Original Article

Facial Morphologies of an Adult Egyptian Population and an Adult Houstonian White Population Compared Using 3D Imaging

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ABSTRACT

Objective: To compare the facial morphologies of an adult Egyptian population with those of a Houstonian white population.

Materials and Methods: The three-dimensional (3D) images were acquired via a commercially available stereophotogrammetric camera capture system. The 3dMDface System photographed 186 subjects from two population groups (Egypt and Houston). All of the participants from both population groups were between 18 and 30 years of age and had no apparent facial anomalies. All facial images were overlaid and superimposed, and a complex mathematical algorithm was performed to generate a composite facial average (one male and one female) for each subgroup (EGY-M: Egyptian male subjects; EGY-F: Egyptian female subjects; HOU-M: Houstonian male subjects; and HOU-F: Houstonian female subjects). The computer-generated facial averages were superimposed based on a previously validated superimposition method, and the facial differences were evaluated and quantified.

Results: Distinct facial differences were evident between the subgroups evaluated, involving various regions of the face including the slant of the forehead, and the nasal, malar, and labial regions. Overall, the mean facial differences between the Egyptian and Houstonian female subjects were 1.33 $\pm$ 0.93 mm, while the differences in Egyptian and Houstonian male subjects were 2.32 $\pm$ 2.23 mm. The range of differences for the female population pairings and the male population pairings were 14.34 mm and 13.71 mm, respectively.

Conclusions: The average adult Egyptian and white Houstonian face possess distinct differences. Different populations and ethnicities have different facial features and averages. (*Angle Orthod.* 2009;79:991–999.)

KEY WORDS: Imaging; Three-dimensional; Anthropometry; Face; Orthodontics

INTRODUCTION

Facial appearance and esthetics today is thought to be a defining characteristic of who we are as individuals. According to a review by Faure et al,[1] facial appearance determines our social behavior, affects with whom we choose to associate, and even reflects other seemingly unrelated personal characteristics. These include the idea that nicer-looking individuals are nicer people, more intelligent, and have a higher educational potential. Applying this principle to orthodontics, Wahl[2] wrote, "Now it appears that facial esthetics is again at the forefront as we realize why patients come to us in the first place." With this in mind, facial profile and esthetics is what we should look at first in terms of our orthodontic analyses of our patients.

Even with the great understanding of the importance of facial esthetics, how do we apply this to orthodontic treatment knowing that there is a high level of variation in facial morphology among people in any one population, and even more so when one evaluates variation between different racial or ethnic groups? Before we decide how to achieve acceptable facial esthetics via or-

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thodontic treatment, we must first understand the variation in facial morphology that exists among individuals we treat and what is normal for the ethnicity of the patient.

In a review of comparisons between various ethnic groups, Bishara et al[3] provided some of the following general conclusions: (1) Mexicans exhibit more dental and skeletal protrusion than white Americans, and North Mexican girls have a more protrusive mandible than girls from Iowa. (2) Compared with white Americans, Iranians show a flat skeletal profile with an increased lip convexity because of dental protrusion. (3) Japanese have a more protrusive dentition, an increased lower facial height, and a steeper mandibular plane than white Americans. (4) Compared with white Americans, black South Africans have a more protrusive maxilla, an increased ANB angle, and a greater labial inclination of the mandibular incisors. (5) South African blacks have less protrusive incisors than American blacks. This study clearly demonstrates the wide variation in facial morphology and skeletal/dental relationships, and thus the need for further research to elucidate these differences and how they may affect our treatment. Unfortunately, a number of the above studies were conducted on two-dimensional (2D) lateral cephalograms.

Today, however, we have the means of producing records that are much more comprehensive via three-dimensional (3D) imaging. Three-dimensional images have the advantage of being able to provide the orthodontist with a more accurate representation of facial soft tissue and morphologies[4–6] and can be a tool used to compare[7,8] and predict orthodontic outcomes.[9–11]

Until now, very little has been published with regard to using 3D images to compare facial morphologies. This study was performed in order to evaluate the differences in facial morphologies between two distinct populations from different areas of the world.

