Application of cone beam computed tomography in facial soft tissue thickness measurements for craniofacial reconstruction

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INTRODUCTION

Diagnostic imaging is an important adjunct to clinical diagnosis of the patient. Intraoral and panoramic radiographs often fulfill the requirements of imaging hard tissues. However, these 2D radiographic methods have limited capabilities in the evaluation of soft tissue. The paradigm shift from two- to three-dimensional imaging has marked the beginning of a new era in diagnosis. Newly developed cone-beam computed tomography (CBCT) designed specifically to visualize maxillofacial pathologies is being used in forensic investigations also. Facial reconstruction is a specialized forensic technique to identify the deceased from the unknown skull. It is dependent on population-specific facial soft tissue thicknesses.

Context: The paradigm shift from two- to three-dimensional imaging has marked the beginning of a new era in diagnosis. Newly developed cone-beam computed tomography (CBCT) designed specifically to visualize maxillofacial pathologies is being used in forensic investigations also. Facial reconstruction is a specialized forensic technique to identify the deceased from the unknown skull. It is dependent on population-specific facial soft tissue thicknesses.

Aims: This study aims to propose the mean dataset of facial soft tissue thickness for South Indian population by utilizing CBCT. It also aims to evaluate the sex and racial differences in the values if any.

Settings and Design: This descriptive study was conducted on CBCT scans of South Indians.

Materials and Methods: Eighty CBCT scans of South Indian adults aged 18–80 years were selected. Facial soft tissue thickness measurements at 34 craniometric landmarks were carried out.

Statistical Analysis: Descriptive statistics was done. Student’s t-test estimated the differences of soft tissue thickness between the sexes; bilateral measurements and also racial differences. Tukey’s honest significant difference test was used for multiple comparisons among Indian studies.

Results: Males had thicker soft tissue than females in most of the landmarks. Differences in the bilateral soft tissue thicknesses were negligible. Indians had thicker facial tissues than the Koreans and CBCT was found efficient in measuring soft tissue thickness.

Conclusion: The present study provides facial soft tissue thickness dataset using CBCT which will be useful in forensic facial reconstructions of South Indian population as well as in maxillofacial and plastic reconstructive surgeries.

Keywords: Cone-beam computed tomography, facial reconstruction, facial soft tissue thickness, human identification, South India

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of three-dimensional (3D) relationships. They also suffer from inherent limitations such as magnification and superimposition of structures. Several imaging technologies such as computed tomography (CT) have now been successful in capturing the missing third dimension.

CT images the subject by passing a fan-shaped X-ray beam to the detector through the patient lying within the rotating gantry. The sequential images acquired by scanning thin slices of body sections were being used extensively for diagnosing complex conditions such as craniofacial fractures, massive intraosseous tumors and others until the advent of cone-beam CT (CBCT) technology in the early 90s designed specifically for dentomaxillofacial imaging.

CBCT is the generation next that has emerged as a potentially low-dose volumetric imaging technique for visualizing maxillofacial structures, in which cone-shaped X-ray beam moves in a helical progression to acquire multiple individual image slices (approximately 150–800) as the X-ray source and the detector makes a single partial or complete circle around the patient. Sequential, single-image captures are stacked as multiple offset lateral cephalograms, corrected, assembled and reconstructed using filtered back projection algorithm. Further, secondary reconstructed images in the personal computer using dedicated software present the images to the radiologist in three orthogonal planes (axial, sagittal and coronal) and 3D reconstructions.

Reduced physical footprint, a relatively low patient dose and its low cost have been responsible for the rapid uptake of CBCT in the dental health-care systems. Apart from volumetric imaging, CBCT allows various nonaxial 2D images and synthesizes cephalograms comparable with the conventional ones. Several such advantages have made CBCT useful in the diagnostic assessment of bony and dental pathologies including fractures, maxillofacial deformities, temporomandibular joint imaging and implant treatment planning; it also facilitates image-guided surgery.

