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A preliminary performance evaluation of 3D facial image reconstruction from computed tomography scan

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ABSTRACT

Background: As a result of all kinds of disasters, people might be injured or killed. Most people could not be able to identify their family members dying in disasters. 3D facial image reconstruction from skull could narrow down the recognition of the faces from their family or close friends.

Objectives: The purpose of this preliminary study is to receive facial soft tissue thickness for forming a preliminary database and to create a 3D facial image reconstruction from Thai people.

Materials and methods: 3D facial image reconstruction based on facial soft tissue thickness data and paranasal sinuses CT scan images from Thai people was studied. Firstly, 15 anatomical facial landmarks to form a facial soft tissue thickness data were collected from Maharaj Nakorn Chiang Mai hospital CT scan database, 45 cases were used (22 males and 23 females). A 3D skull model matrix from CT scan DICOM files was then generated. Finally, the 3D facial soft tissue model matrix was combined with the 3D skull model matrix to create a 3D facial image reconstruction.

Results: The result showed Thai male facial soft tissue was thicker than the female at mid-philtrum and rhinion, respectively. Median values of 15 landmarks were used to create a 3D facial skin on a 3D skull. The random survey of 100 people showed 11% matched a 3D facial image reconstruction with a real 3D face of that skull.

Conclusion: The results also revealed that some people could recognize the real faces from the 3D facial images through facial soft tissue on the skull without any facial organs such as eyes, nose, or lips. It is suggested that facial soft tissue sampling and other facial organ studies could be helpful to create a big database for rebuilding more perfectly facial reconstruction in Thai people.

Introduction

In general, we can identify a dead person using various ways such as DNA or fingerprints matching. However, it is difficult to apply both methods in some cases such as a disaster responsible for appalling massacre. It is a very hard work for running the identification of all bodies through a short period of time. To solve this problem, the facial reconstruction can be helpful by narrowing a finding scope of a pair matching DNA or fingerprints.[1] To recreate face of the unknown skull, facial soft tissue thickness is very important. Therefore, in several years, many researchers in the field have studied about facial soft tissue thickness form a database for facial reconstruction in each nationality, specifically.[2-6]

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It is noticeable that most of the researchers reported that facial soft tissue thickness in their studies was different from the other studies even in the same country. Thus, it is necessary to prescribe the facial soft tissue thickness differences in ethnic diversity related to age, sex and nutritional condition.[7-8]

The facial soft tissue thickness measurement could be done by several methods using facial soft tissue.[9-11] In the past, needle puncture on dead body was applied.[12,13] But once medical imaging technology has been developed, the imaging based method known as CT scan became an illustrious method for measurement because it provides more accurate and reliable results.[14-17] Moreover, this method can use in the living while the needle puncture cannot be performed.[18] According to this study, the facial soft tissue thickness at 15 anatomical facial landmarks collected from paranasal sinuses CT scan DICOM file was used to created 3D facial image reconstruction of Thai people. The main purposes are to get an initiative facial soft tissue thickness data for Thai population and to create a 3D facial image reconstruction.

Materials and methods

Data Collecting

Prior to the measurement, this study was reviewed and approved by the Ethics Committee of Faculty of Associated Medical Sciences, Chiang Mai University. Thus, the researchers did not receive any personal information, except for the sex and age of the patients. The data was obtained from facial soft tissue thickness in 45 cases of 22 males and 23 females from Maharaj Nakorn Chiang Mai hospital CT scan database. The cases in which deformations such as the fracture of the skull or facial bones, tumors, swollen or damages of facial tissue were not included. The ages of the case studies are between 13 – 72, making an average of 37.91 years. One examiner measured and recorded the facial soft tissue thickness data twice, leaving a measurement gap for two weeks to control an intra-observer bias. 15 anatomical facial landmarks of the skull were measured, 5 of which were on the midline and 5 on bilateral (Figure 1).[2] The measurement software used was eFilm Workstation version 3.4. The DICOM images of CT scan had 0.4 mm voxel size (Figure 02).