The purpose of this study is to compare the facial morphologies of an adult Egyptian population with the facial morphologies of an adult Houstonian white population using a 3D surface imaging device.

MATERIALS AND METHODS

Subjects were selected from two different study sites. One group was composed of individuals from the National Research Centre in Cairo, Egypt. The other group was from the University of Texas Health Science Center at Houston. The necessary institutional reviews were acquired from the University of Texas Health Science Center and the National Research Center. All subjects were dental students, and all were asked to participate in the study; a questionnaire was used to determine racial type. They were accepted as participants if they satisfied the following inclusion criteria:

- Subjects of white descent (Houston group) and Egyptian descent (Egyptian group)
- Subjects between the ages of 18 and 30 years
- Subjects with no adverse skeletal deviations (subjects with mild Class II and III were included)
- Subjects with no gross craniofacial anomalies

Imaging System

The imaging system used in this study was the portable 3dMDface System (3dMD LLc, Atlanta, Ga.), a structured light system using a combination of stereophotogrammetry and the structured light technique.[9] This system uses a multi-camera configuration, with three cameras on each side (one color and two infrared),which captures photo-realistic quality pictures. A random light pattern is projected onto a subject, and an image is captured with multiple synchronized digital cameras set at various angles in an optimum configuration. This system is able to capture full facial images from ear to ear and under the chin in 1.5 milliseconds at the highest resolution. The manufacturer accuracy is less than 0.5 mm, and the quoted clinical accuracy is 1.5% of the total observed variance.[12] Three-dimensional surface images captured by surface acquisition systems are highly repeatable, and 3D landmark data can be acquired with a high degree of precision.[13,14]

Images taken from the 3dMDface System (3dMD LLc, 100 Galleria Pkwy SE, Atlanta, Ga.) were analyzed and viewed on a computer using the 3dMDpatient Software Platform (Figure 1).

Image Acquisition

All images were standardized using a portable 3D imaging device by 3dMD. The patient was seated on a chair with his/her face centered on a computer screen. Then 3D images were developed by means of stereophotogrammetry (ie, two cameras, configured as a stereopair, taking an image of the face simultaneously and recording features on the surface of the face by means of triangulation). Each image took approximately 50 milliseconds to capture and was transferred to the 3dMD software which converted the data into a 3D image.

Processing of Facial Shells

All of the images acquired were analyzed by way of the RF6 PP2 software (Rapidform Technology Inc, Gangnam-gu, Seoul, Korea.)[15] As part of the computer analysis, the data were processed before analysis in order to be able to obtain an image that had a pre-

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Figure 1. Sample pictures generated by the 3dMDface System, illustrated using the 3dMDpatient Software Platform. These views are only snapshots taken from the 3D image, which can be rotated 360° in any direction.

served shape, surface, and volume using custom macros for the RF6 as described previously.[15] As a result of this processing procedure, one facial shell was created for each subject. Furthermore, this allowed us to create and compare facial averages of the groups involved.

Average Face Constructions

Utilizing the computer-generated facial shells, facial averages were constructed for the Egyptian male (EGY-M), the Egyptian female (EGY-F), the Houstonian male (HOU-M), and the Houstonian female (HOU-F) subjects. The process of creating average facial constructs was carried out with a previous validated software subroutine as part of the RF6 software. The steps required to produce an average face have been reported previously.[16]

Parameters Measured

The four facial averages that were generated as stated above (EGY-M, EGY-F, HOU-M, HOU-F) were superimposed onto one another and compared by means of a specialized computer-assisted technique[16] for differences in facial morphology. The superimpositions were carried out by selecting various points or landmarks on each of the corresponding facial average images. Using fine registration, the RF6 software then aligned the two facial average shells by means of finding a best-fit of the two images. The following comparisons were made between subgroups:

EGY-F vs EGY-M
HOU-F vs HOU-M
EGY-F vs HOU-F
EGY-M vs HOU-M
EGY-F vs HOU-M
EGY-M vs HOU-F

The parameters utilized were linear measurements, color histograms, and surface areas/shapes, and as previously reported, they can be summarized as seen below.[16]

Linear Measurements

Linear measurements representing the mean differences between two surface shells were recorded in millimeters. This value represents the sum total of all differences recorded between overlapping surfaces of two shells. Additionally, this value could be used as an indicator of the best fit between two shells, as well as an indicator of where changes/differences exist between the corresponding shells.

