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**PAPER**

**ANTHROPOLOGY**

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# Facial Soft Tissue Thickness Database for Craniofacial Reconstruction in Korean Adults

**ABSTRACT:** One hundred Korean adults (50 men, 50 women) were scanned in the upright position using a cone-beam CT (CBCT) scanner. The soft tissue (ST) thicknesses were measured at 31 landmarks, 10 midline and 21 bilateral landmark sites, and the means and standard deviations were obtained for male and female subjects. While 18 of 31 landmarks showed sex differences, the majority showed higher values for male subjects with the exception of a few landmark sites corresponding to the zygoma area, which showed smaller values in men than in women. The mandibular area showed greater differences between the right and left sides. Overall, the ST thickness measurements obtained in this study can be used as a database for the forensic craniofacial reconstruction of Korean adult faces.

**KEYWORDS:** forensic science, soft tissue thickness, cone-beam CT, craniofacial reconstruction, Korean adults

In forensic craniofacial reconstruction, the facial features of unknown individuals are estimated from an unidentified skull (1,2). Most facial reconstruction techniques use sets of averaged facial soft tissue (ST) thicknesses at anatomical landmarks (3). In the past, the reference facial ST thickness data were obtained using needle puncture on the faces of cadavers (2).

The introduction of an ultrasound system enabled large-scale studies of facial ST thickness data to craniofacial reconstructions (4–7). Manhein et al. (4) obtained facial ST thickness data from 807 White, Black, and Hispanic American children and adults using 19 unilateral facial points. Wilkinson (6) scanned 200 British children bilaterally at 21 landmark sites, while El-Mehallawi and Soliman (5) carried out the measurements in the Egyptian adult population. De Greef et al. (7) conducted a large-scale study on 967 Caucasian subjects of both sexes, with various ages and body mass indices.

CT scans were found to be useful for acquiring a facial ST thickness database. Phillips and Smuts (8) used a data set of the ST thickness obtained from CT scans for their facial reconstruction, and Kim et al. (9) reported that CT images can be used to measure accurately the ST thickness in the facial region. Multislice CT measurements were compared with the physical measurements at the same sites. Despite the advantages of CT scans for facial tissue measurement method, one drawback is the influence of gravity, as the images are obtained with the subject in a supine position. In a study regarding comparison between ultrasound system and multislice CT scanning, De Greef et al. (10) stated that measurement differences between the two systems were attributed to a difference in the subject position, in other words a supine position during CT scan. Recently developed cone-beam CT (CBCT), however, enables images to be obtained with the subjects in an upright position. In addition, it is reported that radiation dose in CBCT scan is much less than in multislice CT (11–13). In the CBCT scanner, a conical beam path is produced at a constant cone angle, and the source of radiation swivels with the sensor. According to recent articles, one exposure for a full-mouth series accounts for about 150 μSv, and a panoramic radiograph accounts for 54 μSv, while the patient-effective dose from the CBCT scanning session is similar to the 139 μSv (14–16). Currently, CBCT scanning is used in the diagnosis of orthodontic and orthognathic surgery patients on a routine basis (17–19). Wilkinson (6) highlighted the importance of tissue depth data with respect to ethnicity. Six identical casts of a White male were reconstructed using the same methodology and charts of the tissue depths for different ethnic groups. Most reconstructions were rated similarly with regard to resemblance to the target individual, but some data sets produced more differences than others and decreased the resemblance to the target. Manhein et al. (4) suggested that race influences the facial ST thickness as well as sex and age from their study on White, Black, and Hispanic Americans.

However, there is a paucity of research recording the tissues of Asian faces. Although Birkner (20) and Suzuki (21) reported facial ST thickness data for the Chinese and Japanese, respectively, these studies were performed 100 years ago in the Birkner sample and 60 years ago in the Suzuki sample. A Korean population was involved in research into facial ST thickness from different ethnic groups by Lebedinskaya et al. (22). However, the sample employed

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in the study had emigrated from Korea to central Russia 80 years ago. Utsuno et al. (23,24) published a couple of studies on Japanese children, but the measurements were limited to midline landmarks from two-dimensional (2D) cephalograms. Recently, Chan et al. (25) reported facial tissue depths for adult Chinese-Americans. The data, however, were obtained using ultrasound system and were limited to 19 landmarks.