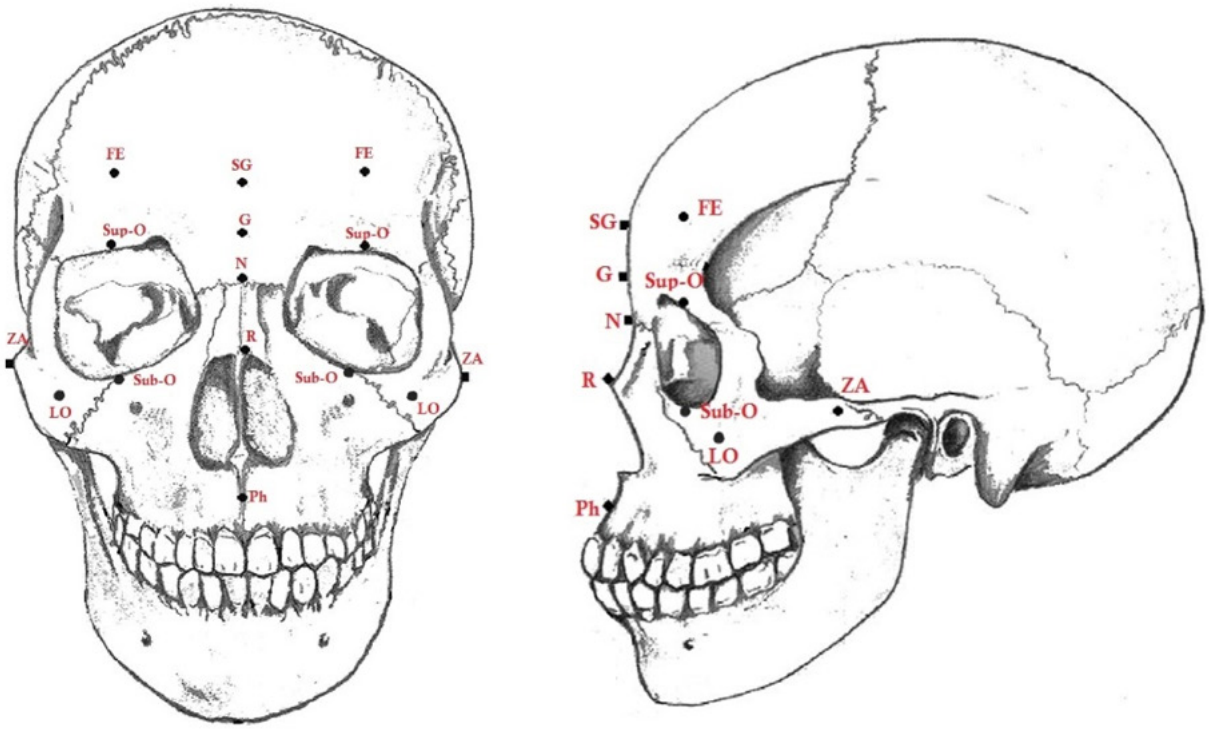

Figure 1. *Anatomical facial landmark of skull. FE: frontal eminence (left and right), SG: supra-glabella, Sup-O: supraorbital (left and right), G: glabella, Sub-O: suborbital (left and right), N: nasion, ZA: zygomatic arch (left and right), R: rhinion, LO: lateral orbit (left and right), and Ph: mid-philtrum.*[2]*.*