Color Histograms

Color histograms are produced using the RF6 software show the areas of change that occurred between the average facial shells. In the given histograms below, the blue areas showed ''negative'' changes and red areas showed ''positive'' changes.

Surface Areas/Shapes

Surface areas and shapes were automatically generated by RF6. These shapes were obtained when a previous tolerance of 0.425 mm was applied to the paired surface shell studies. The areas that corresponded to 0.425 mm were deemed to be similar surfaces, while surface areas above this tolerance, showed up as surface shape and color deviations.

RESULTS

One hundred eighty-six subjects from two population groups were recruited. In total, 50 male and 50 female subjects from Houston and 36 male and 50 female subjects from Egypt were selected.

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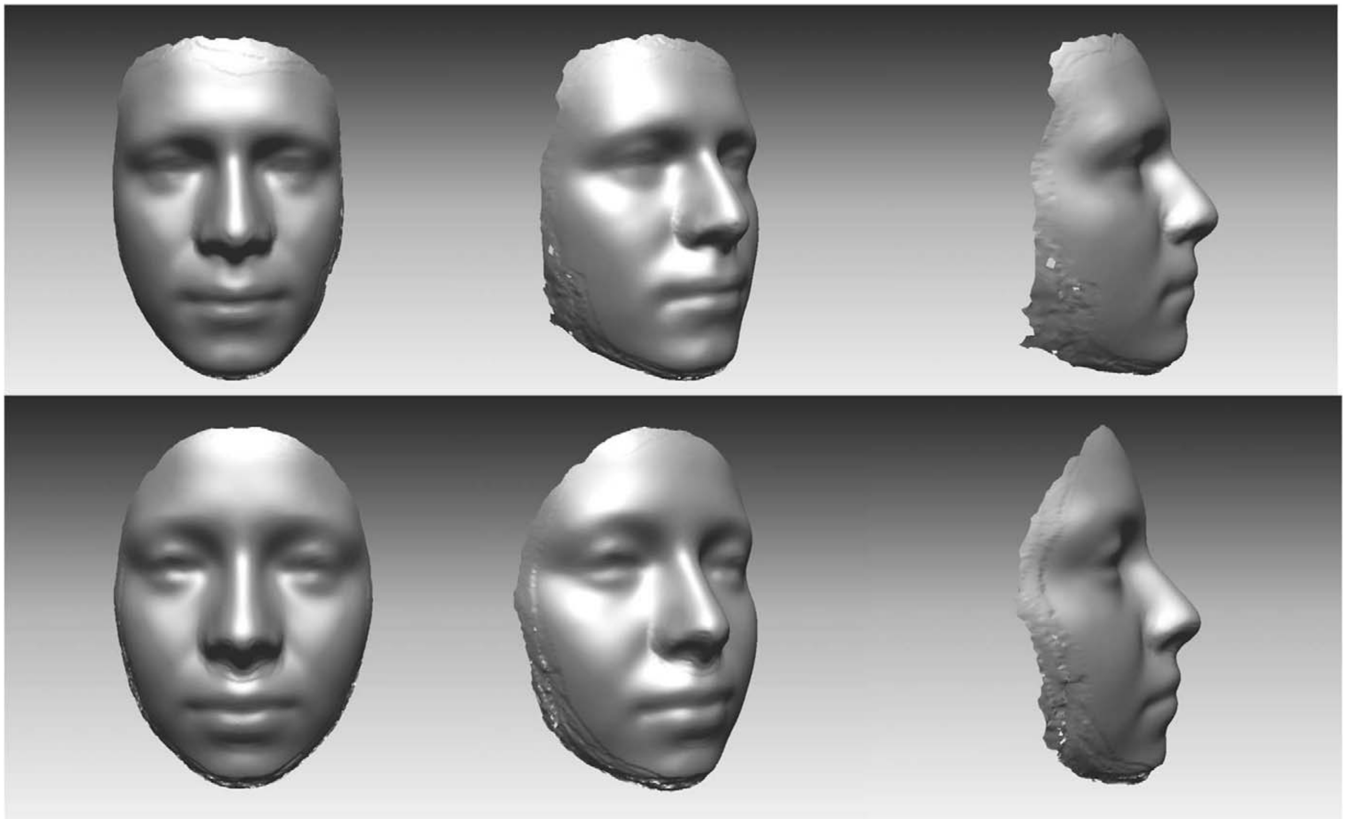

