 DOI: 10.21608/adjalexu.2023.219558.1392

A comparative evaluation of mobile photogrammetry for facial scanning. Face banking

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ABSTRACT

INTRODUCTION: In the last few years, a dramatic development of biometrical recognition systems had evolved, due to increased attention to security. Face scanners are widely used in the medical and dental fields, facial recognition, capturing facial emotions, facial cosmetic planning, and surgical reconstruction. Although various face scanners are available, there is no evidence of a suitable face scanner for practical applications.

AIM OF THE STUDY: To evaluate the reliability of 3D facial models obtained by different numbers of 2D mobile photogrammetry images on being compared to linear facial 2D point measurements, to be used as viable medical records for the face banking concept.

MATERIALS AND METHODS: One healthy adult female volunteer participant with a normal face form was selected from those admitted to the prosthodontic department. Using mobile photogrammetry, different counts (60,90, and 120) of 2D images were used to build 3D models which were compared with the real linear face 2D measurements for selected interpoint distances.

RESULTS: Deviation of the anthropometric distances was statistical significance was observed between the real face measurements and all the photogrammetry test groups (P-Value <0.001).

CONCLUSION: Mobile photogrammetry with a regular smart iPhone demonstrated a reliable face scanning methodology of lesser complexity to obtain 3D facial models. Face banking may be suitable in areas where high technology is not available and where healthcare providers and medicolegal authorities can utilize such affordable technology.

KEYWORDS:face scanners, photogrammetry, facial banking imaging, Virtual reality, 3 dimensional analysis

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INTRODUCTION

The human face demonstrates anatomical and physical landmarks of a human's identity. (1) Facial form is of great interdisciplinary concepts, such as craniofacial-maxillofacial surgery, anaplastologists, biometrics, and forensic odontologists (2,3,4).

Conventional two-dimensional (2D) photography is assessed by linear facial measurements with the use of a Vernier caliper (2,5). Recently, with the great advancement in technology and the evolution of different digital scanners whether for dental or facial purposes, the shift from 2D to three-dimensional (3D) technology showed a massive improvement. The facial biometry can be easily detected by different scanning methodologies and can be recorded digitally generating 3D face models. (6)

With the huge improvement of HD cameras and powerful smartphones in the market, photogrammetry technology has been established as an easy and accurate approach to recognizing and scanning facial features. These devices are regarded as an inventive and cost-effective method of 3D scanning (7,8). Capturing 2D photographs or even videos is considered an easy process, developing images that can be downloadable and high quality. With the help of open software to produce 3D models, preserving such images and 3D models showed a significant and remarkable impact in the field of biobanking. It can be utilized in facial recognition, facial emotions registration, facial surgery, and anaplastology rehabilitation. (9-12)

The use of high-technology scanners influences the quality of the outcome. High-technology face scanners improve the quality of the produced database that are recorded from such face scanner. (13) Although various face scanners are available in the market, there is no particular and absolute evidence of a suitable scanner for practical applications. (14,15)

Moreover, in developing countries where advanced technology is not feasible, the use of affordable low-cost technology can be adequate to bank the facial features better than no records.

Building a digital model enhances patient communication and motivation and can simplify a lot of clinical procedures carried out by both anaplastologists and surgeons. [16-18]

Therefore, the aim of this study was to analyse the reliability of using mobile photogrammetry obtained from a different number of images that are used to build 3D models, as well as the evaluation of the accuracy of constructed models on being compared with the control liner 2D facial measurements using Vernier caliper.

The null hypothesis of this study was that there was no statistically significant difference in the accuracy of the 3D facial models produced from different counts of images obtained using mobile photogrammetry to match with 2D linear facial measurements.

MATERIALS AND METHODS

The clinical study was approved by the ethical committee of the Faculty of Dentistry-Alexandria University under the no (0364-12/2021). One healthy volunteer female adult participant with a normal face form was selected from those admitted to the Department of Prosthodontics, Faculty of Dentistry, Alexandria University. Clinical procedures and possible complications were explained to the participants, who were approved to sign an informed consent considering the 1975 Declaration of Helsinki, revised in 2013.

The inclusion criteria were having volunteered participant of 28 years old, with an integral face form and fully maxillomandibular dentition. no history of any acquired or congenital defects was reported. Exclusion criteria of any medical condition such as epilepsy or other seizers attacks that might interfere with the steadiness during scanning using any of the techniques. This study is a standard diagnostic evaluation study **(Figure 1).**

A total of 60, 90, and 120 2D photos were captured each time using I phone 13 for the participant. 2D photos were repeated 10 times for each count of images, which were captured based on the modification of the original technique that was provided by Salazar et al. [19] Using a 30 cm distance between the operator's eyes and the camera, with the mobile at the same eye-height position. Photos were captured at three different heights, but with a larger number of captured images on three different levels than that provided by the original technique: The first level is the stand up-height of the operator and the mobile camera at 1.50 m of height from the floor. (20, 30, and 40 photos), With the operator seated on the moveable chair at its maximum adjustable height and maintaining the mobile camera at 1.25 m from the floor. (20, 30,40 photos) and the third level with the operator seated on the chair at its lowest adjustable height with the mobile device at 1 m of height above the floor. (20, 30,40 photos). The captured photos were all taken at each height with a standard room illumination and the same operator at different angles (0°, 45°, 90°, 135°, and 180°). All captured images were made the same day and using a tripod holder for the I phone.

