Original Article

Facial Morphology of Slovenian and Welsh White Populations Using 3-Dimensional Imaging

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ABSTRACT

Objective: To use 3-dimensional (3D) facial averages to test the hypothesis that the facial morphologies of 2 European white groups (Slovenia and Wales) have no differences.

Methods: Fifty males and 50 females from Wales and 43 males and 44 females from Slovenia were included in the study. Subjects ranged from 18 to 30 years of age. Four subgroups were formed: Slovenian males (SM), Slovenian females (SF), Welsh males (WM), and Welsh females (WF). 3D data were acquired using a laser scanning system. An average face for each subgroup was obtained using a previously validated mathematical algorithm. Facial differences were quantified after average faces had been superimposed using a previously validated method.

Results: A total of 187 subjects from Slovenia and Wales formed 4 gender-specific subgroups. Absolute differences between subgroups ranged from 0.36 mm to 1.51 mm. The mean linear facial difference between SF and WF was 0.64 $\pm$ 0.51 mm, and between SM and WM was 0.36 $\pm$ 0.41 mm. Similarities between subgroups ranged from 13.43% (SF, WF) to 70.23% (SM, WM). Slovenian males and females tend to express Class III facial morphology when compared with the Welsh gender–specific subgroups. Male faces, in general, have more pronounced nasal, brow, and frontal regions and mandibles when compared with females. Female faces have more prominent malar and periocular areas.

Conclusion: The hypothesis is rejected. Morphologic differences exist between Slovenian and Welsh faces. (*Angle Orthod.* 2009;79:640–645.)

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

INTRODUCTION

Three-dimensional (3D) imaging in orthodontics and maxillofacial surgery has been developing at a fast pace over the past 20 years. Different noninvasive and radiographic methods have been introduced, and they have proved valid and reliable as compared with direct anthropometry.[1] The 3D imaging methods include photogrammetry, laser acquisition systems, structured light systems, video imaging, and x-ray methods such as computerized tomography (CT), cone beam computerized tomography (CBCT), magnetic resonance imaging (MRI), and ultrasound (US).[2]

Clinicians have been using 2-dimensional (2D) diagnostic methods to the present day (lateral and frontal cephalogram, dental panoramic tomogram [DPT], intraoral and extraoral photographs) because 3D systems have been expensive and complex to use. However, technological advances have brought us to the place where acquisition of 3D human data is safe and affordable, and the input is as precise and easy as 3D physical object input. Moreover, to further streamline practice workflow, some practice management and imaging management software applications are being reengineered, so they will be able to efficiently handle and analyze these highly precise 3D data formats.[3]

3D imaging is now being applied for different orthodontic and maxillofacial assessments: 3D treatment planning, preorthodontic and postorthodontic and/or

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surgical treatment, evaluation of postoperative swelling, 3D prefabricated archwires, research, and distinction between different syndromes involving craniofacial deformities.[4,5] 3D imaging using a laser scanning system proved reliable over 3 minutes and 3 days, with accuracy within 0.85 mm.[6] A recent in vitro study using a photogrammetric tool for 3D acquisition showed a system error within 0.2 mm.[7] The 3D CBCT measurements were statistically significantly different from measurements performed on ex vivo skulls in two thirds of measurements, but this statistical significance probably was not clinically relevant.[8]

Data derived from the use of 3D imaging tools to compare facial morphology among different nations are limited. The aim of this study is to use a commercially available laser scanning system and software to compare the facial morphologic differences between white populations from Slovenia and Wales.

MATERIALS AND METHODS

Two uniquely distinct groups were included in this study. Subjects from the first group were invited from the University Medical Centre in Ljubljana, Slovenia, at the Division for Stomatology. Subjects from the second group were invited from the Department of Dental Health and Biological Sciences, Dental School, Cardiff, Wales. Inclusion criteria required that subjects (1) were of white descent; (2) were between 18 and 30 years of age; (3) had no adverse skeletal deviations (a basic orofacial examination was performed to exclude them); (4) had a normal body mass index (BMI)—18.5 to 25; and (5) had no gross craniofacial anomalies.

