonion	12.54	8.61	16.69	1.60	8.08	0.09	−1.21
Sl-N	Sublabiale-Nasion	85.08	74.68	93.91	3.59	19.23	0.05	−1.19
Prn-Sn	Pronasale-Subnasale	18.62	14.29	22.29	1.84	8.00	0.07	−1.23
Sn-Ls	Subnasale-upper lip	12.18	9.08	16.25	1.52	7.17	0.02	−1.21
Prn-Sn	Pronasale-Subnasale	18.62	14.29	22.29	1.84	8.00	0.07	−1.23
Ls-Pg	Upper lip-Pogonion	36.71	31.49	44.87	2.64	13.38	-0.07	−1.17
T_r-Prn	Right Tragi-Pronasale	124.21	114.25	133.44	4.21	19.19	-0.11	−1.16
T_l-Prn	Left Tragi-Pronasale	123.87	115.08	132.69	4.25	17.61	-0.07	−1.16
T_r-Pg	Right Tragi-Pogonion	127.57	119.20	137.00	4.12	17.80	-0.02	−1.15
T_l-Pg	Left Tragi-Pogonion	126.65	112.95	136.67	4.49	23.71	0.04	−1.13
T_r-N	Right Tragi- Nasion	109.99	101.19	117.89	3.55	16.69	0.09	−1.10
T_l-N	Left Tragi-Nasion	109.79	100.03	119.67	4.04	19.64	0.14	−1.10
AGo_l-Pg	Left AnteGoniale-Pogonion	60.99	51.00	68.27	3.88	17.27	0.19	−1.09
Pg-AGo_r	Pogonion-Right Antegoniale	60.85	50.73	66.94	3.51	16.21	0.17	−1.15
T_r-AGo_r	Right Tragi-Right Antegoniale	80.85	72.27	91.52	4.51	19.24	0.15	−1.20
T_l-AGo_l	Left Tragi—Left Antegoniale	81.68	56.84	92.09	6.05	35.26	0.16	−1.25
T_l-Sn	Trago left—subnasale	113.77	103.86	122.43	3.67	18.57	0.18	−1.30
Sn-T_r	Subnasale—Trago_right	113.66	99.32	131.25	6.55	31.93	0.24	−1.28

TABLE 4. Angular Measurements (Degrees)

Landmarks	Measure	Mean	Min	Max	Std. Dev.	Range	Asymmetry	Kurtosis
N-Sn-Pg	Facial convexity excluding the nose	163.55	152.73	172.05	4.37	19.33	0.31	−1.25
Sl-N-Sn	Maxillary prominence	9.33	5.05	15.10	1.98	10.06	0.36	−1.17
Prn-Sn-Ls	Nasolabial	123.12	102.42	150.30	9.53	47.87	0.30	−1.19
(Sn-Ls)^(Sl-Pg)	Interlabial	169.13	148.16	179.16	6.48	31.00	0.39	−1.10
(Sn-Sl)^(Sl-Pg)	Subnasale-Sublabiale-Pogonion	156.64	135.89	176.22	7.93	40.33	0.40	−1.07
N-Prn-Pg	Nasion-Pronasale-Pogonion	131.12	123.33	142.26	4.07	18.93	0.42	−1.01
T_l-Prn-T_r	Left Tragi-Pronasale-Right Tragi	64.06	59.31	67.96	1.83	8.65	0.52	−0.78
T_l-Pg-T_r	Left Tragi-Pogonion-Right Tragi	62.34	58.54	67.08	1.80	8.54	0.54	−0.85
T_l-N-T_r	Left Tragi-Nasion-Right Tragi	73.55	68.46	79.06	2.07	10.60	0.56	−0.93
Sn-N-Prn	Subnasale-Nasion-Pronasale	158.67	152.82	163.92	2.47	11.09	0.61	−0.95
T_l-AGo_l-Pg	Left Tragi-Antegoniale-Left Pogonion	124.62	117.07	138.54	3.70	21.47	0.57	−1.14
T_r-AGo_r-Pg	Right Tragi-Antegoniale-Right Pogonion	127.88	119.19	132.83	2.85	13.63	0.68	−0.91
AGo_l-Pg-AGo_r	Lower face convexity	82.74	70.92	93.90	4.35	22.98	0.68	−0.98
T_l-Sn-T_r	Middle face convexity	69.57	64.02	73.41	2.33	9.40	0.90	−0.55
Ex_r-N-Ex_l	Upper Facial Convexity	126.16	114.47	137.53	4.94	23.06	1.12	−0.10
F (Pg-P-M (T_r-T_l))	Facial angle (Peck and Peck)	104.10	98.62	110.60	2.46	11.98	1.26	0.12
Mf (Pg-N-Ls)	Maxillo-Facial angle (Peck and Peck)	7.93	3.02	12.79	2.10	9.76	1.70	1.91
Nm (Ls_P-P_M (T_r-T_l))	Naso_Maxillary angle (Peck and Peck)	103.60	91.51	113.00	4.52	21.48	1.56	1.41
Na (N-M (T_r-T_l)-Prn)	Nasal angle (Peck and Peck)	23.85	20.03	27.11	1.70	7.08	1.30	0.56
Mx (Prn-M (T_r-T_l)-Ls)	Maxillary angle (Peck and Peck)	14.78	11.73	17.37	1.29	5.64	1.42	0.63
Mn (Pg-M (T_r-T_l)-Ls)	Mandibular angle (Peck and Peck)	19.55	16.15	23.31	1.54	7.16	1.35	0.26
Tv (N-M (T_r-T_l)-Pg)	Total Vertical angle (Peck and Peck)	58.15	52.75	63.74	2.38	10.99	1.39	0.11

