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COMPARATIVE ANALYSIS OF BIOMETRIC MEASUREMENTS OF FACE GEOMETRY OBTAINED WITH THE USE OF DIRECT MEASUREMENTS, PHOTOANTHROPOMETRY AND 3D SCANNING

Kawlewska E.[*], Czarnecki P.[**], Lipowicz A.[***], Graja K.[†], Gzik-Zroska B.[‡], Joszko K.[§], Gzik M.[¶], Wolański W.[‖]

Abstract: *The article presents methods of acquiring face morphometric data using direct measurements, 2D photoanthropometry and 3D scanning. The aim of the work was to compare the accuracy of the dimensions. In the study 15 students at the age of 22-24 years were examined. Subsequently 13 linear dimensions of face were measured with the use of a caliper on the test persons, as well as on 2D photos and on 3D models in the scanner software. Percentage differences of the obtained measurements were calculated in order to check the occurring deviations. In addition, Bland-Altman plots were created for a few selected parameters to assess the compliance of the measurement methods. Three-dimensional scanning has been found to be the optimal method of obtaining reliable anthropometric data.*

Keywords: Anthropometry, 3D face models, 2D biometric photography, Morphometry, Accuracy.

1. Introduction

Face morphometric tests are widely used, e.g. in the assessment of height, in the assessment of occlusal defects, skeletal defects, supporting the design of individually fitted implants, orthodontic appliances, as well as in forensic science and other (Baca et al., 1994; Graja et al. 2019; Lipowicz et al. 2021; Tejszerska et al. 2011)**.** To assess the craniofacial growth or development, whether create standards for certain morphological parameters, assess the severity of some craniofacial defects, it is useful to collect this type of data obtained at specific time points (e.g., every 3 months). The simplest method, that is being used for a few dozen of years, is photoanthropometry, in which the examined person is photographed, and then the distances between characteristic anatomical points that can be marked are measured in the photos. Nowadays the modern 3D scanners are beginning to supersede the conventional 2D methods and allow to perform the quantitative and qualitative morphometric assessment on 3D volumetric models. The accuracy of measurement methods is constantly increasing due to technological development. The application and comparison of these new technologies is of interest to researchers. (Anas et al. 2019; Ayaz et al.; 2020, Lim et al. 2021; Zogheib et al. 2019). The aim of the research was to compare and

[*] Dr Edyta Kawlewska, PhD. Eng.: Department of Biomechatronics, Silesian University of Technology, Roosevelta 40; 41-800 Zabrze; PL, edyta.kawlewska@polsl.pl

[**] Eng. Paweł Czarnecki, BEng.: Department of Biomechatronics, Silesian University of Technology, Roosevelta 40; 41-800 Zabrze; PL, pawecza304@student.polsl.pl

[***] Assoc. Prof. Anna Lipowicz, DSc.: Department of Anthropology, Institute of Environmental Biology, Wroclaw University of Environmental and Life Sciences, 50-375 Wroclaw; PL, anna.lipowicz@upwr.edu.pl

[†] Katarzyna Graja, MSc.: Department of Anthropology, Institute of Environmental Biology, Wroclaw University of Environmental and Life Sciences, 50-375 Wroclaw; PL, katarzyna.graja@upwr.edu.pl

[‡] Dr Bożena Gzik-Zroska, PhD. Eng.: Department of Biomaterials and Engineering of Medical Devices, Silesian University of Technology, Roosevelta 40; 41-800 Zabrze; PL, bozena.gzikzroska@polsl.pl

[§] Dr Kamil Joszko, PhD. Eng.: Department of Biomechatronics, Silesian University of Technology, Roosevelta 40; 41-800 Zabrze; PL, kamil.joszko@polsl.pl

[¶] Prof. Marek Gzik: Department of Biomechatronics, Silesian University of Technology, Roosevelta 40; 41-800 Zabrze; PL, marek.gzik@polsl.pl

[‖] Assoc. Prof. Wojciech Wolański, DSc. Eng.: Department of Biomechatronics, Silesian University of Technology, Roosevelta 40; 41-800 Zabrze; PL, wojciech.wolanski@polsl.pl

evaluate the measurement accuracy of three methods: direct measurements (DM), 2D photoanthropometry (2D), and 3D scanning (3D) used in morphological research.