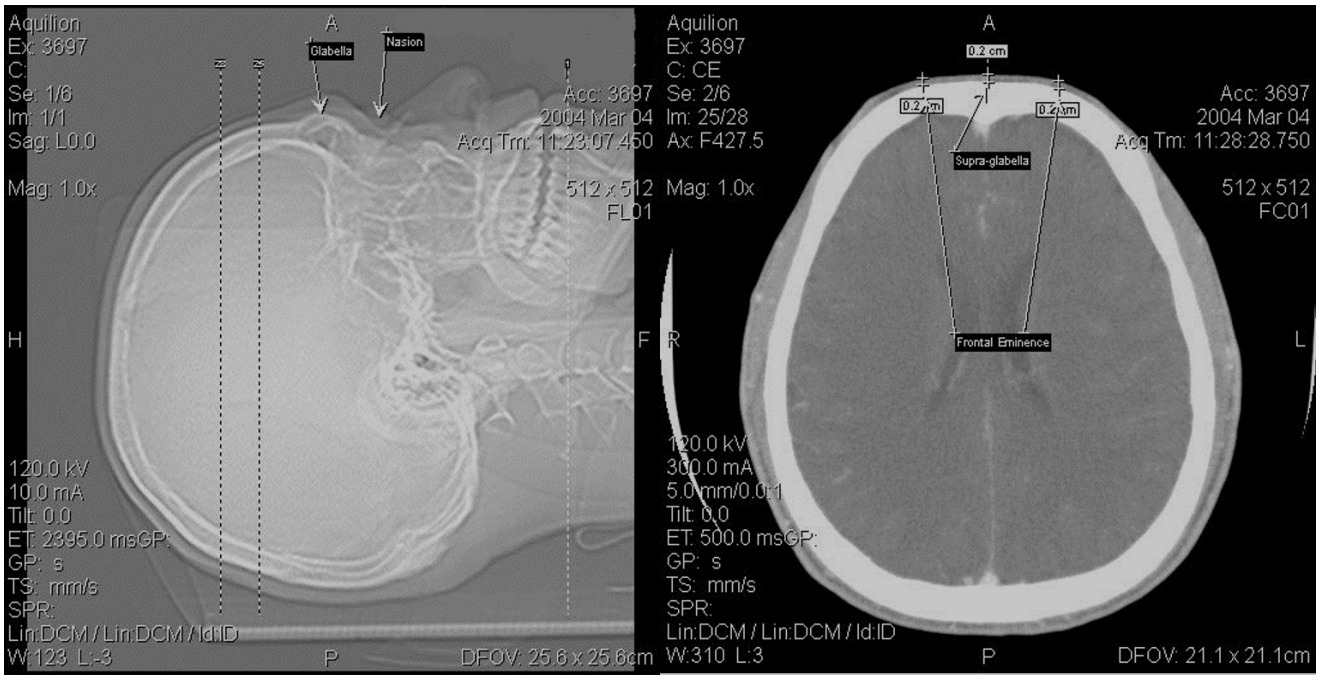

Figure 2. *Measurement window from eFilm Workstation version 3.4.*

Data analysis

The SPSS software version 22.0 (SPSS Inc., Chicago, USA) was applied to analyze the facial soft tissue thickness data. The Kolmogorov-Smirnov and Shapiro-Wilk were used to assess the distribution of the data showing its being distributed not normally. Median was represented as a central value. Wilcoxon Signed Ranks Test was used to assess Intra-observer reliability of the facial soft tissue thickness measurement. Mann-Whitney and Wilcoxon were used to compare the two groups of male and female patients involved in the study. Chi-Square was used to test their age differences. Kruskal Wallis Test was used to compare the differences more than two groups, and a statistically significant difference level, *p*-value <0.05, was used for all statistical analyses.

Generate 3D facial image reconstruction

Firstly, a median of Thai facial soft tissue thickness was collected, then a 3D facial soft tissue of the skull on the 3D model program was created from the central values. Secondly, the software InVesalius, version 3.1 (CTI, Campinas, Brazil) was used to generate a 3D skull image from CT Scan DICOM files and to attach the 3D facial soft tissue model matrix on 3D skull model matrix in software Autodesk Meshmixer platform (Autodesk Inc., California, USA). It should be noted that all 3D programs tools in this work were free software.

Test the recognition of face

In order to prove that the 3D facial image reconstruction of Thai people could be effective, able to be used for the recognition of real faces in any people, the survey paper was developed to evaluate 3D facial images reconstruction. A hundred people were randomly selected to answer 4 questions. They were asked to match the pictures between the 3D real faces model of the skull and our 3D facial image reconstruction.

Results

Facial Soft Tissue Thickness Results

Table 2 demonstrates that the thickest facial soft tissue thickness landmark is mid-philtrum (about 1.00 centimeter) and the thinnest landmark is rhinion (about 0.25 centimeter). Moreover, Figure 3 shows the tissue thickness of the male is thicker than that of the female of both landmarks.