Figure 2. Average facial constructs for the Egyptian male (row 1) and Egyptian female subjects (row 2).

Average Faces

Average faces were constructed for each of the four subgroups: EGY-M, EGY-F, HOU-M, HOU-F (Figures 2 and 3). These averages were later used as a means of comparison between subgroups.

Linear Measurements

Differences in the average absolute linear measurements ranged from 1.33 mm (EGY-F vs EGY-M; EGY-F to HOU-F) to 2.57 mm (EGY-F vs HOU-M) as shown in Table 1. Of special note are the differences between the gender-specific groups: 2.32 mm for the comparison of Egyptian and Houstonian male subgroups and 1.33 mm between the Egyptian and Houstonian female subgroups.

Color Histograms

Definite differences were observed in the average facial shells of the various subgroups as reported in Table 2. The color histograms demonstrated that there was a range of "similarity" between the various subgroups from 7.08% (EGY-F vs HOU-M) to 24.61% (EGY-F vs EGY-M). With regard to the gender-specific subgroups, there was a 12.7% similarity between the Egyptian and Houstonian female subjects and an 18.6% similarity between the Egyptian and Houstonian male subjects. The average linear distance as seen in the signed color histograms between subgroups ranged from −1.58 mm (EGY-M vs HOU-M) to 1.41 mm (EGY-M vs HOU-F).

Surface Areas/Shapes

The differences seen in the surface areas and shape of the facial shells are reported in Figure 4 (absolute color) and Figure 5 (signed color). The subgroup comparison that differed the most was the Egyptian female vs the Houstonian male shells, followed by the comparisons made between the Egyptian female and the Houstonian female shells. Differences were primarily noted in the malar and nasal regions, as well as in the regions of the eyes, lips, mandible, and forehead.

Male Subjects

With respect to the comparison of the Egyptian and Houstonian male shells (EGY-M vs HOU-M), the Egyptian male shell was more protrusive in the malar, perioral, nasal, and mandibular regions as compared with the Houstonian male shell. On the other hand, the Egyptian forehead appears much more sloped and