A literature review revealed that comprehensive studies will be needed to obtain facial ST thickness data for various ethnic groups using CBCT scans. The purpose of this study was to obtain facial ST thickness data using the CBCT scan images of Korean adults.

## Materials and Methods

The sample was collected from university students in Gwangju, Korea. All subjects had Korean ancestry, and none of the subjects had undergone orthodontic treatment. Subjects with facial deformities were excluded. In addition, the subjects who did not fall into normal body mass index range were excluded. One hundred students, 50 men (age range, 20.2–36.1 years; mean, 29.1 years; SD, 3.7 years) and 50 women (age range, 20.0–35.2 years; mean, 27.5 years; SD, 4.2 years), were enrolled in this study. This research was approved by the Institutional Review Board for the Medical Science at the Chonnam National University Hospital, Gwangju, Korea.

The CT scans were obtained using a CBCT scanner (Alphard Vega; Asahi Roentgen Co., Kyoto, Japan) with a voxel size of 0.39 mm and field of view of 200 (diameter) × 179 (height) mm. The subjects were scanned in the seated position with a neutral, relaxed, facial expression. While the exposure time is 17 sec, the subject's head was fixed using the head holder during the scan procedure so motion artifact could be prevented. The signal-to-noise ratio is influenced by many factors: mA, KVp, size of object, slice thickness, and filter. To reduce noise, an increase in slice thickness, a reduction in pixel size, and an increase in radiation dose may be necessary. However, resolution decreases with slice thickness and pixel size. Considering this relationship, proper exposure conditions can be determined according to the type of scanner and the characteristics of the target tissue. In the present CBCT scanner, 80 KVp and 8 mA were used to obtain data of adult individuals.

Maxillofacial 3D images were created from the DICOM data acquired from the CBCT scans and using V Works 4.0 (CyberMed, Seoul, Korea). A couple of 3D object files were constructed with an adjustment of Hounsfield Unit (HU): one for hard tissue image with 550–650 HU and another for an ST image with −570 to −500 HU. Both soft and hard tissue images were imported into specific software, Skull Measure (CyberMed), to measure the distance between a point on the ST image and corresponding point on the hard tissue image (Fig. 1).

### *Measurements*

As sites for the ST thickness measurements, 31 landmarks (10 midline and 21 bilateral) were identified according to De Greef et al. (7). Bilateral landmarks were established on the right side of the subject. Table 1 shows the definition of the landmarks used in this study. All descriptions were adopted from De Greef et al. (7) to allow a comparison. While both "perpendicular to skin" and "perpendicular to bone" manners are possible in the program, "perpendicular to bone" was selected in this study. All landmarks were identified first on the ST images and confirmed by the resultant designation on hard tissue images. If the resultant designation did not appear to be at the appropriate area on the hard tissue image, the landmark identification was performed on the hard tissue images and verified by resultant designation on the ST images. Fifty subjects (25 men and 25 women) were measured