DISCUSSION

Analysis of the Two Main Anthropometric Facial Measurements (Height and Width)

Some of the most significant facial measurements of the face were grouped to verify whether the data were normally distributed and whether there are any evident relationships between the measurements analyzed.

By grouping measurements of facial height (Tr-Sn-Me), width (T_l-T_r) and the ratio of these 2 measurements ((Tr-Sn-Me)/(T_l-T_r)), we may observe that the sample is neither normally distributed nor has the typical distribution of a Gaussian curve; only the distribution of facial height is closer to a normal distribution (Fig. 5).

The "attractive 2010" sample was then checked for evidence of a scale factor relationship between the faces, expressed through a relationship of proportionality between the measurements of facial height and width. Figure 6 shows the plots relating to the analysis of the distance of these measurements from the normal distribution. The P value (between 0 and 1) represents the value for which the null hypothesis is to be rejected at an alpha (α) level equal to 0.05. The AD value refers to the Anderson–Darling test, which compares the empirical cumulative distribution of the sample with the cumulative distribution which would be expected if the sample were distributed following a Gaussian curve.

To check for a correlation between facial height and width (Fig. 7), it is observed that the correlation coefficient of Pearson between Tr-Sn-Me and T_r-T_l is rather low, at 0.387 (with a P value of 0.001). The hypothesis of a statistically significant correlation between these 2 anthropometric facial parameters (according to which an increase in facial height in the "attractive" faces should correspond to a proportional increase also in facial width) was not confirmed: in fact, the distribution of measurements taken does not reflect a constant relationship of proportionality between the 2 parameters, as shown by the graph in Figure 7.

Figure 8 reports the values of the main measurements of facial height and width. The data from the sample were ranked by increasing values with respect to the facial height/width ratio; they highlight the absence of a Gaussian distribution, as can be expected in a normal population.

Comparison With Available Data in the Literature

Figures 9 and 10 show, respectively, the values of 11 linear and 10 angular measurements of samples of "attractive" women in different competitions (Mean 1995,[35] Mean 2006, Mean 2007,[36] Mean girls 2008[37]), comparing them with the values of similar measurements found in the sample reported in this study ("Media 2010").

TABLE 5. Relationship Between Linear Measurements

Landmarks	Measure	Mean	Min	Max	Std. Dev.	Range	Asymmetry	Kurtosis
(T_r-T_l)/(N-Pg)	Middle facial width to facial height	1.35	1.23	1.49	0.06	0.265	2.85	7.06
(N-Sn)/(N-Pg)	Nasion-Subnasale/Nasion-Pogonion	0.52	0.48	0.56	0.02	0.080	2.51	5.13
(Sn-Pg)/(N-Pg)	Subnasale-Pogonion/Nasion-Pogonion	0.49	0.46	0.53	0.02	0.075	2.13	3.23
(Tr-N)/(Tr-Sn)	Right Tragi-Nasion/Right Tragi-Subnasale	0.56	0.47	0.60	0.03	0.133	1.67	1.37

TABLE 6. Percentage Relationship Between Linear Measurements (%)

Landmarks	Measure	Mean	Min	Max	Std. Dev.	Range	Asymmetry	Kurtosis
(Sn-Pg/N-Sn) × 100	Lower to upper facial height	95.88%	80.84%	108%	6.0%	27.18%	1.05	−0.38

In the study of facial anthropometric parameters, we must verify the 3 key hypotheses formulated.

Hypothesis 1

It was necessary to determine whether the samples analyzed ("attractive") and the reference samples ("normal") of the studies found in the literature belong—based on statistical evidence—to the same population, or whether the differences are such as to suggest a population of "attractive" subjects that is different from the population of "normal" subjects. Using the paired Student t test for the analysis of the mean, assuming the difference to be NS (not significant), if alpha $>$ 0.05 (probability $>$ 95%), the differences with alpha = 0.00 (probability 100%) will certainly be significant.

The scientific literature contains very few articles that report measurements and specific analyses on attractive women, compared with the normal population. Ferrario et al[35] published data on 10 "beauties," which they compared with a reference sample of 40 "normal" women (standard). From an analysis of their data, it can be deduced that only a few measurements differ to such an extent as to constitute statistical evidence that they belong to samples of 2 different populations.