The sample size was calculated to be 30 3D models (n= 10 3D models per group), assuming a 5% alpha error and an 80% study power using Rosner's method by G*Power 3.1.9.7. [20,21] Normality was checked using descriptive statistics, plots (Q-Q plots and histogram), and normality tests.

Methodology of Comparison.

The images captured by a smart device were imported and integrated using -Meshmixer software 3.5 (Autodesk Inc. San Rafael, California, USA) to construct a 3D face model producing STL file. **(Figure 2)** Artifacts were removed, and the model was cut off to the edges of the face in which the file was then exported, again in STL format. The first kind of comparison was made clinically between different models related to the same number of images, and then across groups to produce 3D models.

A linear comparison was made using the following 8 points (medial canthi, lateral canthi, commissures of the mouth, and alae of nose) of the 3D models for each group to evaluate the projection of the finest grid to normal linear 2D measurements using Geomagic software (Control X 2022; 3D Systems). **(Figure 3)** As well as, clinical evaluation of the imaging capturing duration for each protocol of images, besides the operator learning curve in the reproducibility of well-captured images.

Normality was checked using descriptive statistics, plots, and normality tests. Comparisons of different measurements between Photogrammetry (P) in several images 60,90 and 120 as P1, P2, and P3 respectively were done for normally distributed variables. The significance level was set at p-value <0.05. Data were analyzed using one-way repeated measure ANOVA followed by Post hoc LSD (Fisher's least significance difference) using IBM SPSS for Windows (Version 26.0).

Figure 1: Normal captured face image**.**

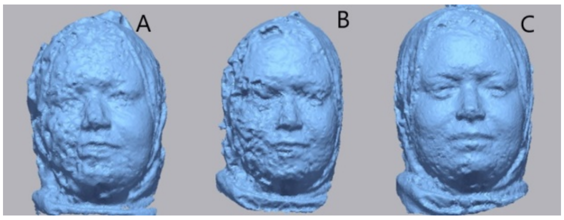

Figure 2: Different 3D models of mobile photogrammetry using different number of images, (60,90,120) respectively. (Fig 2A, Fig 2B and Fig 2C)

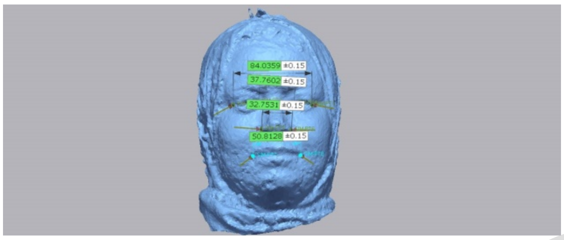

Figure 3: linear inter- points measurements using Geomagic software comparison for model obtained by 120 images.

RESULTS

Deviation of the anthropometric distances was calculated for all previously defined data sets in the form of linear measurements. Using one-way repeated measure ANOVA, mobile photogrammetry (60, 90, and 120) images deviated from the real measurements and showed a statistically significant difference of P-value < 0.001 by a range of 2-10 mm as measured clinically**. (Table 1)**

Using Post hoc LSD (Fisher's least significance difference) comparisons of real dimensions versus mobile photogrammetry between study groups, there was a statistically significant difference between models produced by different numbers of images with the conventional one where the P-value <0.001, in which the use of 120 images showed a more clinically produced 3D model that resembles more clinical features of the participant's face. **(Table 2)**

Table 1: Comparison of real dimensions versus mobile photogrammetry using different numbers of images with one-way repeated measure ANOVA

Anthropometric measurement N=10	Real dimensions Mean (SD)	120 images Mean (SD)	90 images Mean (SD)	60 images Mean (SD)	P value
Medial canthi	36(0)	37.36(0.40)	40.98(0.18)	46.23(0.22)	<0.001
Lateral canthi	80(0)	84.70(0.33)	88.42(0.20)	91.49(0.34)	<0.001
Nasal alae	33(0)	32.66(0.27)	34.41(0.34)	35.65(0.44)	<0.001
Mouth commissures	45(0)	50.75(0.35)	52.37(0.31)	60.36(0.35)	<0.001

Statistical significance is set at the P-value ≤0.05.

Table 2: Post hoc LSD (Fisher's least significance difference) comparisons of real dimensions versus mobile photogrammetry between study groups.