Table 1 Explains the definitions of anatomical facial landmarks.

No.	Landmarks	Definition
1.	SG (Supra-glabella)	The most anterior point on midline of forehead.
2.	G (Glabella)	The most prominent point between the supraorbital ridges in the midsagital plane.
3.	N (Nasion)	Midpoint of the fronto-nasal suture.
4.	R (Rhinion)	The anterior tip of the nasal bone.
5.	Ph (Mid-philtrum)	Point at the intermaxillary suture, placed as high as possible before the curvature of the anterior nasal spine begins.
6, 7	Left and Right FE (Frontal Eminence)	Centered on eye pupil, most anterior point of the forehead.
8, 9	Left and Right Sup-O (Supraorbital)	Center upper part of margin of the orbit.
10, 11	Left and Right Sub-O (Suborbital)	Center lower part of margin of the orbit.
12, 13	Left and Right ZA (Zygomatic Arch)	Maximum, most lateral curvature of the zygomatic bone.
14, 15	Left and Right LO (Lateral Orbit)	Lateral side of the eye, point on the zygomatic bone.

Table 2 Median values of 15 anatomical facial landmarks.

No.	Landmarks	Median 1st	Median 2nd	Average of Median
1	Supra-glabella	0.4	0.4	0.4
2	Glabella	0.5	0.5	0.5
3	Nasion	0.4	0.4	0.4
4	Rhinion	0.3	0.2	0.25
5	Mid-philtrum	1.0	1.0	1.0
6	Left FE (Frontal eminence)	0.4	0.3	0.35
7	Right FE (Frontal eminence)	0.3	0.3	0.3
8	Left (Supraorbital)	0.6	0.6	0.6
9	Right (Supraorbital)	0.6	0.6	0.6
10	Left (Suborbital)	0.6	0.6	0.6
11	Right (Suborbital)	0.6	0.6	0.6
12	Left (Zygomatic arch)	0.8	0.8	0.8
13	Right (Zygomatic arch)	0.8	0.8	0.8
14	Left (Lateral orbit)	0.4	0.4	0.4
15	Right (Lateral orbit)	0.4	0.4	0.4

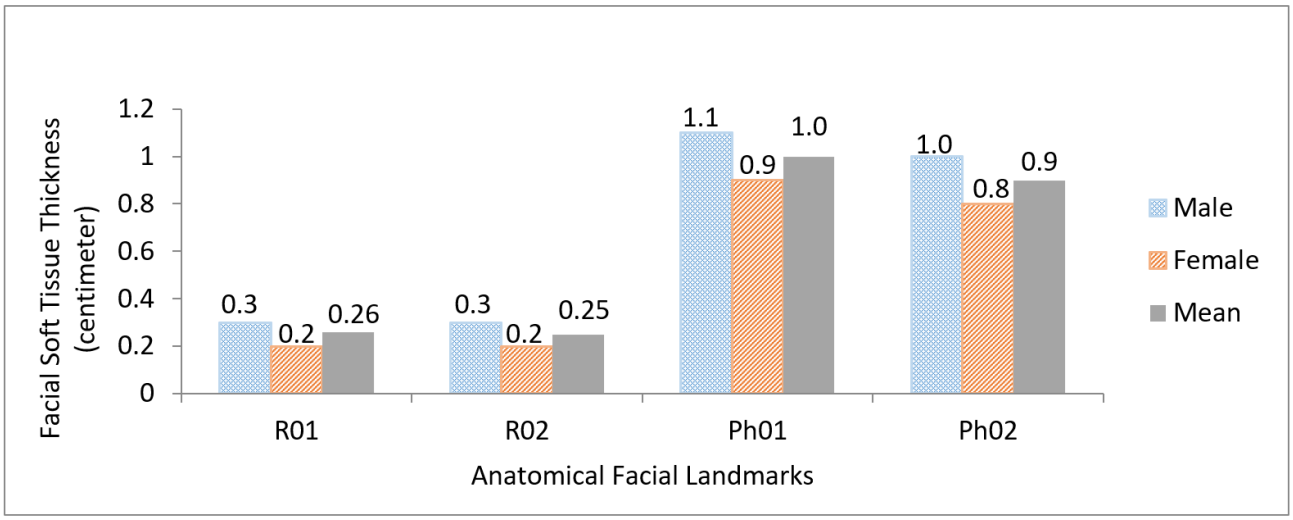

Figure 3. *Thicknesses of rhinion and mid-philtrum between male and female. R01: rhinion first measurement values, R02: rhinion second measurement values, Ph01: mid-philtrum first measurement values, Ph02: mid-philtrum second measurement values. The values are in centimeters.*