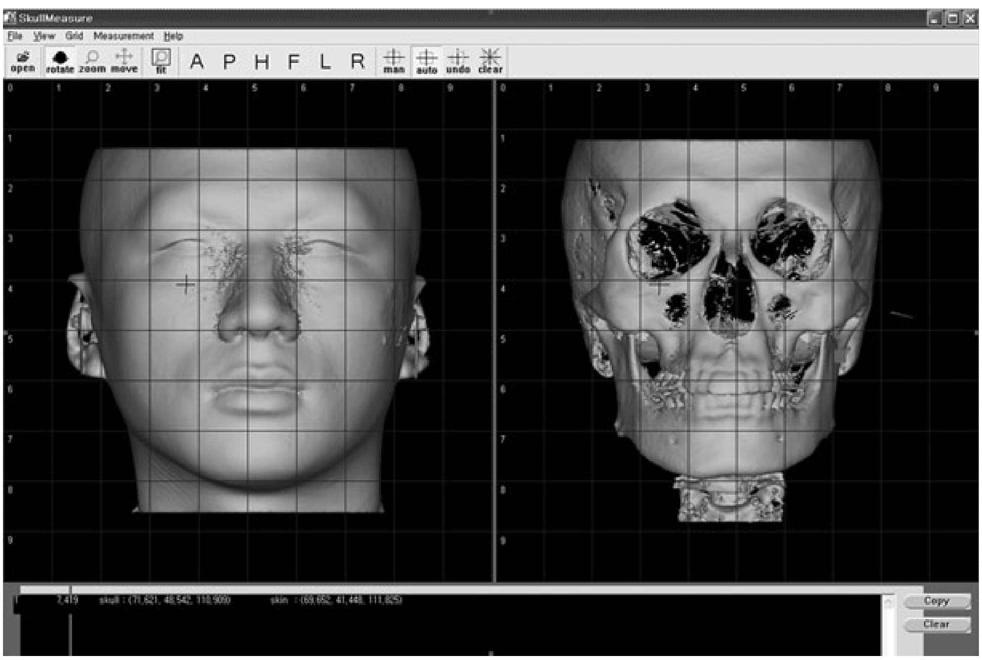


FIG. 1—*A window of the Skull Measure program utilized to measure facial soft tissue (ST) depths from cone-beam CT images. Both the ST and hard tissue images are rotated freely so the landmarks are identified accurately according to their definitions. Once the position is established on the ST image, the corresponding point is designated automatically on the hard tissue image enabling the investigator to verify the correct position of the landmark. As an example, the landmark of the suborbital was identified in the present window and the resultant designation is observed on the hard tissue image just under the inferior margin of the orbit.*

bilaterally to examine the right and left differences of the ST thickness, while the remaining subjects were measured unilaterally on the right side of the face. All landmark identifications were carried out by a single investigator to eliminate inter-observer error (Table 1).

*Statistical Analysis*

To assess the measurement errors, the images from 20 subjects (10 men and 10 women) were selected randomly, and the landmarks were identified twice at an interval of 4 weeks by a single investigator. The method errors (MEs) of the double registration of all landmarks were calculated using the Dahlberg's formula (26) as follows:

$$ME = \sqrt{\sum d^2/2n}$$

where $d$ is the difference between the two measurements and $n$ is the number of the subjects. All measurements except for one landmark, sub-M2, were reproducible with the MEs of <0.8 mm (Table 2).

The means and standard deviations were calculated for each landmark as well as for male and female subjects. Student's *t*-tests were used to determine the sex differences. To determine the right and left differences in the bilateral landmarks, paired *t*-tests were used. In addition, the bilateral differences were analyzed without considering side (in other words the differences were assessed regardless of whether the right side was greater than the left or vice versa), and the relative bilateral differences were computed in percentiles according to De Greef et al. (7). The statistical analysis was carried out using SPSS software, version 17.0 for Windows (SPSS Inc., Chicago, IL).

TABLE 1—*Description of the anatomical landmarks used for soft tissue (ST) depth measurement using cone-beam CT images.*

| Landmarks | Description* |
|---|---|
| Midline landmarks | |
| Supraglabella | Most anterior point on midline |
| Glabella | Cross-point between midline and supraorbital line |
| Nasion | Midpoint of the fronto-nasal suture |
| End of nasal | Junction between bone and cartilage of the nose |
| Mid-philtrum | Centered between nose and mouth on midline |
| Upper lip | Midline on the upper lip |
| Lower lip | Midline on the lower lip |
| Chin–lip fold | Midline centered in fold chin, below lips |
| Mental eminence | Centered on most anteriorly projecting point of chin |
| Beneath chin | The vertical measure of the ST on the most inferior point of the chin |
| Unilateral landmarks | |
| Frontal eminence | Centered on pupil, most anterior point of the forehead |
| Supraorbital | Centered on pupil, just above eyebrow |
| Lateral glabella | Junction of the frontal, maxillary, and lacrimal bones on the medial bone of the orbit |
| Lateral nasal | Side of the bridge of the nose on the Frankfurt horizontal plane |
| Suborbital | Centered on pupil, just under infra-orbital margin |
| Inferior malar | Centered on pupil, just interior to zygomatic process |
| Lateral nostril | Next to the most lateral point of the alar border |
| Naso-labial ridge | The prominence either side of the philtrum |
| Supracanina | Vertically lined up with the cheilion, on the horizontal level of the mid-philtrum |
| Subcanina | Vertically lined up with the cheilion, on the horizontal level of the chin–lip fold |
| Mental tubercle anterior | Most prominent point on the lateral bulge of the chin mound |
| Mid-lateral orbit | Vertically centered on the orbit, next to the lateral orbital border |
| Supraglenoid | Root of the zygomatic arch just anterior to the ear |
| Zygomatic arch | Most lateral curvature of the zygomatic bone |
| Lateral orbit | Lined up with the lateral border of the eye on the center of the zygomatic process |
| Supra-M2 | Cheek region, lateral: lined up with nasal base; vertical: lined up beneath lateral border of the eye |
| Mid-masseter | Middle of the masseter, the halfway point between the supraglenoid and the gonion |
| Occlusal line | Border of the masseter, on vertical level of the cheilion |
| Sub-M2 | Below the second molar on horizontally lined up with supra-M2 |
| Gonion | At the angle of the mandible |
| Mid-mandibular angle | Inferior border of the mandible, vertically lined up with supra-M2 |