This study was approved by the relevant institutional review boards. It was conducted according to the principles of the Helsinki-Tokyo declaration. Informed consent was obtained from all subjects.

Imaging System

The laser scanning system consisted of 2 high-resolution Minolta Vivid VI900 3D cameras (Konica Minolta, Tokyo, Japan), with a reported manufacturing accuracy of 0.1 mm, operating as a stereo pair. Each camera emits an eye-safe Class I laser, 690 nm at 30 mW, with an object-to-scanner distance of 600 to 2500 mm and a fast mode scan time of 0.3 second. The system uses a one-half-frame transfer charge-coupled device and can acquire 307,000 data points. The scanner's output data includes 640 $\times$ 480 pixels for 3D and red, green, and blue color data. Data were recorded on a desktop workstation with a 2 GHz Pentium 4 processor (Dell, Wicklow, Ireland). For surface registration, a Minolta medium-range lens with a focal length of 14.5 mm was used. Cameras were placed 1350 mm from subjects. Scanners were controlled with multiscan software (Cebas Computer, GmBH, Eppelheim, Germany), and data coordinates were saved in a vivid file format. Information was transferred to a reverse modeling software package, Rapidform 2006 (RF6) (INUS Technology, Seoul, Korea), for analysis.

Imaging

Images were acquired with subjects in their natural head posture (NHP). NHP proved to be clinically reproducible.[9] Subjects sat on an adjustable chair and were asked to look into an object that was located centrally between cameras. Adjustments to the height and angle were made to achieve NHP and appropriate positioning. Subjects were asked to keep the facial musculature as relaxed as possible, and to stay as still as possible during the scan. Image acquisition took approximately 10 seconds for every patient and was repeated if any movement in the head position or mimic was noted.[6]

Processing of the Images

Images were analyzed with RF6 software. Absolute mean shell deviations, standard deviations (SDs) of errors during shell-to-shell overlaps, maximum and minimum range maps, histogram plots, and finally color maps were generated. The data were processed further before analysis to obtain an image that had a preserved shape, surface, and volume, using custom-made macros for the RF6.[10] Surface defects were filled automatically or manually without loss of raw data material. The result was one composite shell per subject.

Average Face Constructions

Average faces were constructed for the Slovenian male (SM) group, as well as for Slovenian females (SF), Welsh males (WM), and Welsh females (WF). Average construction was performed using a previously validated software subroutine available in RF6. The steps required to produce an average face have already been described[11] and are summarized as follows: (1) Images were prealigned to determine the principle axes of rotation; (2) manual corrections were made to positioning; (3) best fit alignment was ensured by the built-in algorithm in RF6; (4) "z" coordinates of the images were averaged on the basis of normal images to a facial template; (5) point cloud was triangulated to obtain an average face; (6) defects and unwanted areas were removed, and the holes were filled; (7) a color texture was applied; and (8) shells with 1 positive and 1 negative SD were created.

Parameters Measured

Superimpositions of average facial shells for the groups SM, SF, WM, and WF were performed using the previously described technique.[12] Morphologic differences between groups were observed as follows: SM vs SF, WM vs WF, SM vs WM, SM vs WF, SF vs WM, and SF vs WF.

The process of comparing average facial shells involved manual alignment of the 5 points on the facial scans (4 points at the outer and inner canthus of the eyes, and 1 point on the nasal tip), followed by fine alignment performed automatically by RF6.[12] Linear measurements, color histograms, and surface areas and shapes were the parameters used in the study.

Linear measurements. Linear measurements representing the mean differences between 2 surface shells were recorded in millimeters. The value of linear measurement represents the sum of all differences between superimposed surfaces of the 2 shells. This sum could be used as an indicator of the best fit between 2 shells and as an indicator of regions where changes are present on the face.

Color histograms. Color histograms give us an indication of the differences between average facial shells: the blue areas show negative values, and the red areas show positive values.

Surface areas and shapes. Surface areas and shapes were generated automatically by RF6. These shapes were obtained when a previous tolerance of 0.425 mm was applied to the paired surface shell studies. Areas corresponding to 0.425 mm were deemed to be similar; shapes above this tolerance represented differences and were shown as surface shapes and color deviations.