Sforza et al[37] published data on 24 "beauties" measured in 2006, which they compared with a reference sample of 71 "normal" girls. In this case, too, it was found that only some measurements differed to such an extent as to constitute statistical evidence that they belong to samples of 2 different populations.

Sforza et al[37] published data on 24 "beauties" measured in 2007, which they compared with a reference sample of 71 "normal" girls. As with the analysis of previous samples, only some measurements differed to such an extent as to constitute statistical evidence that they belong to samples of 2 different populations.

Sforza et al[36] published data on 23 "attractive girls" aged between 13 and 15, which they compared with a reference sample of 51 "normal" girls (standard). From an analysis of their data, it can be deduced that no measurement deviates to such an extent as to constitute statistical evidence for belonging to samples of 2 different populations.

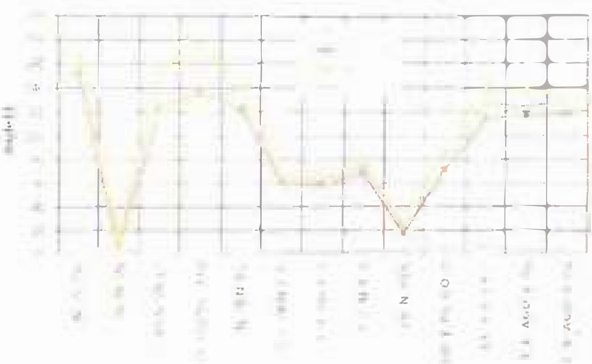

FIGURE 4. Angular measurements: average, minimum, and maximum values of the sample, and standard deviation.

Table 7 shows the measurements which, in the analyses mentioned above, diverge to such an extent as to constitute statistical evidence of belonging to samples of 2 different populations.

Hypothesis 2

It was necessary to determine whether the "attractive 2010" sample and the reference sample (standard) adopted by other researchers in the works mentioned above belong—based on statistical evidence—to the same population, or whether they differ to such an extent as to suggest that the "attractive 2010" population can be considered different from the "normal" reference population. In this case, too, a paired Student t test was used; assuming the difference to be NS (not significant), if alpha $>$0.05 (probability $>$95%), the differences with alpha = 0.00 (probability 100%) will certainly be significant.

The data for the "normal" sample published by Ferrario et al[35] in 1995 and data for the "attractive 2010" sample were thus compared. In this case, strong statistical evidence was found to

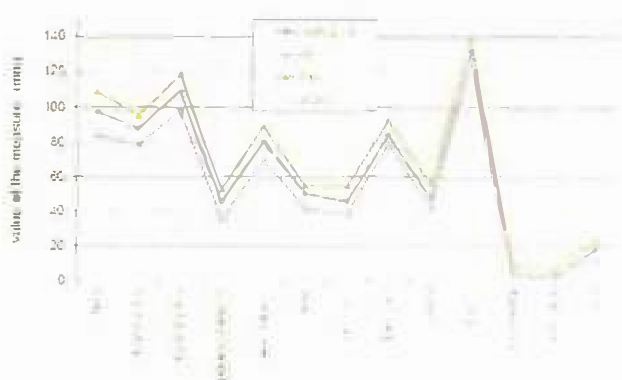

FIGURE 3. Linear measurements: average, minimum, and maximum values found in the sample, and standard deviation.

FIGURE 5. Facial measurement collection and distribution into classes.