*The present study used the same description as in De Greef et al.'s (7) study.

## Results

The means and standard deviations of the ST thickness measurements for each landmark site are presented in Table 3, and this database can be used for the forensic facial reconstruction of Korean adults. In the comparison between male and female subjects, 18 of 31 landmarks showed statistically significant sex differences. Thus, the data for male and female subjects were displayed separately.

Regarding the sex differences of midline landmarks, six of 10 sites showed statistically significant differences between male and female subjects. All of them presented higher values in the male

TABLE 2—*Method errors of facial soft tissue depth measurements.*

| Landmarks | Method Error |
|---|---|
| Midline landmarks (mm) | |
| Supraglabella | 0.13 |
| Glabella | 0.07 |
| Nasion | 0.10 |
| End of nasal | 0.08 |
| Mid-philtrum | 0.39 |
| Upper lip | 0.28 |
| Lower lip | 0.37 |
| Chin–lip fold | 0.25 |
| Mental eminence | 0.19 |
| Beneath chin | 0.51 |
| Bilateral landmarks (mm) | |
| Frontal eminence | 0.18 |
| Supraorbital | 0.17 |
| Lateral glabella | 0.55 |
| Lateral nasal | 0.22 |
| Suborbital | 0.21 |
| Inferior malar | 0.63 |
| Lateral nostril | 0.30 |
| Naso-labial ridge | 0.28 |
| Supracanina | 0.21 |
| Subcanina | 0.37 |
| Mental tubercle anterior | 0.32 |
| Mid-lateral orbit | 0.17 |
| Supraglenoid | 0.25 |
| Zygomatic arch | 0.17 |
| Lateral orbit | 0.22 |
| Supra-M2 | 0.73 |
| Mid-masseter | 0.26 |
| Occlusal line | 0.15 |
| Sub-M2 | 1.10 |
| Gonion | 0.55 |
| Mid-mandibular angle | 0.22 |

subjects. In particular, the landmarks of the mid-philtrum, upper lip, and lower lip which correspond to the lip area presented higher values (1.8, 1.8, and 1.4 mm, respectively), indicating a distinctly thicker lip in men than in women.

In the case of bilateral landmarks, 12 of 21 sites showed statistically significant sex differences. While the majority presented greater values in male subjects, such as the midline landmarks, the lateral orbit that corresponds to the zygoma area showed a smaller value in male subjects than in female subjects. This indicates that the ST over the zygoma area is thinner in men than in women, unlike the majority of the face (Table 3).

No significant differences were found between the right and left ST thickness measurements at all landmarks of the face. The relative bilateral differences showed higher values at the lower face, including the masseter muscle area (Table 4).

## Discussion

As an effective tool for measuring the facial ST thickness, 3D images obtained from CBCT scan are encouraged even though the majority of current databases were obtained using ultrasound devices. CT scan images have many advantages over ultrasound systems. Above all, the measurements can be repeated and confirmed, whereas this confirmation procedure is not feasible in an ultrasound system, which is an in vivo measurement. In addition, an unlimited number of measurements can be added according to the research requirements. Once the scan images are obtained, more detailed investigations are possible according to the study design. In addition, advances in software have improved the display technology, allowing soft and hard tissue images to be obtained simultaneously on a window. The landmarks can be identified easily and accurately on one of two images, and the corresponding point is designated automatically on the other image enabling the investigator to confirm the correct position of the landmark. This is different to ultrasonic analysis where the measurement is determined according to the transducer orientation where the highest peak corresponds to the most perpendicular orientation of the transducer to the bone. As the underlying bony surface is not seen by the ultrasound investigator, the correct position cannot be verified. With the use of CT images, more accurate measurements of the ST thickness can be obtained according to the definition of the landmark.