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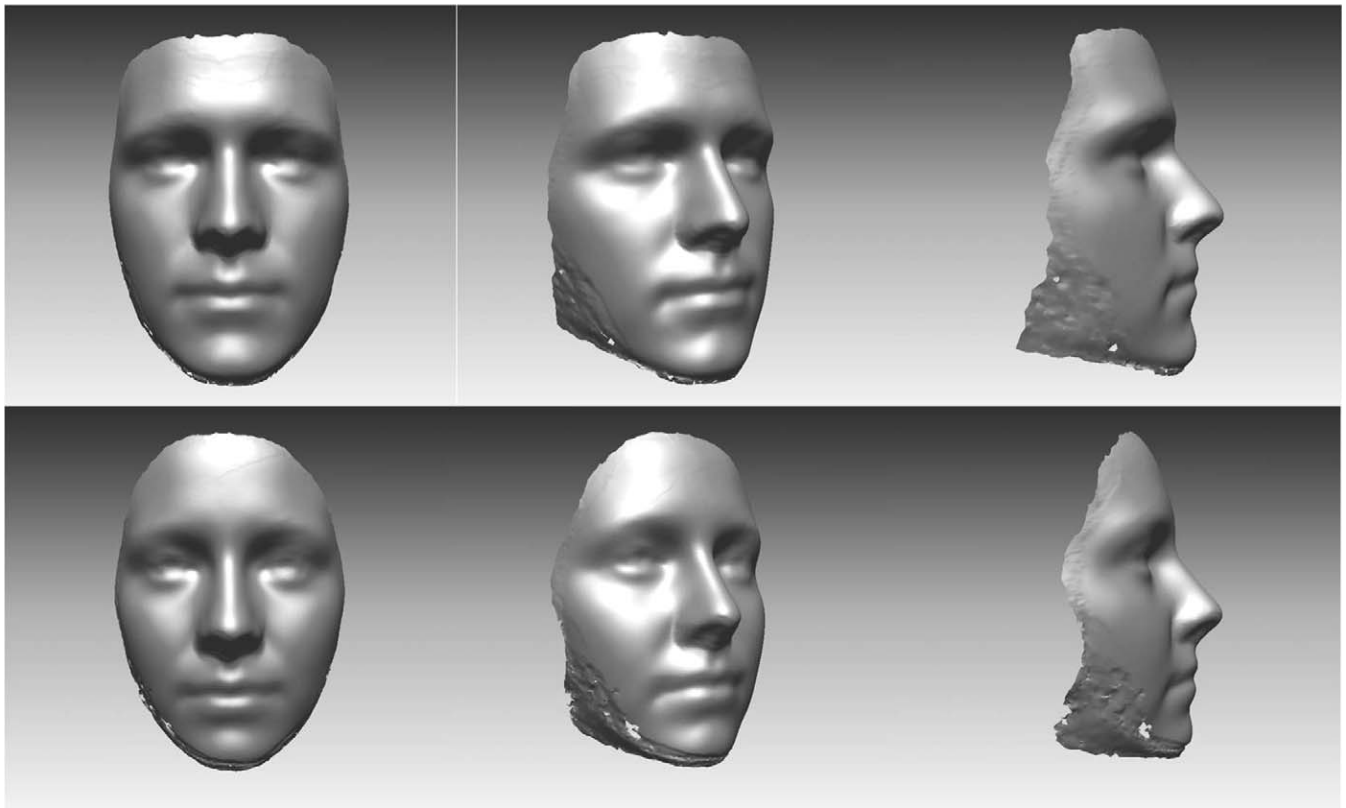

Figure 3. Average facial constructs for the Houstonian male (row 1) and Houstonian female subjects (row 2).

less prominent than the Houston counterpart does. The shells only demonstrated an 18.6% similarity.

Female Subjects

The female-specific subgroup comparison (EGY-F vs HOU-F) also reveals an Egyptian female shell that appears to be more protrusive in the malar, perioral, and mandibular regions as compared to the corresponding Houstonian subgroup. Similar to the male comparison as well is the fact that the Egyptian female forehead is not as prominent as that of the Houstonian female subgroup. Opposite the male comparison, however, is the observation that the bridge of the nose is not as prominent in the Egyptian female subgroups as it is in the Houstonian female subgroup. Overall, the EGY-F vs HOU-F comparison demonstrated a 12.7% similarity.

DISCUSSION

Overall Differences Between Subgroups

In order to determine if differences existed between all of the various subgroups, we analyzed the absolute differences between them, and it was clear that differences do indeed exist. The variation between the shells as depicted by the linear measurements, color histograms, and shapes/areas portrayed differences among the six subgroups, and helped arrive at the conclusion that each should be treated as an independent population. A previous anthropometric study has shown that the establishment of facial databases for different ethnic groups/races is necessary.[17] This study attempted to contribute to such data. One of the limitations was that the images were taken only once and hence detector and equipment error was not recorded.

The differences observed between the subgroups were mainly in the area of the eyes, nose, lips, forehead, mandible, and malar region. Based on our understanding of facial morphology, many of the differences between the female and male subgroups were expected. Further, the differences between the Egyptian and Houstonian subgroups were also anticipated. However, the differences noted in this study are very interesting due to their magnitude, location, and consistency.