Facial image reconstruction result

Figure 4 demonstrates the 3D facial images before and after the facial reconstruction process. Four examples of original 3D skulls before facial reconstruction were shown in Figures 4.1(a)-4.4(a). These skull images were extracted from the original CT scan images of known people whereas Figures 4.1(b)-4.4(b) are 3D skull matrices after the facial soft tissue reconstruction on each original 3D skull image. Thin and soft tissue layer generated from 15 anatomical facial landmarks can be noted in the resulting images. However, these constructed facial images are generated as a preliminary work at this point. The more advanced the techniques or imaging software are the more tremendous the quality of the polygonal mesh in these reconstructed 3D skull images can obtain.

Recognition result

Figure 5 shows the number of 100 people, 31 males and 69 females, who answered a survey paper. 11% of people can truly match all pictures between 3D real face images and 3D facial images reconstruction, 5% can match 3 of 4 faces, 34% can match 2 of 4 faces, 28% can match just one face and 22% cannot match all of the face images.

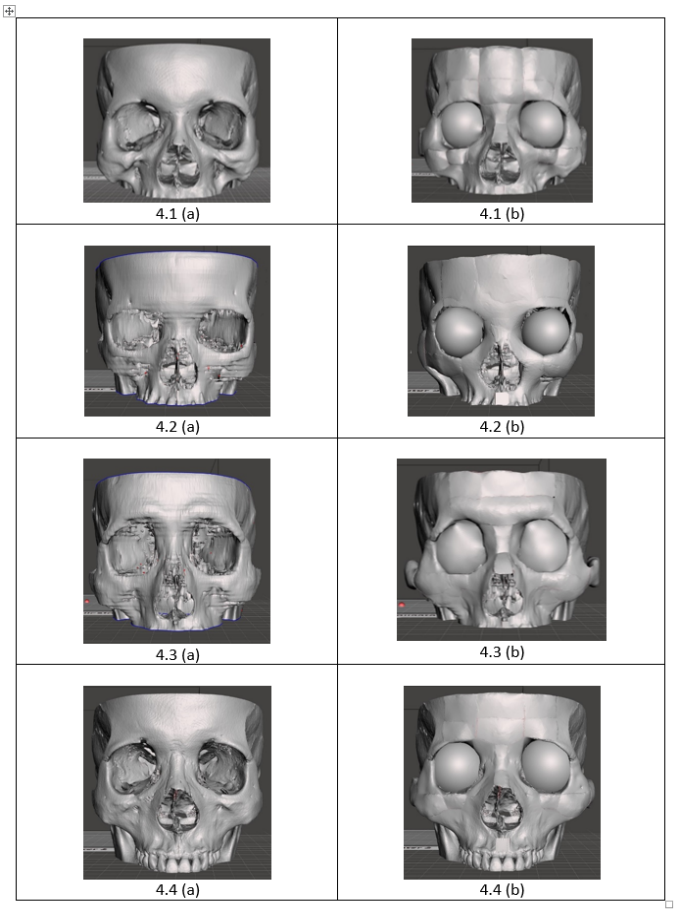

Figure 4. *3D facial image reconstruction; 4.1(a)-4.4(a) show the original 3D skull matrix whereas figures 4.1(b)-4.4(b) show the correspondent skull images after the facial reconstruction process.*