Radiography has been an integral part of forensic investigation ever since the discovery of X-ray in 1895. Radiographic analyses have become a routine method in assessing biologic characteristics such as age and sex, in locating foreign objects such as projectiles and their wound paths, in evaluating fragmentary remains of the skull and other body parts. The ability of CT to depict the anatomic structures in 3D perspective has made it useful for performing noninvasive postmortem examinations such as viropties. Apart from being smaller, CBCT offers several technical and practical advantages over conventional CT that can easily replace for all forensic case purposes, especially when medical CTs are inaccessible.

Craniofacial reconstruction is a well-established but sparingly used forensic technique of predicting and recreating the face of the deceased over the skull to trigger individual identification. Since its first attempt in the late 19th century, manual and computer-aided techniques have been developed, both of which involve reconstructing the lost soft tissues under the guidance of soft tissue pegs placed at specific sites on the face that represent the average facial soft tissue thickness (FSTT).

Since the contributions of renowned Russian anthropologist Mikhail Gerasimov, numerous studies have been undertaken to measure the average FSTT at specific sites on the face. On understanding the relationship of FSTT to age, sex, race and ethnicity, researchers have focused on establishing databases of FSTT for Caucasians, Germans, Japanese, Koreans and others. However, studies providing soft tissue thickness for South Indian population are limited.

FSTT has been measured by both invasive and noninvasive methods. Historically, thin needles were probed into the cadaveric face at specific sites until they hit the bone surface and the depth of penetration was measured. This invasive method was gradually overcome by several imaging-based methods including lateral cephalometric radiography, ultrasound (USG), magnetic resonance imaging (MRI) and CT, all of which have inherent advantages and limitations. While 2D lateral cephalometric radiographs are affected by magnification errors, additional landmarks cannot be incorporated at a later date in USG. Both CT and MRI techniques are collected with patients in supine position causing gravity induced FSTT deformation. In addition, CT is limited by the health risks associated with radiation. Cone-beam CT scanner enables images to be obtained with the subject in an upright position at a lower radiation dose. The purpose of this study was to utilize CBCT for measurements of FSTT with an attempt to propose soft tissue thickness dataset for South Indian population. In addition, the study has attempted to analyze the efficiency of CBCT over other imaging techniques in the measurement of FSTT.

MATERIALS AND METHODS

This research was approved by the Institutional Review Board, Rajiv Gandhi University of Health Sciences, Bengaluru, India. CBCT images of 80 adults aged 18–80 years were randomly selected. Care was taken to exclude the scans of cases with swelling, trauma, facial deformities and those
under orthodontic treatment. The scans were obtained using CBCT scanner (Planmeca ProMax 3D Mid; Planmeca Oy; Helsinki, Finland) with a voxel size of 0.3–0.4 mm and a field of view of 20 cm × 17 cm. All the cases were scanned with their Frankfurt Horizontal (FH) plane parallel to the floor with teeth in occlusion. The resulting DICOM data were imported into OnDemand3D software (Cybermed, Seoul, Korea) in the personal computer to measure the distance between a point on the skull surface to the corresponding point on the soft tissue image which gives FSTT at the respective anatomical points. A total of 34 landmarks (12 midline and 11 pairs of bilateral) were chosen according to Stephan and Simpson[20][Figure 1]. The landmarks on the skull surface were located on the reconstructed 3D image first, and the corresponding soft tissue landmark was identified using the preset hard and soft tissue display tool. Further, the identified points were accurately marked using two of the three orthogonal sections (coronal-axial or sagittal-axial) depending on the location of the landmarks.

Statistical analysis

General descriptive statistics such as mean and standard deviation were calculated for FSTT at each landmark using IBM Statistical Package for the Social Sciences version 21.0 software (Armonk, New York, United States). The difference between the mean values in the two sexes was compared using Student’s t-test and also the differences between the averages of the right and left sides. P value was set as 0.05 at 5% significance level.