RESULTS

Linear Measurements

Absolute linear differences among average surface shells of the subgroups ranged from 0.36 mm (SM and WM) to 1.51 mm (SM and WF), as presented in Table 1. The absolute linear difference between SF and SM was 0.98 mm, and between WF and WM, 1.29 mm.

Color Histograms

The results of differences between subgroups shown on color histograms are presented in Table 1. Similarities between the subgroups ranged from 13.43% (SM and WF) to 70.23% between male subgroups (SM and WM). The percentage of similarity in Slovenian gender–specific subgroups (SF and SM) was 20.43%, and in Welsh gender–specific subgroups (WF and WM), 16.37%.

Table 1. Linear and Average Shell-to-Shell Distance and Standard Deviation, Percentage of Similarity for the Subgroup Pairs

Groups/	Linear Distance		Shell-to-Shell Average Distance		Similarity,
Parameter[a]	mm	SD	mm	SD	%
SM-SF	0.9798	0.5965	0.10007	1.1427	20.4200
SM-WM	0.3637	0.4105	0.12393	0.5341	70.2340
SM-WF	1.5073	0.9506	0.22156	1.7682	13.4252
SF-WM	0.8357	0.6408	0.23211	1.0273	29.2628
SF-WF	0.6380	0.5060	0.06989	0.8081	43.6680
WF-WM	1.2864	0.8250	0.10403	1.5246	16.3722

[a] SM indicates Slovenian males; SF, Slovenian females; WF, Welsh females; and WM, Welsh males.

Differences Regarding Shape and Area

Subgroups differed in terms of shapes and areas of the face. These differences were shown with the color histogram (Figure 1). The surface area that varied most was between SM and WF subgroups. Differences between SM and WF were mainly present in the area of the eyes and were spreading to the malar area. The SM average shell most differed from the SF average shell in the areas of the eyes, nose, malar region, and mandible. The WF and WM groups also exhibited greatest differences in the malar regions, the areas of the eyes, and the mandible. The SF and WF groups differed most in the areas of the eyes, malar region, mandible, and upper lip. The SM and WM differed in the areas of the eyes, nose, mandible, and upper lip.

Females. The periocular, perinasal, and malar areas of the SF subgroup are less protruded than those of the WF group. On the other hand, the mandible in the SF subgroups is more protruded and wider. The upper lip of the SF group is more pronounced than that of the WF group (Figure 2).

Males. The SM group has a farther protruded mandible when compared with the WM group, and the tip of the nose of the WM is more pronounced. The upper lip of the WM is a little more prominent than that in the SM subgroup. Subtle differences in the areas of the eyebrows are also evident. The masseteric area of the WM group seems more pronounced (Figure 3).

DISCUSSION

3D imaging in orthodontics and maxillofacial surgery has been developing at a fast pace over the past 20 years. In this study, 3D data were obtained with a noninvasive laser scanning device. Differences between the 2 populations of European descent were depicted (Slovenian and Welsh, respectively) using a previously described method of averaging faces.[11] Standard anthropometric measurements are still being used to estimate differences between the faces of different de-