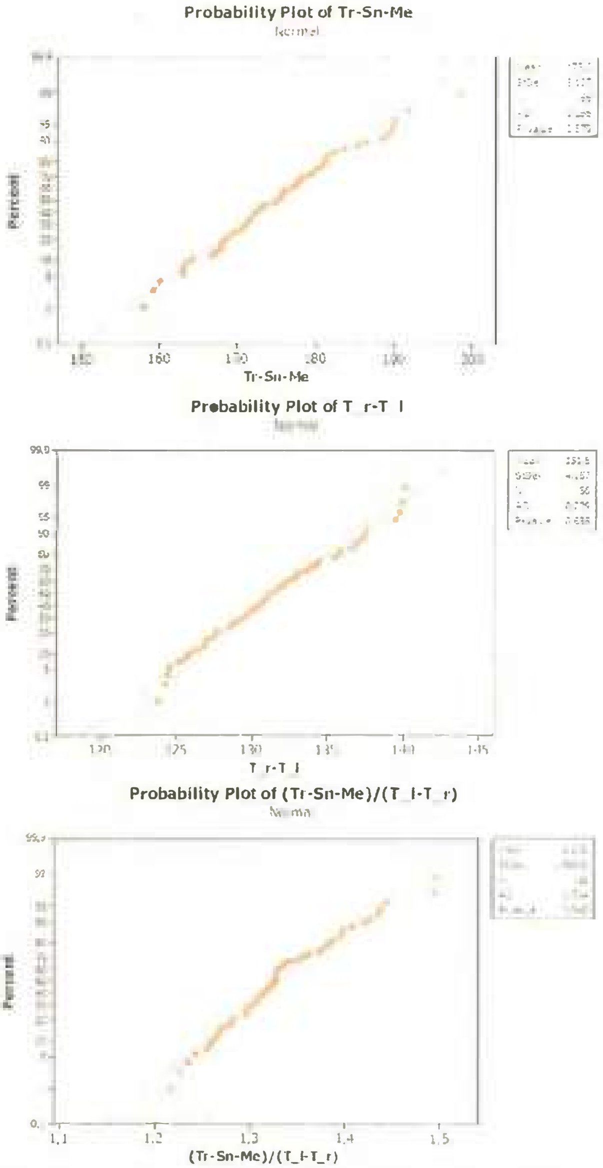

FIGURE 6. Analysis of the deviation from the normal distribution of measurements.

support the hypothesis that the samples belonged to 2 different populations.

Similarly, in the comparison between the "normal" sample data measured in 2006 and published by Sforza et al[37] and data from the "attractive 2010" sample, statistical evidence was found to suggest that the samples belong to 2 different populations.

In contrast, a comparison of the "normal "sample data measured in 2007 published by Sforza et al[37] and data from the "attractive 2010" sample found statistical evidence of the samples belonging to 2 different populations.

In summary, through the analysis of comparative statistics on multiple samples, it was possible to identify the facial anthropometric parameters that provide statistical evidence of the samples belonging to 2 different populations ("attractive" and "normal") and therefore define the anthropometric characteristics of

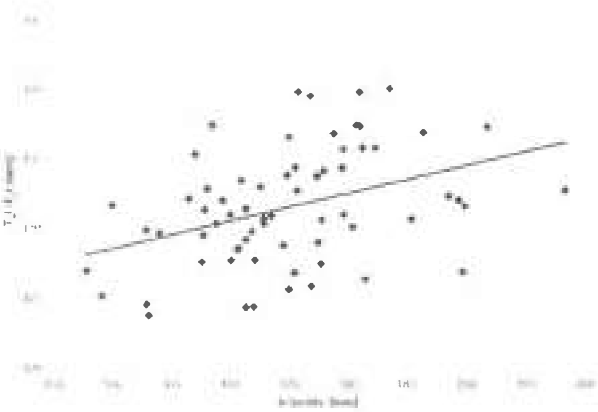

FIGURE 7. Correlation between facial width and height.

attractiveness (Table 8) more accurately. Specifically, the following measurements have the greatest influence on the attractiveness of the face:

- for the upper 3rd: upper facial width Ex_r-Ex_l; upper facial convexity Ex_r-N-Ex_l;
- for the middle 3rd: distance between nasion and midpoint of tragi N-M(T_r-T_l); anterior facial height N-Sn; nasolabial corners Prn-Sn-Ls, T_l-N-T_r, T_l-Prn-T_r;
- for the lower 3rd: mouth width Ch_r-Ch_l; distance between pogonion and midpoint of tragi Pg-M(T_r-T_l); distance between pogonion and midpoint of gonion Pg-M(Go_l-Go_r); lower facial width Go_l-Go_r; front height of lower face Sn-Pg; height of vermilion Ls-Li; protrusion of upper lip LS-(Prn-Pg); angles T_l-Pg-T_r and T_r-Go_r-P; lower facial convexity Go_l-Pg-Go_r; angle (Sn-Ls)^(Sl-Pg).
- for the middle and lower 3rd considered together: facial line N-Pg; facial convexity excluding nose N-Sn-Pg; maxillary prominence Sl-N-Sn.

In detail (Table 9), as regards linear measurements, the major influences on facial attractiveness are those relating to:

- width: top facial width Ex_r-Ex_l; mouth width Ch_r-Ch_l; lower facial width Go_l-Go_r;
- height: anterior facial height N-Sn; lower facial width Go_l-Go_r; lower facial height Sn-Pg; height of vermilion Ls-L; facial line N-Pg;
- distance: distance between nasion and midpoint of tragi N-M(T_r-T_l); distance between pogonion and midpoint of tragi Pg-M(T_r-T_l); distance between pogonion and midpoint of gonion PG-M(Go_l-Go_r); protrusion of upper lip LS-(Prn-Pg).
- With regard to angular measurements, the major influences are those relating to:

FIGURE 8. Values of the main facial widths and heights.

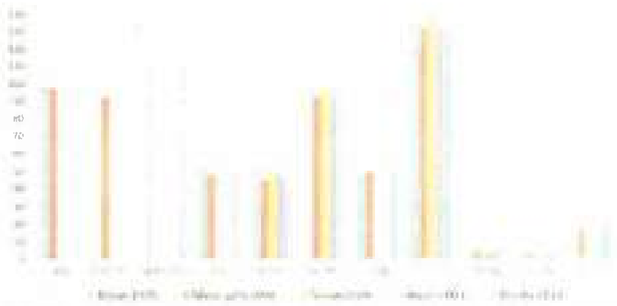

FIGURE 9. Comparison between the linear measurements (in millimeters) of attractive women in different competitions.

