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PROPOSAL OF A NEW SOFTWARE FOR CONVERTING 2D FACIAL PHOTOGRAPHS INTO 3D DIGITAL MODELS

Hady K. Abdelhalim*, Kareem M. Gaber** *and* Wael M.Refai***

ABSTRACT

Objective: To propose of new software for converting 2D facial photographs into 3D digital models and determine the accuracy and precision of 3D face models through an indirect facial anthropometric technique.

Materials and Methods: Ten standard linear and horizontal craniofacial measurements were obtained from 22 subjects using the proposed software inaddition to five angular measurements and these were compared with direct anthropometry through digital caliper.

Results: Mean measurements derived from three-dimensional (3D) images and direct anthropologic measurements were mostly similar However, statistically significant differences regarding linear and horizontal measurements were noted for four measurements (Al-Al, Ch-Ch, N-Sn and Sn-Sto) . Regarding angular measurements only nasolabial revealed statistically significant difference.

Conclusions: Overall, soft tissue facial measurements (angles and distances) on 3d face model generated from proposed software demonstrated moderate agreement, accuracy and precision with traditional anthropometry .

KEY WORDS: Three-dimensional; Anthropometry.

INTRODUCTION

3D imaging had been developed in the early of 1990's and has gained a precious place in dentistry, especially in orthodontics, and also in orofacial surgical applications, in 3D diagnostic imaging a series of anatomical data is gathered using certain technological equipment, processed by a computer and later showed on a 2D monitor to present the illusion of deepness.

With increased attention being given to radiation exposure from dental radiographs, less reliance on cephalometric analysis and increased utilization of facial photographs in a quantitative manner for diagnosis is justified[10]. As patients are not accustomed to interpreting radiographs, facial photographs as diagnostic records may be a more comprehensible tool.

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Often 3D modeling is meant only as the process of converting a measured point cloud into a triangulated network (“mesh”) or textured surface, while it should describe a more complete and general process of object reconstruction.

MATERIALS AND METHODS

Twenty two subjects were imaged in three different locations in natural head position according to standardized measures.

Standardized measures

- A fixed distance was made between mirror and pronale point of the subject which was 297 cm.
- A fixed distance was made from the center of tripod to pronasal point of the subject which was 80 cm in all views (fig.1).

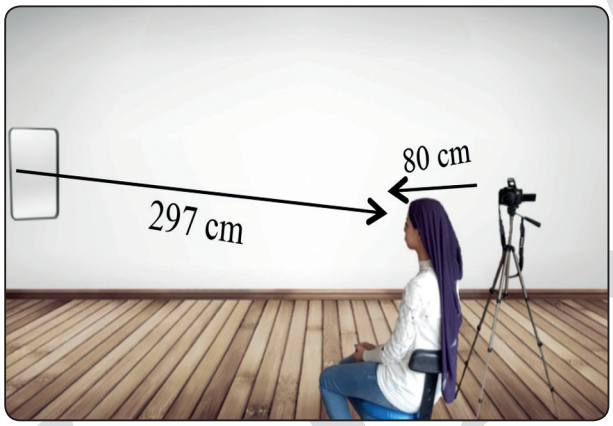

Fig. (1) photographic method during capturing profile view.

- The 45 degree view was reached through bisecting the angle between frontal and profile view and measure 80 cm then the tripod was positioned to reach 45 degree view.
- These images entered through proposed software to generate 3D face models according to certain points marked on images before generating the models as Glabella, Pronasal, Exocanthion, Endocanthion, subnasale etc (fig.2,3). The face model was viewed as wave front object file (Obj file) using specific software***.

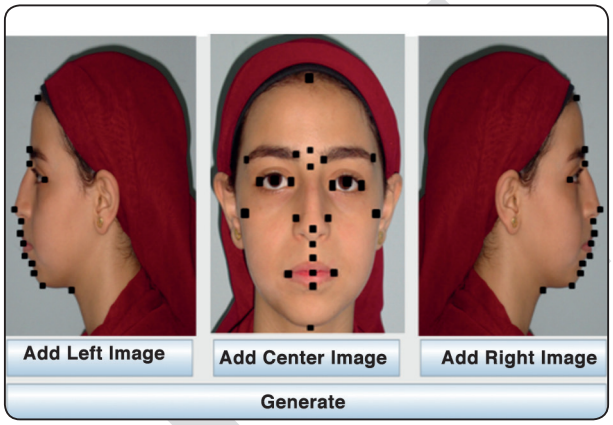

Fig. 2: Points taken on front and side images before generating the 3D model.