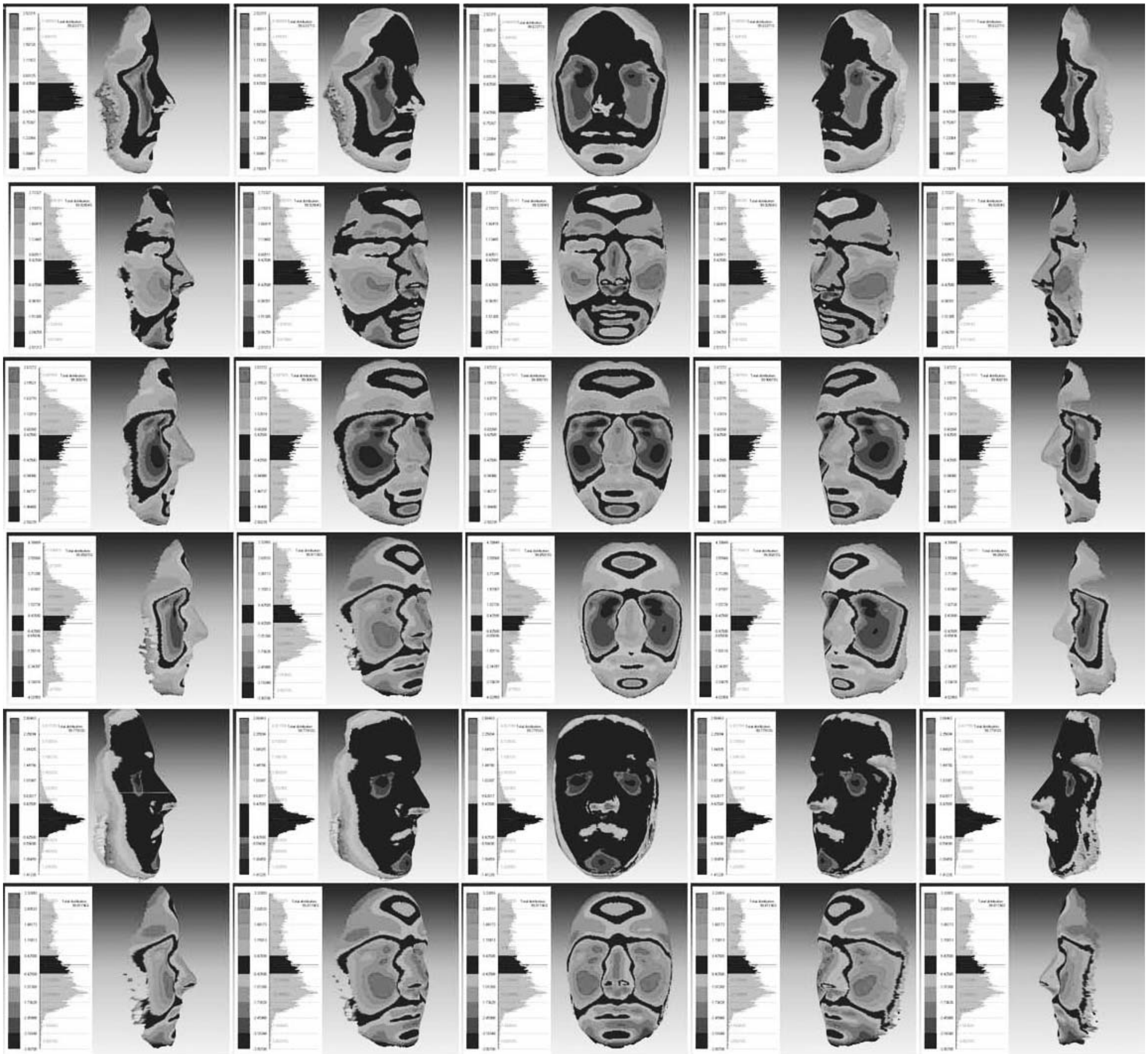

Figure 1. Differences regarding shapes and areas. *From right to left:* right profile, right semiprofile, frontal view, left semiprofile, left profile. *From top to bottom:* SF-WF, SF-WM, SM-SF, SM-WF, SM-WM, WF-WM. SM indicates Slovenian males; SF, Slovenian females; WM, Welsh males; and WF, Welsh females.

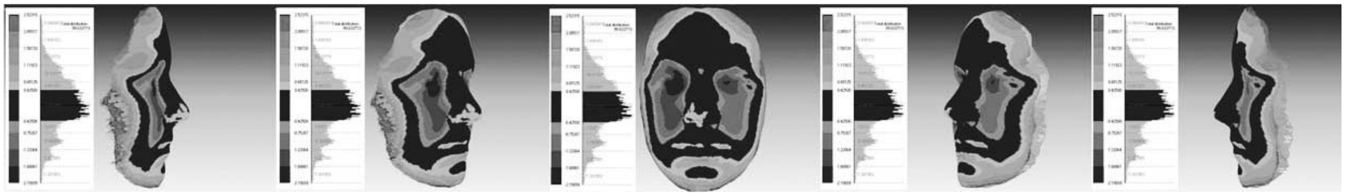

Figure 2. Differences regarding shapes and areas for the superimposed SF-WF. SF indicates Slovenian females; WF, Welsh females.