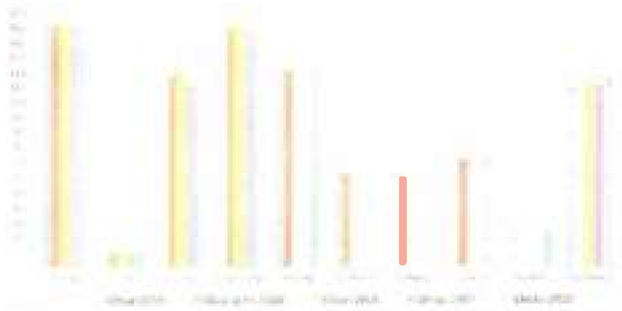

FIGURE 10. Comparison between the angular measurements of attractive women in different competitions.

- upper facial convexity Ex_r-N-Ex_l; nasolabial angles Prn-Sn-Ls, T_l-N-T_r, T_l-Prn-T_r, T_l-Pg-T_r, T_r-Go_r-Pg; lower facial convexity Go_l-Pg-Go_r; (Sn-Ls)^(Sl-Pg); facial convexity (excluding nasal pyramid) N-Sn-Pg; maxillary prominence Sl-N-Sn.

Finally, other significant results include ratios of average width to average height (T_r-T_l)/(N-Pg), (N-Sn)/(N-Pg), (Sn-Pg)/(N-Pg), (Tr-N)/(Tr-Sn), (Sn-Pg)/(N-Sn) × 100.

Hypothesis 3

It was necessary to determine whether the "attractive 2010" sample and other "attractive" samples cited in this paper belong—based on statistical evidence—to the same population, or whether the differences are such as to suggest that the "attractive 2010" sample belongs to a population that can be considered different from the other "attractive" reference samples. Here, too, a paired Student t test was used; assuming the difference to be NS (not significant), if alpha >0.05 (probability >95%), the differences with alpha = 0.00 (probability 100%) will certainly be significant.

In 1969, Peck and Peck[38] analyzed the characteristic angles of the profile of 52 actresses with a photographic method; it may be observed that the values of the data reported in (38) and those found in the "attractive 2010" sample are still perfectly comparable, despite the fact that over 40 years elapsed between the findings of the 2 samples and that the 2 samples relate to different ethnic groups.

The comparison shows that only the mandibular angle and the total vertical extent appear to be slightly higher in measurements on 3D models of the "attractive 2010" sample compared with the measurements made by Peck and Peck of landmarks on the skin for their "attractive 1969" sample.[38]

The comparison between the anthropometric measurements of the "attractive" women in Sforza et al in 1995[35] and those found in the "attractive 2010" sample did not find statistical evidence of the samples belonging to 2 different populations. Similarly, the comparison between the anthropometric measurements of the "attractive" sample in Sforza et al[36] and the measurements of the "attractive 2010" sample produced statistical evidence of the samples belonging to 2 different populations only for a small number of measurements. This was also the case with the comparison between the anthropometric measurements for the "attractive" sample in Sforza et al (2006 competition)[37] and measurements

TABLE 7. From Sforza et al the Measurements That Show Differences Leading to the Hypothesis of a "Beautiful" Population That Is Different From the "Normal" Population

Measure	Description	Units	Probability	alpha	to	Sp	ng	References
N-Pg	Facial line (Peck and Peck)	Distance (mm)	100.00%	0.000	4.63	5.11	48	Ferrario and Sforza 1995[34] Beauties (10) vs normals (40)
N-Sn	Anterior upper facial 2nd third height (Farkas, neoclassic)	Distance (mm)	100.00%	0.000	9.22	3.04	48	
Sl-N-Sn	Maxillary prominence	Angle (deg.)	100.00%	0.000	5.02	1.62	48	
Ex_r-N-Ex_l	Upper facial convexity	Angle (deg.)	100.00%	0.000	4.69	6.81	48	
(N-Sn)/(N-Pg)	Nasion-Subnasale/Nasion-Pogonion	Ratio	100.00%	0.000	9.61	0.01	48	
(Sn-Pg)/(N-Pg)	Subnasale-Pogonion/Nasion-Pogonion	Ratio	100.00%	0.000	9.61	0.01	48	
(Tr-N)/(Tr-Sn)	Right Tragi-Nasion/Right Tragi-Subnasale	Ratio	100.00%	0.000	5.19	0.03	48	
Ex_r-Ex_l	Upper facial width	Distance (mm)	100.00%	0.000	6.14	3.45	93	Sforza[35] Soft-Tissue Facial Characteristics 2006 competition (24) vs ref (71)
Ls-(Prn-Pg)	Upper lip to E-line distance	Distance (mm)	100.00%	0.000	4.47	1.33	93	
Li-(Prn-Pg)	Lower lip to E-line distance	Distance (mm)	100.00%	0.000	5.43	1.33	93	
(Sn-Ls)^(Sl-Pg)	Interlabial	Angle (deg.)	99.99%	0.000	4.03	7.78	93	
Ex_r-Ex_l	Upper facial width	Distance (mm)	100.00%	0.000	5.68	3.73	93	Sforza[35] Soft-Tissue Facial Characteristics 2007 competition (24) vs ref (71)
T_r-T_l	Middle facial width	Distance (mm)	99.36%	0.006	2.79	5.47	93	
Li-(Prn-Pg)	Lower lip to E-line distance	Distance (mm)	100.00%	0.000	4.47	1.61	93	