The present study recorded the facial ST thickness of Korean adults using CBCT images. The means and standard deviations of 31 landmarks were computed. Considering that there are few reports on Asians based on recent population groups, the results of the present study will provide more up-to-date facial ST profiles relevant to Korean subjects and might allow a forensic artist to give its appropriate racial character to the face.

It would be interesting to compare the results of this study with those of other races. With this in mind, the present study used the same landmarks employed by De Greef et al. (7), who conducted a study on White Europeans (Belgians). In the comparison of the measurements with the De Greef et al.'s (7) data, the majority of landmarks showed higher values indicating thicker ST in Koreans

TABLE 3—*Facial soft tissue depth data from cone-beam CT images and gender differences for Korean adults.*

| | Male (n = 50) | | | | Female (n = 50) | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Min | Max | Mean | SD | Min | Max | Sex Difference |
| Midline landmarks (mm) | | | | | | | | | |
| Supraglabella | 5.3 | 0.7 | 4.0 | 6.9 | 4.8 | 0.8 | 3.0 | 7.0 | NS |
| Glabella | 5.6 | 0.6 | 4.5 | 7.0 | 5.3 | 0.7 | 4.3 | 7.1 | NS |
| Nasion | 6.4 | 0.9 | 4.4 | 8.4 | 5.4 | 0.9 | 3.8 | 7.9 | 0.000*** |
| End of nasal | 2.3 | 0.6 | 1.0 | 3.8 | 2.2 | 0.9 | 1.1 | 6.1 | NS |
| Mid-philtrum | 12.5 | 1.1 | 10.1 | 14.8 | 10.7 | 1.4 | 7.2 | 13.5 | 0.000*** |
| Upper lip | 11.7 | 2.0 | 8.2 | 16.5 | 9.9 | 1.7 | 7.0 | | 0.000*** |
| Lower lip | 13.0 | 1.9 | 8.3 | 17.1 | 11.6 | 1.6 | 8.6 | 14.8 | 0.001** |
| Chin–lip fold | 11.6 | 1.1 | 9.8 | 13.7 | 10.2 | 1.1 | 8.3 | 12.7 | 0.000*** |
| Mental eminence | 12.3 | 1.4 | 9.5 | 14.8 | 12.0 | 1.8 | 8.6 | 16.0 | NS |
| Beneath chin | 8.0 | 1.5 | 5.0 | 11.1 | 6.9 | 1.5 | 4.0 | 10.6 | 0.018* |
| Bilateral landmarks (mm) | | | | | | | | | |
| Frontal eminence | 6.2 | 0.8 | 4.1 | 7.4 | 5.4 | 1.0 | 2.9 | 7.0 | 0.001** |
| Supraorbital | 7.2 | 1.1 | 4.7 | 11.1 | 6.4 | 1.0 | 4.1 | 8.5 | 0.001** |
| Lateral glabella | 9.2 | 1.7 | 6.4 | 14.3 | 8.2 | 2.1 | 5.1 | 13.0 | 0.013* |
| Lateral nasal | 7.3 | 1.5 | 4.1 | 10.5 | 6.5 | 1.4 | 4.5 | 9.9 | 0.013* |
| Suborbital | 7.4 | 1.4 | 4.9 | 10.7 | 7.3 | 1.3 | 4.4 | 9.2 | NS |
| Inferior malar | 18.6 | 2.7 | 12.7 | 24.6 | 17.5 | 2.6 | 12.3 | 22.5 | NS |
| Lateral nostril | 14.3 | 1.7 | 10.5 | 18.9 | 12.4 | 1.7 | 9.6 | 15.5 | 0.000*** |
| Naso-labial ridge | 12.9 | 1.0 | 10.4 | 14.5 | 10.9 | 1.2 | 8.6 | 13.4 | 0.000*** |
| Supracanina | 11.0 | 1.0 | 9.0 | 12.9 | 10.3 | 1.5 | 8.0 | 15.6 | 0.016* |
| Subcanina | 12.2 | 1.5 | 9.1 | 15.1 | 10.8 | 1.5 | 8.2 | 14.7 | 0.000*** |
| Mental tubercle anterior | 9.5 | 2.0 | 5.0 | 13.0 | 8.8 | 2.1 | 3.5 | 11.8 | NS |
| Mid-lateral orbit | 4.8 | 0.8 | 3.0 | 6.6 | 5.2 | 1.1 | 3.4 | 8.2 | NS |
| Supraglenoid | 12.6 | 2.0 | 8.8 | 16.6 | 11.2 | 1.8 | 8.3 | 14.9 | 0.004** |
| Zygomatic arch | 8.1 | 1.7 | 3.8 | 11.6 | 8.7 | 1.4 | 5.6 | 11.8 | NS |
| Lateral orbit | 8.6 | 1.4 | 6.1 | 12.0 | 10.2 | 1.4 | 6.7 | 13.5 | 0.000*** |
| Supra-M2 | 28.5 | 2.7 | 23.5 | 35.9 | 27.7 | 3.4 | 19.7 | 36.6 | NS |
| Mid-masseter | 19.5 | 3.8 | 13.2 | 28.5 | 17.5 | 2.5 | 12.6 | 24.1 | 0.008** |
| Occlusal line | 22.9 | 2.6 | 17.2 | 27.5 | 21.2 | 2.3 | 15.5 | 27.1 | 0.004** |
| Sub-M2 | 21.1 | 2.8 | 14.2 | 26.1 | 20.3 | 2.4 | 14.5 | 25.8 | NS |
| Gonion | 14.3 | 4.0 | 6.6 | 24.6 | 12.9 | 2.3 | 7.5 | 17.7 | NS |
| Mid-mandibular angle | 7.9 | 1.7 | 3.9 | 11.3 | 7.7 | 1.7 | 4.7 | 11.4 | NS |