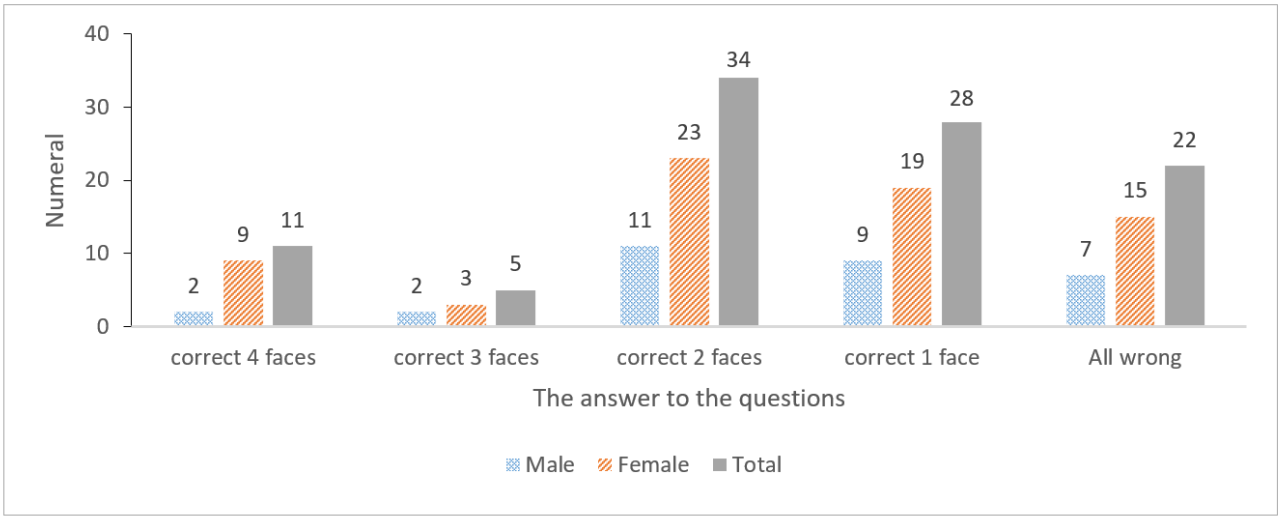

Figure 5. *The result of the survey.*

Discussion

According to the results of this study, the authors compared the facial soft tissue thickness values obtained with the results by other 2 researchers collecting the data from Thai people. Both studies focused on different parts of Thailand, the Northeast region, and the Central region, respectively.[12,15] When comparing with both works, it is worth noting the facial soft tissue thickness in males and female at rhinion and mid-philtrum. Similar to the work of Puavaranukroh who studied in the Central Region of Thailand and revealed his result that males in a normal BMI category showed facial soft tissue thickness thicker than females at the end of nasal (rhinion), as well as at mid-philtrum.[12] However, the results showed difference in the female patients. In this study, it was shown that there was no statistically significant difference which revealed the female was greater than male while Puavaranukroh showed that female soft tissue thickness is greater than male at lateral orbit. Compared to Puavaranukroh and our work, the study done in the Northeast has shown different results with regard to the soft tissue thickness. Sirisin showed that the average of soft tissue thickness in some landmarks of the males was higher than those of the females at nasospinale, right and left area, anterior nasal spine (this landmark was very nearly with mid-philtrum) and nasion.[15] In reverse, the females displayed higher thickness than the males at right ectomolare, left and right gonion, left and right jugale, left and right ectoconchion, and right orbitale superius (supra orbital). However, it is not easy to compare this study and other studies because of the variation in anatomical facial landmarks in each work. It is possible to compare the central values, mean and median, and some of the landmarks which were a repeated measurement point and with no statistically significant differences between the three works. However, it is unlikely to assume that the thickness values from this work can be generalized to create a facial image reconstruction for all regions of Thailand.

Conclusion

The result of the survey paper proves that some people are able to recognize real faces from a 3D facial image reconstruction showing just only skin on the skull without other facial organs such as eyes, nose, and lips. It is believed that further studies on facial soft tissue sampling and other facial organ studies on such facial organs in Thai people might be helpful to create a huge database for rebuilding most satisfying result of facial reconstruction. This database could, in turn, be effective to increase the number of people recognizing real faces.

Conflict of Interest

The authors declare no conflict of interest.

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