Interesting observations can be made between the male and female subjects of the same race. Houstonian and Egyptian female shells have more prominent periocular and malar regions than do the corresponding Houstonian and Egyptian male shells. On the contrary, Houstonian and Egyptian male shells appear to have more prognathic mandibles than do Houstonian

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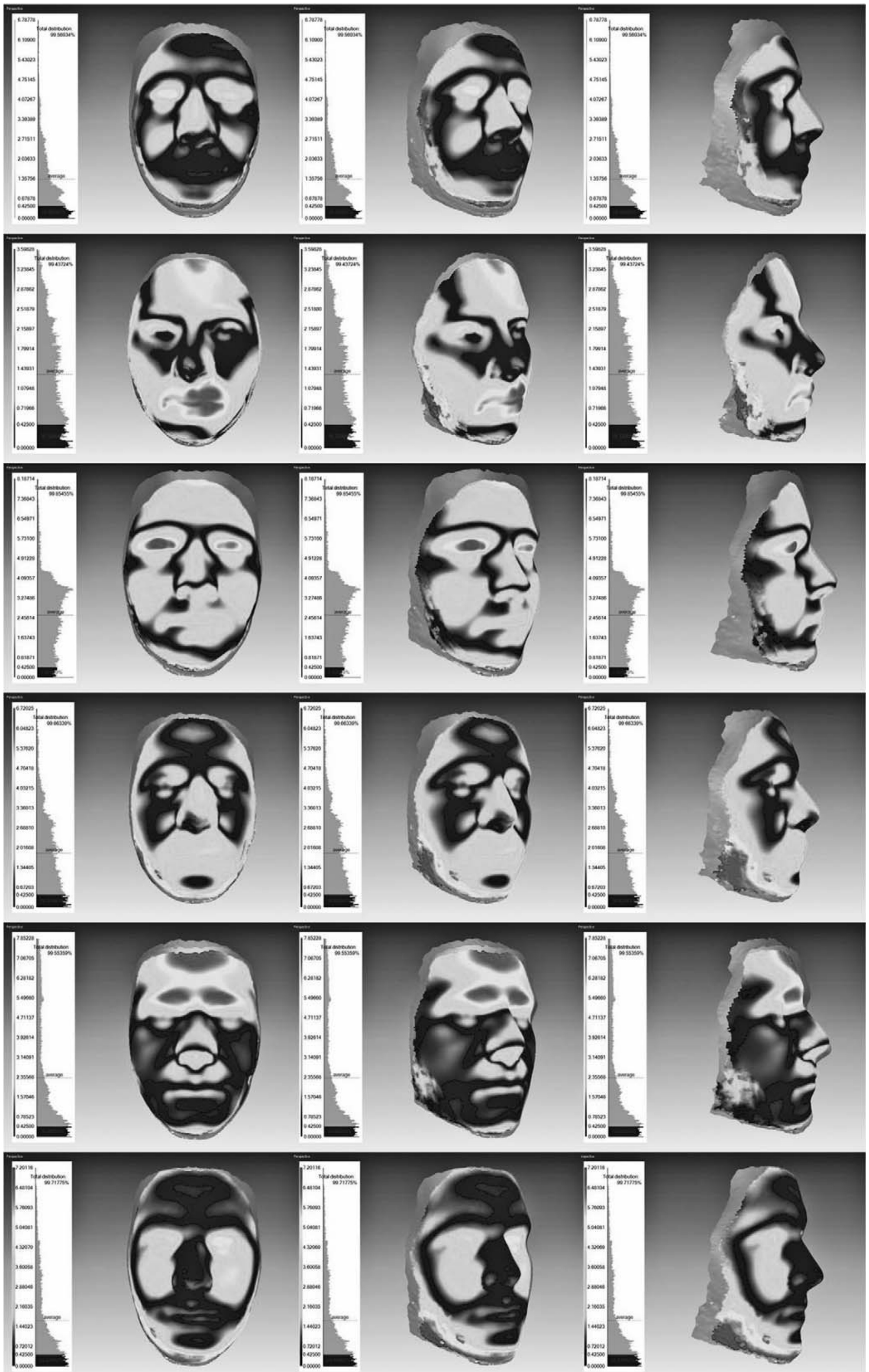

Figure 4. Absolute color histograms and facial mapping showing the facial differences between average shells. Row 1: EGY-F vs EGY-M; Row 2: EGY-F vs HOU-F; Row 3: EGY-F vs HOU-M; Row 4: EGY-M vs HOU-F; Row 5: EGY-M vs HOU-M; Row 6: HOU-M vs HOU-F.