The measurements were obtained on the right side of face; *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.
NS, not significant.

TABLE 4—*Right and left facial soft tissue depth differences at bilateral landmarks (unit: mm) using cone-beam CT images for Korean adults.*

| | Right | | Left | | | R–L difference | | \|R–L difference\| | |
|---|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | Significance | Mean | RD (%) | Mean | RD (%) |
| Frontal eminence | 6.0 | 1.1 | 5.9 | 1.1 | NS | 0.1 | 2.0 | 0.3 | 5.1 |
| Supraorbital | 6.8 | 1.0 | 6.7 | 1.1 | NS | 0.1 | 2.0 | 0.5 | 6.8 |
| Lateral glabella | 8.6 | 1.6 | 8.8 | 1.6 | NS | −0.1 | −1.6 | 0.6 | 6.9 |
| Lateral nasal | 7.0 | 1.4 | 6.9 | 1.4 | NS | 0.1 | 1.8 | 0.6 | 9.2 |
| Suborbital | 7.5 | 1.4 | 7.6 | 1.4 | NS | −0.1 | −1.2 | 0.6 | 7.7 |
| Inferior malar | 18.3 | 2.3 | 18.3 | 2.6 | NS | 0.1 | 0.3 | 0.7 | 3.9 |
| Lateral nostril | 13.7 | 1.7 | 13.5 | 1.6 | NS | 0.2 | 1.4 | 0.7 | 4.8 |
| Naso-labial ridge | 12.1 | 1.6 | 12.1 | 1.5 | NS | 0.0 | 0.2 | 0.4 | 2.9 |
| Supracanina | 10.9 | 1.2 | 10.8 | 1.2 | NS | 0.0 | 0.3 | 0.4 | 3.9 |
| Subcanina | 11.9 | 1.4 | 11.7 | 1.4 | NS | 0.2 | 1.5 | 0.5 | 3.9 |
| Mental tubercle anterior | 9.1 | 1.6 | 9.3 | 1.6 | NS | −0.1 | −1.5 | 0.5 | 5.6 |
| Mid-lateral orbit | 5.0 | 1.0 | 5.0 | 1.0 | NS | 0.0 | 0.9 | 0.1 | 2.0 |
| Supraglenoid | 12.1 | 1.5 | 12.2 | 1.8 | NS | −0.1 | −0.6 | 0.8 | 6.2 |
| Zygomatic arch | 8.3 | 1.5 | 8.5 | 1.8 | NS | −0.2 | −2.1 | 0.5 | 5.5 |
| Lateral orbit | 9.3 | 1.6 | 9.4 | 1.6 | NS | −0.1 | −0.8 | 0.5 | 4.9 |
| Supra-M2 | 27.8 | 3.1 | 27.9 | 3.0 | NS | −0.2 | −0.6 | 1.1 | 3.9 |
| Mid-masseter | 17.8 | 2.9 | 18.3 | 3.0 | NS | −0.5 | −2.6 | 1.2 | 6.6 |
| Occlusal line | 21.8 | 2.4 | 21.9 | 2.6 | NS | 0.0 | −0.2 | 0.8 | 3.7 |
| Sub-M2 | 20.6 | 2.5 | 20.7 | 2.7 | NS | −0.1 | −0.5 | 1.1 | 5.1 |
| Gonion | 12.5 | 2.8 | 13.0 | 2.7 | NS | −0.5 | −3.7 | 0.9 | 7.6 |
| Mid-mandibular angle | 7.7 | 1.4 | 7.9 | 1.5 | NS | −0.2 | −3.1 | 0.8 | 9.7 |