- The accuracy of the proposed software was tested by comparing measurements obtained from the 3d facial models of proposed software to the direct measurements on subject's faces. Direct anthropometric facial measurements were taken directly on the patient's face with a sliding digital caliper (fig. 3).
- Landmark points[5] were marked on frontal view of face model. Linear and horizontal measurements were taken on 3D face model using specific software*(fig.4). The focus and position of the 3D model was adjusted to be 13.6 [Fps(Focal position site) =13.6] before making measurements.
- The Accuracy of the side of 3D model was tested by measuring certain angles as (Nasofrontal angle, Nasolabial angle, Mentolabial angle, Facial angle and facial convexity angle) on the face model and compare these angles to the original side photographs through specific software** (fig.5) and table 2.

* MeshLab_64bit v1.3.4BETA* software.
** ImageJ software

TABLE (1) Anthropometric measurements which made for comparison with software measurements.

Measurement	Description
Exocanthion- Exocanthion	Outer canthus width
Endocanthion- Endocanthion	Inner canthus width
Right Alare – left Alare	Nasal width
Nasion – Subnasale	Nasal height
Subnasale – Stomion	Upper lip height
Prn – Subnasale	Nasal tip protrusion
Right Cheilion – left Cheilion	Mouth width
Crista philtri superior right - Crista philtri superior left	Upper prolabial width
Zygion right – Zygion left	upper facial width
Stomion – soft tissue menton	Lower lip height

TABLE (2) angular measurements which made for comparison with software measurements.

Measurement	**Description**
Nasofrontal angle	This angle formed by connecting glabella, nasion and pronasal.
Nasolabial angle	This angle is formed by the intersection of the upper lip anterior and columella at subnasale.
Mentolabial angle	This angle formed by connecting labial inferior, supramental and pogonion.
Facial angle or angle of facial convexity	This angle formed by connecting glabelle, subnasale and soft tissue pogonion.
Total facial angle or facial convexity angle	This angle formed by connecting glabella, pronasal and soft tissue pogonion.

RESULTS

The results of the accuracy of 3D face model concerning linear and horizontal measurements compared to antropometric measurements revealed that there were no statistical significance differences except at Al-Al, Ch-Ch, N-Sn and Sn-Sto distances (table 3).

Fig. (3) anthropometric measurements between right and left exocanthus of eye.

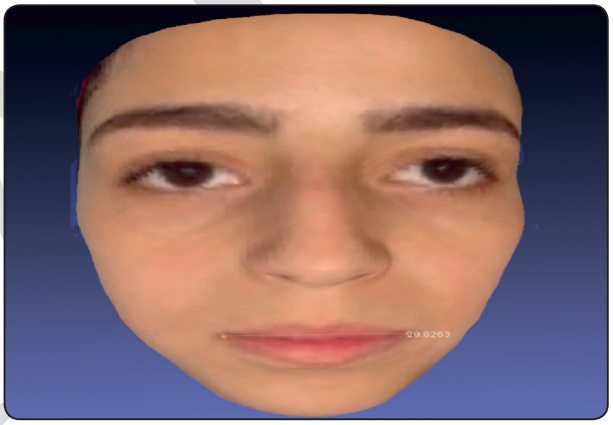

Fig. (4) Measuring the distance between right and left cheilion using MeshLab_64bit v1.3.4BETA* software.

Fig. (5) Measuring nasolabial angle in Imagej software.

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TABLE (3) Results differences between direct anthropometric measurements on subjects and same measurements on face model measurements.