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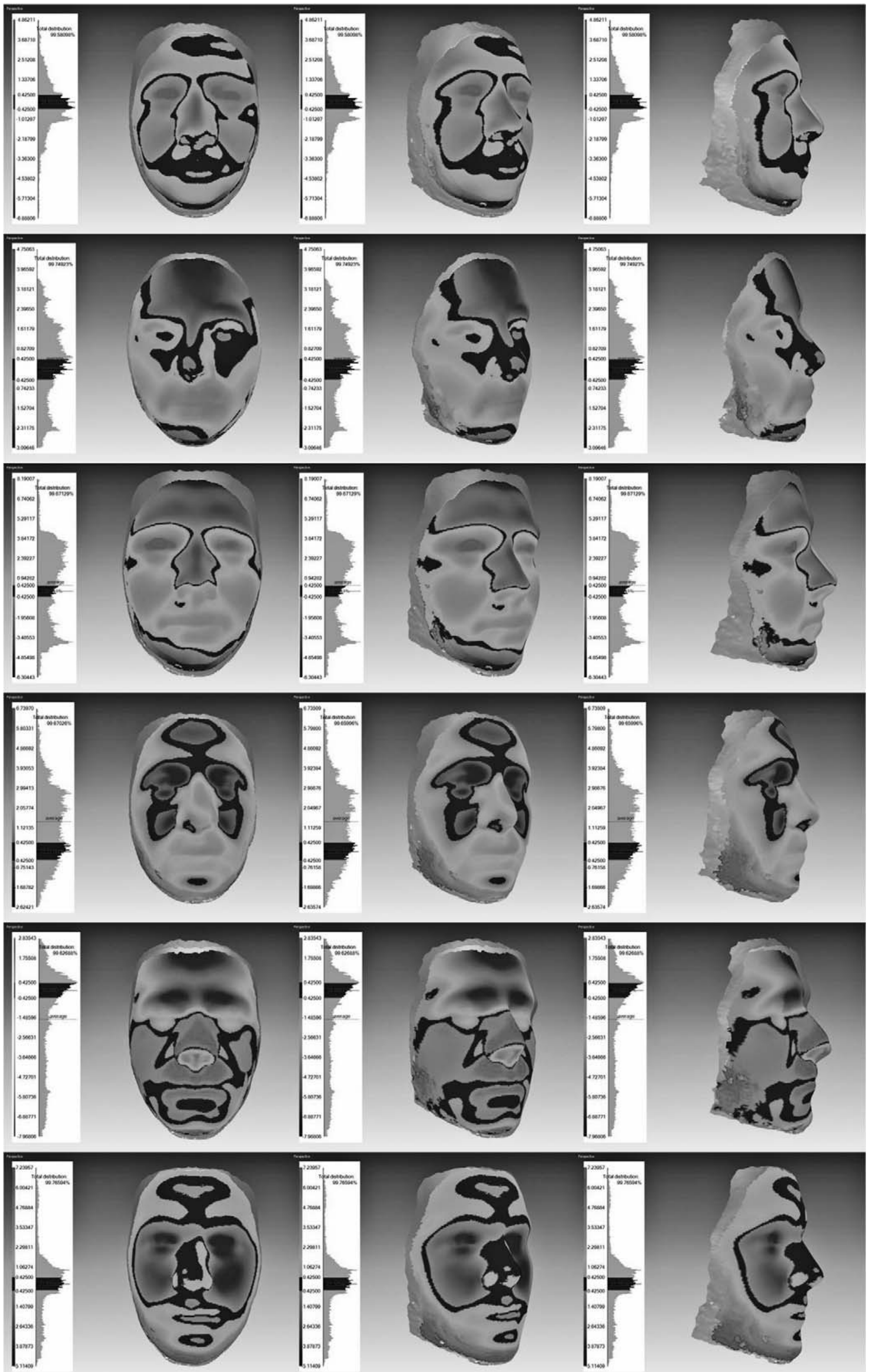

Figure 5. Signed color histograms and facial mapping showing the facial differences between average shells. Row 1: EGY-F vs EGY-M; Row 2: EGY-F vs HOU-F; Row 3: EGY-F vs HOU-M; Row 4: EGY-M vs HOU-F; Row 5: EGY-M vs HOU-M; Row 6: HOU-M vs HOU-F.