TABLE 8. Differences That Are Sufficiently Statistically Significant to Hypothesize an "Attractive 2010" Population That Is Different From the "Normal" Reference Population ("Average" of the Samples Obtainable From Literature)

Measure	Description	Units	Probability	alpha	to	Sp	ng	References
N-Pg	facial line (Peck and Peck)	Distance (mm)	100.00%	0.000	11.38	4.42	104	Miss Italia 2010 (66) vs Ferrario Sforza 1995[34] Normals (40)
N-M (T_r-T_l)	Nasion - Midpoint of Tragi (Peck and Peck)	Distance (mm)	100.00%	0.000	9.60	3.67	104	
Pg-M (T_r-T_l)	Pogonion—midpoint of Tragi (Peck and Peck)	Distance (mm)	100.00%	0.000	4.69	4.18	104	
Pg-M (Go_l-Go_r)	mandibular corpus length	Distance (mm)	100.00%	0.000	40.66	3.93	104	
Go_l-Go_r	lower facial width	Distance (mm)	100.00%	0.000	21.18	5.89	104	
N-Sn	Anterior upper facial 2° third height (Farkas, neoclassic)	Distance (mm)	100.00%	0.000	22.16	2.70	104	
Ch_r-Ch_l	Oral length (Farkas, neoclassic)	Distance (mm)	100.00%	0.000	7.70	3.41	104	
Ex_r-Ex_l	Upper facial width	Distance (mm)	100.00%	0.000	11.78	4.88	104	
Sn-Pg	Anterior lower facial height	Distance (mm)	100.00%	0.000	4.45	2.73	104	
N-Sn-Pg	Facial convexity excluding the nose	Angle (deg.)	100.00%	0.000	5.98	4.12	104	
Sl-N-Sn	Maxillary prominence	Angle (deg.)	100.00%	0.000	10.09	1.85	104	
T_l-N-T_r	Left Tragi-Nasion_Right Tragi	Angle (deg.)	100.00%	0.000	5.76	3.06	104	
Go_l-Pg-Go_r	lower face convexity	Angle (deg.)	100.00%	0.000	16.00	4.52	104	
T_r-Go_r-Pg	Right Tragi-Right Gonion-Pogonion	Angle (deg.)	100.00%	0.000	9.14	4.76	104	
Ex_r-N-Ex_l	Upper facial convexity	Angle (deg.)	100.00%	0.000	14.63	5.85	104	
(T_r-T_l)/(N-Pg)	Middle facial width to facial height	Ratio	100.00%	0.000	7.39	0.08	104	
(N-Sn)/(N-Pg)	Nasion-Subnasale/Nasion-Pogonion	Ratio	100.00%	0.000	21.10	0.02	104	
(Sn-Pg)/(N-Pg)	Subnasale-Pogonion/Nasion-Pogonion	Ratio	100.00%	0.000	24.59	0.02	104	
(Tr-N)/(Tr-Sn)	Right Tragi-Nasion/Right Right Tragi-Subnasale	Ratio	100.00%	0.000	36.58	0.03	104	
Ch_r-Ch_l	Oral length (Farkas, neoclassic)	Distance (mm)	100.00%	0.000	5.22	3.14	135	Miss Italia 2010 (66) vs Sforza[35] 2008 Soft-Tissue Facial Characteristics ref (71)
Ex_r-Ex_l	Upper facial width	Distance (mm)	100.00%	0.000	10.65	3.40	135	
Ls-(Prn-Pg)	Upper lip to E-line distance	Distance (mm)	100.00%	0.000	4.25	2.00	135	
Ls-Li	Vermillon height	Distance (mm)	100.00%	0.000	63.78	1.65	135	
Prn-Sn-Ls	Nasolabial	Angle (deg.)	100.00%	0.000	14.04	7.13	135	
(Sn-Ls)^(Sl-Pg)	Interlabial	Angle (deg.)	100.00%	0.000	5.88	9.70	135	
Ex_r-N-Ex_l	Upper Facial Convexity	Angle (deg.)	100.00%	0.000	6.61	5.27	135	
(Sn-Pg/N-Sn)x100	Lower to upper facial height	%	100.00%	0.000	4.29	0.07	135	
N-M (T_r-T_l)	Nasion—Midpoint of Tragi (Peck and Peck)	Distance (mm)	100.00%	0.000	9.29	4.02	115	Miss Italia 2010 (66) vs Sforza[35] ref (51)
Ex_r-Ex_l	Upper facial width	Distance (mm)	100.00%	0.000	8.97	3.46	115	
Ls-Li	Vermillon height	Distance (mm)	100.00%	0.000	4.69	2.25	115	
Prn-Sn-Ls	Nasolabial	Angle (deg.)	100.00%	0.000	9.64	8.90	115	
T_l-Prn-T_r	Left Tragi-Pronasale-Right Tragi	Angle (deg.)	100.00%	0.000	10.60	1.95	115	
T_l-Pg-T_r	Left Tragi-Pogonion-Right Tragi	Angle (deg.)	100.00%	0.000	8.20	1.99	115	
T_l-N-T_r	Left Tragi-Nasion_Right Tragi	Angle (deg.)	100.00%	0.000	9.33	2.27	115	