2. Methods

The research was carried out on a group of 15 healthy people aged 22-24 years. All volunteers gave informed written consent for participation in this study. Before the examination, characteristic points were marked on the patients' faces (Tab. 1). Markers allowed for precise marking of points with three different methods: caliper (accuracy 0.05 mm), 2D photoanthropometry and 3D scanning. The pictures were taken with a Canon camera *(Canon Inc., Ōta, Tokyo, Japan)* with the flash in the 'en face' position so that the line joining the center of the nose and the center of the ear was parallel to the ground. The distance between the camera and the subject was 2 meters, and the set parameters of the camera were: focal length 70 mm, diaphragm equaled 5.6, exposure time 1/125 s. To obtain 3D models it was used the iReal 2E Scantech scanner *(Scantech Gmbh, Andernach, Germany)* enabling measurements with an accuracy of 0.05 mm and simultaneous texture registration (Fig. 1).

Tab. 1: Linear measurements of face defined by the anatomical points

Measurement	Landmarks symbols	Description
exocanthion.l-exocanthion.r	***ex.l-ex.r***	the width between the outer commissure of the left and right eye fissures
zygion.l-zygion.r	***zy.l-zy.r***	the maximal width of face
zygion.l-pogonion ***zygion.r-pogonion***	***zy.l-pg*** ***zy.r-pg***	left and right zygomatic height of face
nasion-pogonion	***n-pg***	the height of face
exocanthion.l-pogonion ***exocanthion.r-pogonion***	***ex.l-pg*** ***ex.r-pg***	left and right height of face
alare.l-alare.r	*al.l-al.r*	the width of nose
endocanthion.l-endocanthion.r	*en.l-en.l*	the width between the inner commissure of the left and right eye fissures
cheilion.l-cheilion.r	*ch.l-ch.r*	the width of mouth
gonion.l-gonion.r	*go.l-go.r*	the width of mandible (gonial distance)
gonion.l-pogonion *gonion.r-pogonion*	*go.l-pg* *go.r-pg*	left and right length of ramus

Fig. 1: Exemplary model of face with marked anatomical points, obtained with the use of iReal 2E three-dimensional scanner

For the analysis, 13 linear measurements of the face were selected (Tab. 1). Each of the parameters was measured three times:

1. Direct measurement (DM) on the examinated person, with the use of a caliper.
2. Two-dimensional measurements – the distances were measured on printed photos and calculated according to the scale, that was determined for each photo separately.
3. Spatial measurements in the scanner's software *(RealView)*, that enables to perform some basic measurement directly on the prepared model (each distance were measured manually).

All measurements were carried out by one researcher, to avoid errors due to different point identification. The actual and percentage measurement errors between the three data acquisition methods were analyzed.

3. Results

Firstly, Bland-Altman plots (Bland & Altman, 1999) were created for the measurements with comparable values (Tab. 1 – bold font) in order to illustrate the compliance of the measurement methods. To confirm the agreement of the mentioned methods, it is recommended that min. 95% of the collected data were within the range called the limit of agreement (LOA), which is equal to ± 1.96 SD of mean differences. With regard to the presented studies, a significant difference of LOA range between the 2D and 3D as well as 2D and DM methods was revealed – for 3D scanning it is about 7.0 mm and for 2D method in comparison with DM and 3D the same range is equal to 15.0 mm. It should also be noted that the data spread for DM-3D is symmetrical, while for DM-2D and 2D-3D it is significantly biased (Fig. 2).

Subsequently, the lengths of all analyzed parameters were compared between the presented measurement methods. The absolute values of the percentage differences between the measurements made on the test person, the photo and the 3D scan were calculated then.

The graphs (Fig. 3) show the percentage differences obtained in the three methods of parameters measurements. It should be noted that the maximum deviations for most dimensions oscillate around 6%, and for 3D scanning they are not exceeding 3%, but for measurements based on *gonion* points, the deviations measured on the photos are even 10 times greater, which is due to the inability to mark the *gonion* points in the front view photo.