Anthropometric measurement	Group	Compared to	P value
Medial canthi	Real	120	<0.001
		90	<0.001
		60	<0.001
	120	90	<0.001
		60	<0.001
	90	60	<0.001
Lateral Canthi	Real	120	<0.001
		90	<0.001
		60	<0.001
	120	90	<0.001
		60	<0.001
	90	60	<0.001
Nasal alae	Real	120	0.003
		90	<0.001
		60	<0.001
	120	90	<0.001
		60	<0.001
	90	60	<0.001
Mouth commissures	Real	120	<0.001
		90	<0.001
		60	<0.001
	120	90	<0.001
		60	<0.001
	90	60	<0.001

Statistical significance is set at the P-value ≤0.05

DISCUSSION

The constant advancement of reverse engineering RE techniques is being enhanced in the biomedical field leading to the ability to measure and digitize human parts. With the significant impact on the development of biometry, the implementation of the face banking concept as medical recording data is deemed clinically acceptable. [22-24]

With the high risks related to bacterial as well as viral infections, burns, and even tumors, preserving such 3D models as medical recording databases to be utilized as a viable method. The banking concept has been introduced to the community in the form of tissues, cells, and organoids, However, the human face is not less important than its cells and tissues. Therefore, facial banking is of great importance to the community to document and preserve the face form before any face deformity or in case of facial recognition purposes. [25,26]

The use of different face scanners to obtain 3D facial models are being popular over the recent decades, especially in the field of anaplastology and plastic surgery. There are several ways to utilize face scan images, such as in evaluating the reliability of recent technology machines to produce 3D models that resemble human face morphology or to allow facial reconstruction in case of any loss. Despite the presence of different technologies, the reproducibility and efficacy of such produced models to clinically simulate the patient was found to be profound but still debatable. [5,6,27]

In the current study, the use of smart mobile devices such as Iphone 13 to construct 3D models generated from 2D photographs was found to be a reliable method that produces accurate data of the normal face form. There was a higher clinical significance in using 120 images in comparison to 60 and 90 images to produce a reliable 3D model. Although photogrammetry is not a high-precision technology but deemed clinically acceptable. However, it can be used as a viable methodology to produce 3D models which are of low cost and easy to obtain. [28] Implementing mobile photogrammetry as a diagnostic facial protocol was found to be practical, affordable, and technique friendly with dental and medical practitioners. Facilities that cannot provide high-technology scanners, can utilize mobile photogrammetry as a viable technique for face banking and data recording.

Since imaging technology for face recognition was found to be dependent on illumination and pose variation. [23] In the current study images were captured same day and using the same illumination to allow reliability of testing as well as maintaining a tripod stand for the mobile in which the patient is seated while the operator rotates around the patient to capture images from different angles with equidistance between operator and participant.

The study concluded that the imaging technique emphasized the need for a skilled operator with which the duration ranged from 8-10 minutes However, experience with regular clinical data imaging showed a significant improvement in the learning curve of the operator between the first imaging model and the final imaging one. This finding was consistent with the improvement of skills in practice to produce high-quality imaging. Therefore, the skill of the service provider was found to be of significance in producing a quality image with less time than that produced by beginners. [28]

In the present study, the distortion of 3D models produced from 60 and 90 images was significant with a value of more than 5 mm in which the partial face was distorted because of image stitching as well as using dark head covers showed the production of shadow during the imaging phase. In which the deviation within each group was significantly observed in both commissures and intercanthal distances, this was concluded to be a result of normal body reflexes such as eye blinking and swallowing. While for the 120 images, it had the least impact in relation to the other test groups, due to the larger number of images that allowed proper stitching during 3D model construction. The linear measurements for photogrammetry models using 60 and 90 images were technically not comparable, as a huge distortion showed measurement deviation from the normal face measurement.

The main disadvantage of mobile photogrammetry present in the study was the need for many captured images to build a detailed 3D model that produces a reliable model of similar conventional measurements. This finding was consistent with Bartella et al [20] who stated that there were, an average, number of photos required, and then being fused which was deemed to be unsuitable to be used as a routing protocol.

Therefore, the null hypothesis was rejected, and it proved that to assess the geometric reliability, the 3D model produced by a higher no of images 120 allowed a clinical polygonal algorithm pattern that reproduces the normal face grid deemed clinically more acceptable, However, it caused a burden on the participant to be fixed during capturing images.

CONCLUSION

Virtual reality technology is undergoing massive technical development and clinical re-evaluation; however, Smartphone scanning is more intuitive and could be preferable in different scanning facilities. In remote areas or facilities that cannot provide high-technology equipment, the use of affordable low-cost face scan technology is considered a reliable methodology for face banking and facial reconstruction in case of any loss. A large count (120 images or more) of high-quality images can adequately produce a reliable 3D model using mobile photogrammetry.

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