Distance	On patient	On face model	P value
Ex-Ex	85.3±7.5	85.8±7.2	0.359
En-En	30.7±3.5	31.3±3.7	0.100
Al-Al	30.8±3.7	34±4.3	**<0.001***
Ch-Ch	43.1±5.2	45.7±5	**0.002***
N-Sn	49.8±5.8	52.3±7.6	**0.021***
Pn-Sn	12±1.6	12.2±1.7	0.173
Sn-Sto	18.3±3.1	19.8±2.6	**<0.001***
Sto-me	32.8±6.1	32.8±5.2	0.946
Caphs-Caphs	11.1±2.4	11.7±2.5	0.124
Zyg-Zyg	106.5±8.8	107.5±8.7	0.512

Concerning angular measurements revealed that there were no statistical significance difference except in nasolabial angle in which p-value <0.001 (table 4).

TABLE (4) Results differences between angular measurements in side photographs and on face model measurements.

Angles	Mean On side photo	Mean On face model	P value
Naso-frontal angle	141.1±5	140.1±4.7	0.124
Naso-labial angle	101.2±9.1	105.8±7	**<0.001***
Mento-labial angle	128±11.2	129±7.4	0.464
Facial convexity angle	161.7±4.9	162.4±3.9	0.460
Total facial angle	135.9±4.1	135.5±3.5	0.673

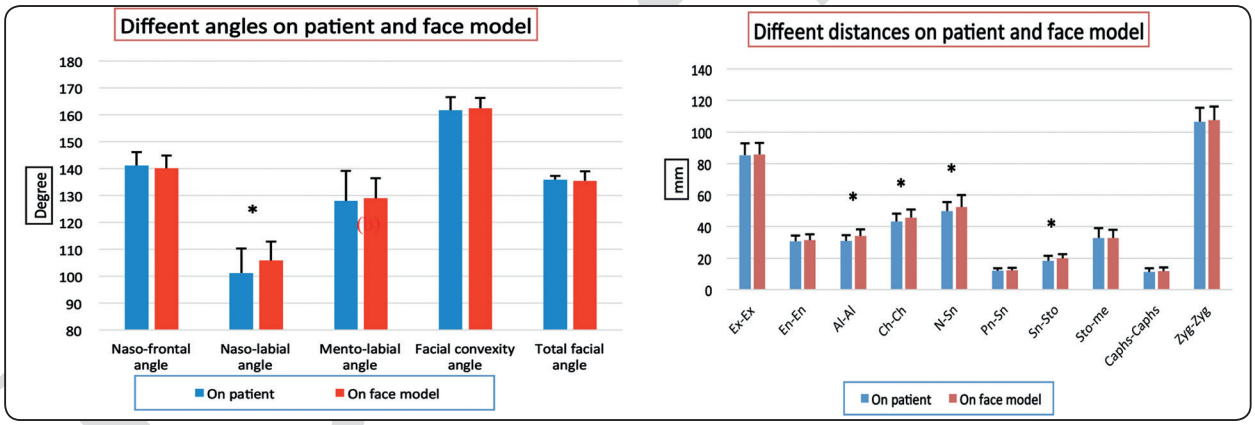

Fig. (6) (a) mean differences for measured angles on the side photo and on the face model, (b) mean differences for measured distances directly on patient and indirectly on face model.

DISCUSSION

3D modeling systems could be categorized into active and passive vision systems. An active vision system calculated 3D information by measuring a beam of light radiated from an external device such as a beam projector or laser. The typical 3D face modeling method was using an active vision system constructed a 3D face mesh using a captured 3D point cloud.

In such systems, a 3D laser scanner or calibrated stereo camera with structured light could be used to capture 3D coordinates and texture information.

While these methods were highly accurate, they were also time consuming, and the necessary equipment was expensive.

Conversely, in the current study, Passive vision-based modeling was depended upon. Passive vision-based 3D modeling system was preferred for human faces because the glare from light-emitting devices can be unpleasant for the users. This system needs no light-emitting devices and estimates 3D information from 2D images. In addition, 3D information could be calculated by analyzing camera geometry from corresponding features in multiple views or adjusting the statistical 3D face model to captured facial images[3,15]. This is nearly the same method which was used in the **proposed** software of the current study.