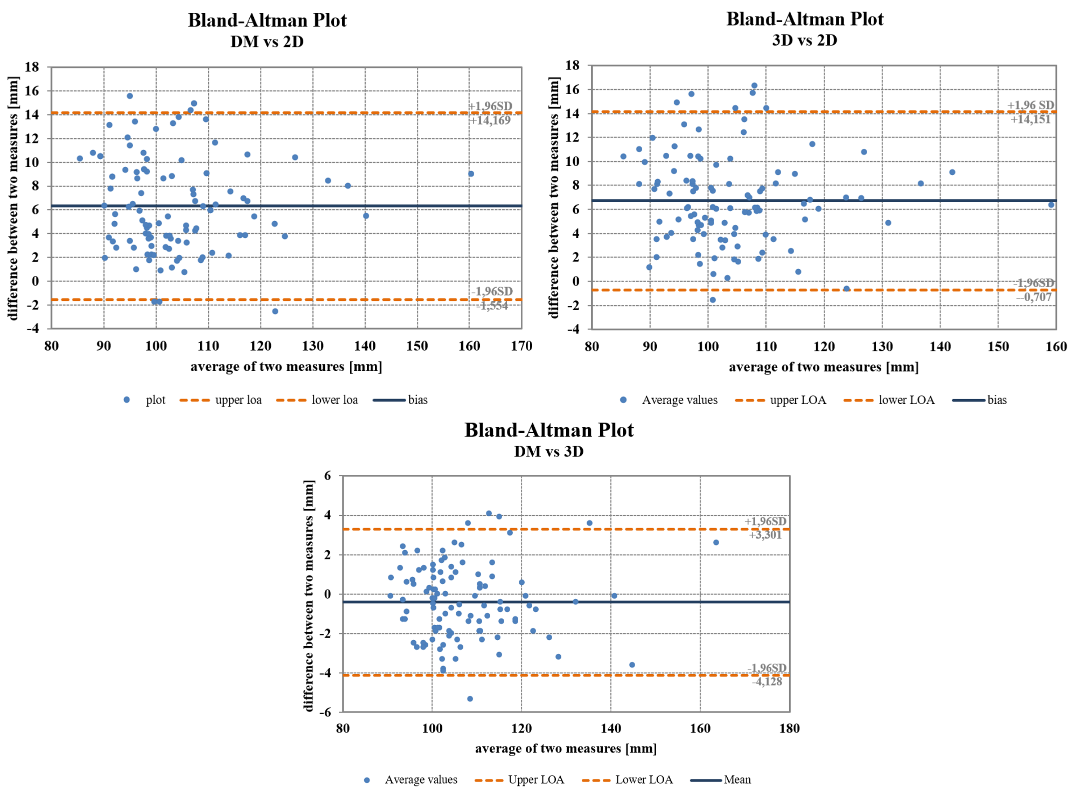

Fig. 2: Bland-Altman plots comparing three measurement methods: a) direct measurements and 2D, b) 3D and 2D, c) direct measurements and 3D

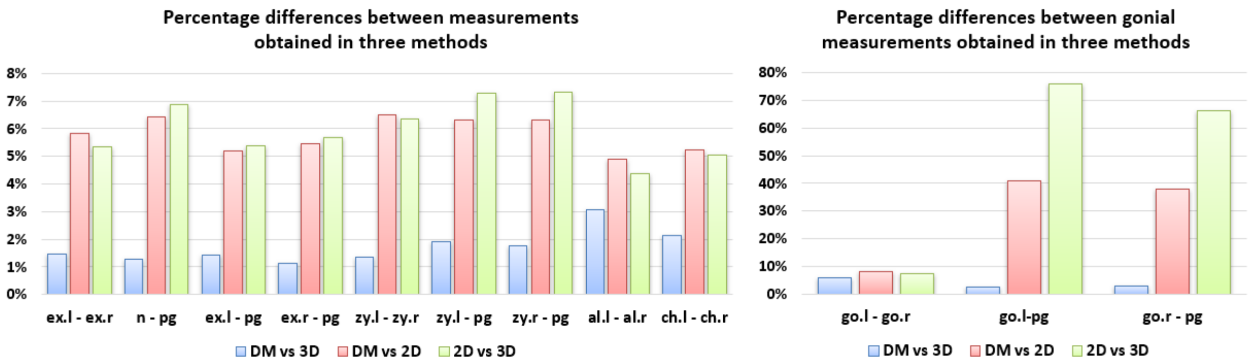

Fig. 3: Percentage differences of selected linear dimensions for three measurement methods

4. Conclusions

The article presents an independent crosscheck verification of three measurement methods used in morphometric studies (direct measurements, 2D and 3D). The iReal 2E scanner used in the research allowed for very fast and accurate three-dimensional data acquisition (the time of the 3D examination with measurements was approx. 5 minutes, which is about two times less than with a traditional photoathropometry. The average measurement error in 3D method was ~2%, while with the use of photoanthropommetry it was about 7%. Additionally, there are some limitations in marking anatomical points in the photo. Research has shown that gonial distances can be unreliable, and the 2D measurements are not very accurate due to the considerable difficulty in marking points in the photograph.

The conducted analyzes confirmed that 3D scanning is the optimal method of obtaining reliable anthropometric data. However, relatively small measurement errors of the 2D method (~5-8%) do not exclude photogrammetry, especially since it is a cheaper and more accessible method than professional 3D scanning.

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