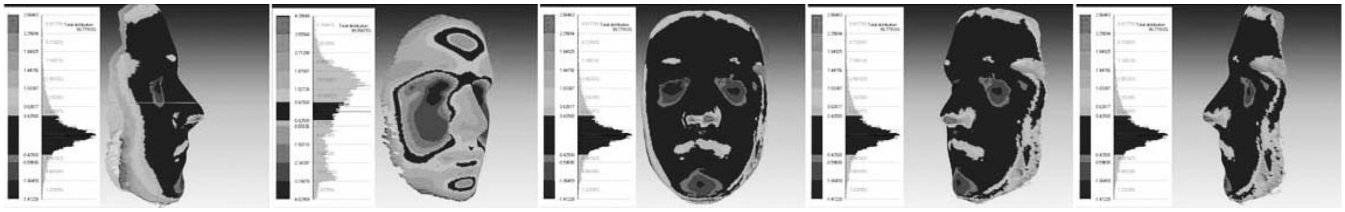

Figure 3. Differences regarding shapes and areas for the superimposed WM-SM. WM indicates Welsh males; SM, Slovenian males.

scents.[13] A "mega project" using standard anthropometric measurements showed that establishment of facial databases for various ethnic groups/races is essential.[14]

Furthermore, it was shown that 3D imaging with laser scanning devices can be used reliably and with great accuracy.[15,16] The 3D average face has already been used in several studies. It has been used to distinguish people with Noonan's syndrome,[4] to compare different groups of orthodontically treated patients (ie, postextraction groups vs nonextraction groups),[17] and to detect growth changes among children.[18] In this study, average facial templates were used to discover differences in the facial morphology of white Slovenian and Welsh populations.

In comparisons of the absolute linear measurements of the subgroups, differences were noted mainly in the areas of the eyes, nose, upper lip, malar region, and mandible. The differences between male and female gender subgroups were expected for obvious reasons. In a study that included people of different ethnicities, the fronto-occipital circumference and the outer canthal distance of males were shown to be significantly ($P < .01$) wider than those of females in all age groups.[19] According to our study, the males from Slovenia and Wales have more pronounced noses, brow and frontal regions, and mandibles when compared with females from both countries. Females from Slovenia and Wales have more prominent malar regions and periocular areas when compared with males from both countries. It is interesting that the similarity between SM and WM was as high as 70.2%, but between SF and WF, it was only 43.7%. The comparison of SF vs WM showed a similarity of 29.3%, but between SM and WF, it was only 13.4%.

The data on facial soft tissues are based most often on cephalometric measurements in orthodontics. The 3D surface acquiring systems, however, are becoming more readily available and are accurate and reliable. The findings of this study have shown that male and female faces in Slovenia and in Wales differ in the same areas: nose, malar region, and mandible. However, differences between Slovenian and Welsh males show that the Slovenian mandible is more protruded. This could mean that Slovenian males tend to belong more to the skeletal Class III, in contrast to Welsh males. The same conclusions can be drawn when the Slovenian and Welsh female subgroups are compared: Slovenian females tend to belong more to skeletal Class III as compared with Welsh females. These results could be clinically important, given the indications for a functional appliance in orthodontic treatment. The results include an average face built only from our small database though, and larger studies are needed. Additional 3D imaging studies will reveal the differences and similarities between persons of different descent and will help to create new 3D norms, which eventually will replace the traditional 2D cephalometric norms. The 3D norms of the faces of different races will lead to better surgical and orthodontic corrections of facial irregularities.

CONCLUSIONS

- Facial morphologic differences between white populations from Slovenia and Wales were noted using a commercially available laser scanning system and software.
- Slovenian males and females tend to better express Class III facial morphology as compared with Welsh gender–specific subgroups.

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