TABLE 9. Measurements That Mainly Influence Attractiveness (Miss Italia 2010 Beauty Contest and Reference Samples From Literature)

Linear Measurement	Relative Incidence	Angular Measurement	Relative Incidence	Ratio Between Linear Measurement	Relative Incidence
Ex_r-Ex_l	3	Ex_r-N-Ex_l	2	(T_r-T_l)/(N-Pg)	1
Ch_r-Ch_l	2	Prn-Sn-Ls	2	(N-Sn)/(N-Pg)	1
N-M (T_r-T_l)	2	T_l-N-T_r	2	(Sn-Pg)/(N-Pg)	1
Pg-M (T_r-T_l)	1	T_l-Pg-T_r	1	(Tr-N)/(Tr-Sn)	1
Pg-M (Go_l-Go_r)	1	T_r-Go_r-Pg	1	Sn-Pg/N-Sn)x100	1
Go_l-Go_r	1	Go_l-Pg-Go_r	1		
N-Pg	1	T_l-Prn-T_r	1		
N-Sn	1	N-Sn-Pg	1		
Sn-Pg	1	Sl-N-Sn	1		
Ls-(Prn-Pg)	1	(Sn-Ls)^(Sl-Pg)	1		
Ls-Li	1				

TABLE 10. Measurements for Which the Differences Between the Samples Are Such as to Hypothesize an "Attractive 2010" Population Different From Other "Attractive" Reference Populations Taken From Samples Available in the Literature

Measure	Description	Units	Probability	alpha	to	Sp	ng	
Mf (Pg-N-Ls)	Maxillo-Facial angle (Peck and Peck)	Angle (deg.)	100.00%	0.000	5.67	1.93	116	Miss Italia 2010 vs Peck and Peck[37]
Ch_r-Ch_l	Oral length (Farkas, neoclassic)	Distance (mm)	100.00%	0.000	4.59	4.30	74	Miss Italia 2010—Ferrario Sforza[34] 1995 beauties
Ex_r-Ex_l	Upper facial width	Distance (mm)	100.00%	0.000	7.46	6.76	74	
(Sn-Pg)/(N-Pg)	Subnasale-Pogonion/Nasion-Pogonion	ratio	100.00%	0.000	5.86	0.01	74	
(Tr-N)/(Tr-Sn)	Right Tragi-Nasion/Right Tragi-Subnasale	ratio	100.00%	0.000	13.76	0.03	74	
N-M (T_r-T_l)	Nasion - Midpoint of Tragi (Peck and Peck)	Distance (mm)	100.00%	0.000	4.69	3.76	87	Miss Italia 2010—Sforza Laino[35] Attractive girls 13–15 y (23) 2008
Ex_r-Ex_l	Upper facial width	Distance (mm)	100.00%	0.000	10.43	3.30	87	
Prn-Sn-Ls	Nasolabial	Angle (deg.)	100.00%	0.000	10.10	7.12	87	
T_l-Prn-T_r	Left Tragi-Pronasale-Right Tragi	Angle (deg.)	100.00%	0.000	4.89	1.99	87	
T_l-Pg-T_r	Left Tragi-Pronasale_Right Tragi	Angle (deg.)	99.99%	0.000	4.13	2.03	87	
T_l-N-T_r	Left Tragi-Nasion-Right Tragi	Angle (deg.)	100.00%	0.000	4.79	2.28	87	
Ch_r-Ch_l	Oral length (Farkas, neoclassic)	Distance (mm)	100.00%	0.000	5.63	2.61	88	Miss Italia 2010—Sforza et al[36] 2006 competition (24)
Ex_r-Ex_l	Upper facial width	Distance (mm)	100.00%	0.000	15.31	3.07	88	
T_r-T_l	Middle facial width	Distance (mm)	100.00%	0.000	4.39	4.47	88	
N-Sn-Pg	Facial convexity excluding the nose	Angle (deg.)	99.74%	0.003	3.09	4.54	88	
Sl-N-Sn	Maxillary prominence	Angle (deg.)	99.89%	0.001	3.38	2.07	88	
Prn-Sn-Ls	Nasolabial	Angle (deg.)	100.00%	0.000	9.12	6.26	88	
(Sn-Ls)^(Sl-Pg)	Interlabial	Angle (deg.)	99.84%	0.002	3.25	7.95	88	
(Sn-Pg/N-Sn)x100	Lower to upper facial height	%	100.00%	0.000	4.99	0.07	88	
Ch_r-Ch_l	Oral length (Farkas, neoclassic)	Distance (mm)	99.97%	0.000	3.75	2.80	88	Miss Italia 2010—Sforza et al[36] 2007 competition (24)
Ex_r-Ex_l	Upper facial width	Distance (mm)	100.00%	0.000	15.03	3.12	88	
Prn-Sn-Ls	Nasolabial	Angle (deg.)	100.00%	0.000	13.11	6.82	88	
Ex_r-N-Ex_l	Upper Facial Convexity	Angle (deg.)	100.00%	0.000	4.72	4.76	88	