RD, relative difference that is calculated by dividing the difference value by one-side measurement, the right side in this study; NS, not significant; |R–L difference|, relative bilateral difference.

than in White Europeans. Utsuno et al. (24) also reported that Japanese children had thicker facial ST than Black African American, Hispanic, and White European children in their study with the use of cephalometric radiograms. While the results of this study showed greater values than those of the De Greef et al.'s (7) study, it does not necessarily mean that the facial ST is thicker in Koreans, because a different tool was used for the measurement in each study. In particular, it should be noted that the facial ST can be indented by the transducer during the measurement in the case of an ultrasound system (7). It is believed that the establishment of a Caucasian database using the CBCT scan images would be necessary to evaluate the ethnic differences in the facial ST thickness properly. In fact, Utsuno et al. (24) who mentioned racial differences in the ST thickness did not perform direct comparisons with other races. They compared their results indirectly with previous publications (4,6,27,28). Stephan and Simpson (29) also mentioned that wide variation exists in ST depth measures between different measurement techniques in their review of the published data. All these literature reviews suggest that data acquisition with CBCT scan would be necessary to evaluate the ethnic difference in the facial ST thickness properly.

In the comparison between male and female subjects, the ST thickness showed different patterns according to the measurement sites: no significant sex differences for some landmarks and statistically significant differences for others. Most of the landmarks that showed sex differences presented greater values in male subjects than in female subjects. Stephan et al. (30) also reported a sexual dimorphism in facial ST thickness from the review of published data, but they insisted that its difference was not marked and of little practical meaning for craniofacial identification. In the present study, however, most landmark sites showed significantly greater values in the male subjects compared to the female subjects. In particular, the landmarks corresponding to the lip area presented large differences, almost 2.0 mm. De Greef et al. (7) also reported a similar pattern, and a recent publication regarding Japanese children showed the same results (24). They reported that the landmarks of the subnasale, labrale superius, and labrale inferius presented statistically significant sex differences at 16- to 18-year groups, which is the oldest age-group in their study. Taken together, it is apparent that the ST thickness in the lip area is distinctly thicker in men than in women, regardless of race.

One landmark, the lateral orbit, which corresponds to the zygoma area, showed a smaller value in male subjects, while most landmarks showed greater values in male subjects. Other landmarks, the zygomatic arch and mid-lateral orbit, also showed a tendency of smaller values in male subjects. This indicates that the ST in this area is thinner in men, unlike the other areas of the face. De Greef et al. (7), who conducted a large-scale study on White Europeans, also reported the similar findings. While the measurements showed smaller values in this area in men, this does not necessarily mean that the ST contour is less prominent on this area. This might be the result of prominent bone in this area with the same contour of the overlying ST. The results of the present study should only be interpreted as the ST thickness itself.

## Conclusion

Using the CBCT scan images of Korean adults, the means and standard deviations of the facial ST thickness were obtained to enable forensic facial reconstruction. While 18 of 31 landmarks showed sex differences, the majority presented greater values in men, except for a few landmark sites corresponding to the zygoma area, which showed smaller values in male than in female subjects. There were larger differences at the mandibular area between the right and left sides of the face, including the masseter muscle region. The ST thickness measurements obtained in this study can be used as a database for the forensic craniofacial reconstruction of Korean adults.

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