In the **proposed** software, the 3D generic face model was adjusted to all captured images. Moreover, it did not require certain geometrical features in camera. Accordingly it could work with any camera system. A generic facial model was used in the **proposed** software which was a simplified polygonal mesh representing the morphometric information of an average face with known 3D co-ordinates of each point of the mesh in addition to a reproducible polygonal index. The mesh is generic so it can be adapted universally to any face for the purpose of morphometric analyses.

Photographic technique was done using tripod and mirror to standardize the photographs and to obtain natural head position during taking photographs.

Anatomical points were used in **proposed** software for fabricating 3D face model to reach more accurate details of face which were better than using artificial or non anatomical points according to **Khambay et al**[10] who made registration of the facial stereophotogrammetry image and CT skin image using anatomical landmarks.

The face organs such as mouth and nose were handled separately from the head Shape. These parts were complicated in shape and thus made direct modeling more Difficult so to simplify the process a number of simplified generic organs were used and manual selection of some control points on the images. The 3D positions of the face organs and face organ models were integrated into the coordinate system of the head model to increase the accuracy of 3D face model especially the area of nasolabial area.

Many previous studies that examined the reliability of facial measurements had marked landmarks on the subjects' face directly as **Farkas**[5] and compare these measurements after marking landmarks on face before image acquisition using 3dMDface system **Aynechi et al**[11] although the reliability of the same system was measured by **Metzger et al**[16] without previous marking of the points so in the current study, facial images were captured without marking the landmarks on the subjects' skin before image capture to simulate a procedure that is more appropriate for an orthodontic practice. Physically marking landmarks on the skin prior to facial photographs was time consuming and may be objectionable to some orthodontic patients.

Direct anthropometry was considered the gold standard for in vivo soft-tissue assessment it was simple and relatively inexpensive, and it did not require complex instrumentation. It was widely used as it was simple, low-cost, non-invasive method, and easy to interpret.

There was no significant difference regarding angular measurements as nasofrontal, mentolabial, facial convexity angle and total facial angle. however, there was statistical significant difference at the nasolabial angle in which the mean difference between angles on the face model and on photo was about 6 degrees. This results were agreed with the results of **Beeler et al**[4] **and** disagreed with results of **Jin et al**[8] **, Jo et al**[9] **and Patel et al**[1] which used 3D morphable model (3DMM) in their work**.**

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The significant differences in some of angular measurements as nasolabial angle came from the fact that generic model which used in the proposed software was not so universal that cannot perfectly fitted for everyone so there were differences and some errors in fitting the generic face model .

There was no significant difference regarding distance between landmarks which made directly on the subjects and on face model except at Al-Al, Ch-Ch, N-Sn and Sn-Sto distances which was agreed with Bland-Altman plot analysis. This results were disagreed with the results of **Aynechi et al. 2011[11] and Premjani et al[14] and Metzger et al.[16]** which used active modeling systems in their work.

Variation in landmarks that crossed the stomion in which attributed to alterations in the position of lips caused by changes in facial expression, breathing, or speaking and also difficult localization of landmarks on nose as paired alae which led to inaccuracies in Al-Al, Ch-Ch and Sn-Sto distances in which agreed with **Aldridge et al[2] and Weinberg et al[17]** which used other 3d systems.

Distortion in the base of the nose and at nostrils in the 3D model made error in positioning of subnasale point which may led to inaccuracy in N-Sn distance. In addition, there were some of error in measurements including data points as cheilion and alae showed the possibility of less predictable landmark identifications because of camera flash and facial hair that caused obscuring and blurring of landmark margins.

CONCLUSION

-Overall, soft tissue facial measurements (angles and distances) on 3d face model generated from proposed software demonstrated moderate agreement with traditional anthropometry.

-Differences were observed in Al-Al, Ch-Ch, N-Sn and Sn-Sto distances and nasolabial angle.

RECOMMENDATIONS

- These software needs multidisplinary team of software developers with a powerful academic background in 3D work, biomedical engineers, orthodontist and maxillofacial surgeon to produce accurate results with previous fund.
- Adding a data base which contains hundreds of facial model obtained from soft tissue CBCTs of certain popoulation so using multiple generic models will solve the problems of stretching and inaccuracy of nasolabial angle and Al-Al, Ch-Ch, N-Sn and Sn-Sto distances.

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