for the "attractive 2010" sample, in which only some measurements provided statistical evidence of belonging to 2 different populations (Table 10).

In summary, the results of statistical comparisons conducted on several samples can give an indication of which facial parameters mainly differ in the different samples of "attractive" girls (Table 10).

From this last comparison, the measurements that have the greatest influence of the attractiveness of a face (Table 11) are the following:

- for the upper 3rd: upper facial width Ex_r-Ex_l; upper facial convexity Ex_r-N-Ex_l;
- for the middle 3rd: distance between the nasion and the midpoint of the tragi N-M(T_r-T_l); nasolabial angles Prn-Sn-Ls, T_l-N-T_r, T_l-Prn-T_r;
- for the lower 3rd: mouth width Ch_r-Ch_l; angles T_l -Pg-T_r and (Sn-Ls)^(Sl-Pg);
- for the middle and lower 3rd considered together: maxillofacial angle Mf (Pg-N-Ls).

In particular, regarding the linear measurements, the major influences are those relating to:

- width: upper facial width Ex_r-Ex_l; mouth width Ch_r-Ch_l;
- distance: distance between the nasion and the midpoint of the tragi N-M(T_r-T_l).

TABLE 11. Measurements That Most Influence Attractiveness ("Attractive 2010" and Reference "Attractive" From Samples Available in the Literature)

Linear Measurement	Relative Incidence	Angular Measurement	Relative Incidence	Ratio Between Linear Measurement	Relative Incidence
Ex_r-Ex_l	4	Prn-Sn-Ls	3	(Sn–Pg/N–Sn) × 100	1
Ch_r-Ch_l	2	Ex_r-N-Ex_l	1		
N-M (T_r-T_l)	1	T_l-N-T_r	1		
		T_l-Pg-T_r	1		
		T_l-Prn-T_r	1		
		Mf (Pg-N-Ls)	1		

For angular measurements, the major influences are those relating to:

- upper facial convexity Ex_r-N-Ex_l; nasolabial angles Prn-Sn-Ls, T_l-N-T_r, T_l-Prn-T_r, angles T_l-Pg-T_r, (Sn-Ls)^(Sl-Pg), maxillofacial angle Mf (Pg-N-Ls).

A further significant measurement is the ratio between the sizes (Sn-Pg)/(N-Sn) × 100.

CONCLUSIONS

This research work highlights the importance of having an updated date base relative to the facial anthropometric measures of attractive young women of the same ethnic group, to set a proper diagnosis and appropriate therapy in female patients with outcomes of facial trauma or syndromic or suffering from malformations of the cranio-facial region.

By comparing the data obtained from the "attractive 2010" sample with data reported in the literature for "normal" and "attractive" samples, it was possible to identify the main anthropometric parameters which influence facial attractiveness at the levels of upper, middle, and lower facial third, and in reference to facial width, height, and depth, comparing linear, angular measurements and proportions. The measurements found in the sample analyzed do not have a normal distribution.

It was also verified whether or not the faces of attractive women show statistical evidence of a relationship between scale measurements: for example, the existence of proportionality between height and facial width measurements, according to which any increase in facial height should correspond to a proportional increase in facial width. This hypothesis was not, however, confirmed by the results of the measurements made: in fact, the distribution of any measurement does not reflect a constant relationship of proportionality between the 2 parameters.

Our study of this data also shows that there are some statistically significant differences between most of the measurements performed on the sample of "attractive" and "normal" samples in the literature: statistically significant differences were found for some measurements, and these measurements should be considered elements of evaluation for facial attractiveness.

From a comparison of the "attractive 2010" sample and the reference samples (standard) adopted by other researchers in the literature, it is not possible to deduce that these samples belong to the same population. In contrast, from a comparison of the "attractive 2010" sample and samples of attractive women analyzed by the researchers mentioned above, it can be deduced that they belong to the same population. Indeed, no significant differences were observed between most of the measurements of the 2 samples, and statistically significant differences were found only for some measurements.

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