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Table 1. Absolute Linear Measurements[a] Indicating Differences Between Facial Shells[b]

	Avg Distance, mm	SD, mm	Max Distance, mm
EGY-F vs EGY-M	1.33	1.29	14.30
EGY-F vs HOU-F	1.33	0.93	14.34
EGY-F vs HOU-M	2.57	1.52	13.13
EGY-M vs HOU-F	1.83	1.41	12.98
EGY-M vs HOU-M	2.32	2.23	13.71
HOU-M vs HOU-F	1.66	1.58	13.21

[a] Avg indicates average; SD, standard deviation; Max, maximum.
[b] EGY-F indicates Egyptian female; EGY-M, Egyptian male; HOU-F, Houstonian female; HOU-M, Houstonian male.

and Egyptian female shells, respectively. However, even though the comparisons of EGY-F and EGY-M and HOU-F and HOU-M yielded similar results as far as the surface/area differences, the EGY-F vs HOU-F and EGY-M vs HOU-M resulted in a low "percent similarity" value: 18.6% similarity for EGY-F vs HOU-F, and 12.7% similarity for EGY-M vs HOU-M. Overall, the Egyptian subgroups had more prominent noses, lips, mandibles, and malar regions and a less prominent forehead as compared with the Houstonian subgroups.

Clinical Relevance

As we diagnose and plan treatment for our patients, it is important to treat them as individuals, and this study made it apparent that differences exist between the two populations included in the study. Although the information acquired as a result of this study refers to soft tissue comparison, it is likely that these differences represent similar differences in the underlying skeletal structures. Therefore, due to the relative overall protrusion of the Egyptian lower face, extractions may be warranted more often in an Egyptian population if this is in accordance with the patient desires. Additionally, this study suggests that Class III treatment may occur more often in male populations, while Class II treatment, including the use of functional appliances, may be performed more often in female populations. Overall, the Egyptian subgroups had more protrusive lips along with a more prominent bridge of the nose. In the Egyptian male subgroup, however, the tip of the nose was more prominent than in the Houstonian male subgroup.

It is important to note, however, that these observations and suggestions are taken from the average facial shells and related superimpositions generated as a part of this study, and may not apply to every patient. This study demonstrated differences in the subgroups involved in the study. However, future research regarding the establishment of 3D norms and evaluation of our current 2D norms is warranted.

Table 2. Signed Color Map Measurements[a] Indicating Differences in Facial Shells[b]

	Avg Distance, mm	SD, mm	Similarity, %
EGY-F vs EGY-M	−0.25	1.84	24.61
EGY-F vs HOU-F	0.30	1.60	12.70
EGY-F vs HOU-M	0.42	2.96	7.08
EGY-M vs HOU-F	1.41	1.83	15.51
EGY-M vs HOU-M	−1.58	2.80	18.60
HOU-M vs HOU-F	0.03	2.30	21.38

[a] Avg indicates average; SD, standard deviation.
[b] EGY-F indicates Egyptian female; EGY-M, Egyptian male; HOU-F, Houstonian female; HOU-M, Houstonian male.

CONCLUSIONS

- Facial averages can be successfully created and utilized in order to compare facial morphology of various ethnic populations and genders.
- Facial morphologic differences were demonstrated between the Houstonian and Egyptian populations that were used as part of this study.
- Egyptian female faces tend to be more prominent in the malar regions, periocular region, and lips as compared with the average white Houstonian female face. On the other hand, they tend to have more sloping foreheads, smaller bridge of the nose, and softer chins.
- Egyptian male faces tend to have lips that are more prominent, malar regions, periocular regions, and larger bridge of the nose as compared with average white Houstonian male faces. Egyptian males, however, have a more sloping forehead and a less prominent tip of the nose and chin.

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