RESULTS

Tables 1 and 2 summarize the mean, standard deviation, as well as minimum, maximum and range determined for each of the 34 anatomical landmarks. For all the inferential statistics, the P value was set as 0.05 at 5% significance level. “T” score from independent t-test and P values for significance level of all the variables are derived and results are tabulated in Tables 3 and 4. Along both right and left sides, a significant difference between the mean values of male and female was noticed at mid-supraorbital margin, alare curvature point, gonion, suprakanine, infrakanine and midramus. In the remaining landmarks, i.e., mid-infraorbital margin, zygion, supramolar, inframolar and mid-mandibular border, although the mean values differed between the two sexes, the statistical differences could not be established. In general, males

| Table 1: Descriptive statistics of midline facial soft tissue thickness (mm) at various craniometric landmarks |
|---------------------------------|--------|--------|--------|----------|-----|
| Landmarks                      | Mean   | Minimum| Maximum| Range    | SD   |
| g                              | 5.11   | 2.86   | 9.77   | 6.91     | 1.23 |
| n                              | 6.78   | 1.71   | 11.16  | 9.45     | 1.73 |
| mn                             | 3.98   | 1.42   | 7.57   | 6.15     | 1.15 |
| rhi                            | 2.35   | 0.84   | 4.58   | 3.74     | 0.74 |
| sn                             | 13.62  | 3.69   | 20.25  | 16.56    | 2.77 |
| mp                             | 12.00  | 3.06   | 17.24  | 14.18    | 2.55 |
| ls                             | 12.15  | 3.19   | 19.27  | 16.08    | 2.91 |
| li                             | 13.97  | 4.46   | 20.12  | 15.66    | 3.03 |
| mls                            | 11.42  | 5.56   | 18.09  | 12.53    | 2.15 |
| pg                             | 11.71  | 2.83   | 19.37  | 16.54    | 3.31 |
| gn                             | 8.46   | 1.97   | 17.68  | 15.71    | 3.35 |
| m                              | 5.92   | 2.29   | 15.58  | 13.29    | 2.29 |

SD: Standard deviation, g: Glabella, n: Nasion, mn: Midnasal, rhi: Rhinion, sn: Subnasal, mp: Midphiltrum, ls: Labrale superius, li: Labrale inferius, mls: Mentolabial sulcus, pg: Pogonion, gn: Gnathion, m: Menton

| Table 2: Descriptive statistics of bilateral facial soft tissue thickness (mm) at various craniometric landmarks |
|---------------------------------|--------|--------|--------|----------|-----|
| Landmarks                      | Mean   | Minimum| Maximum| Range    | SD   |
| Right mso                      | 8.04   | 4.81   | 11.91  | 7.10     | 1.70 |
| Left mso                       | 7.72   | 4.74   | 11.33  | 6.59     | 1.63 |
| Right mio                      | 5.72   | 2.98   | 10.54  | 7.56     | 1.59 |
| Left mio                       | 5.82   | 3.17   | 11.37  | 8.20     | 1.57 |
| Right acp                      | 9.39   | 5.41   | 12.85  | 7.44     | 1.74 |
| Left acp                       | 9.73   | 5.22   | 14.16  | 8.94     | 1.87 |
| Right go                       | 13.99  | 4.23   | 32.51  | 28.28    | 5.77 |
| Left go                        | 14.13  | 2.96   | 30.25  | 27.29    | 5.96 |
| Right zy                       | 7.97   | 3.21   | 15.13  | 11.92    | 2.30 |
| Left zy                        | 7.89   | 3.62   | 12.53  | 8.91     | 2.20 |
| Right sC                       | 11.91  | 6.26   | 19.59  | 13.33    | 2.56 |
| Left sC                        | 11.77  | 5.29   | 17.73  | 12.44    | 2.27 |
| Right IC                       | 13.20  | 5.96   | 19.87  | 13.91    | 2.88 |
| Left IC                        | 13.10  | 5.40   | 21.67  | 16.27    | 3.04 |
| Right sM<sup>2</sup>           | 29.88  | 13.67  | 41.41  | 27.74    | 4.96 |
| Left sM<sup>2</sup>            | 29.56  | 17.39  | 40.19  | 22.80    | 4.54 |
| Right IM<sub>2</sub>           | 26.31  | 16.91  | 36.11  | 19.20    | 4.48 |
| Left IM<sub>2</sub>            | 25.71  | 14.80  | 34.87  | 20.07    | 4.73 |
| Right mr                       | 20.11  | 10.66  | 30.63  | 19.97    | 4.62 |
| Left mr                        | 19.99  | 10.57  | 31.15  | 20.58    | 4.65 |
| Right mmb                      | 12.48  | 4.59   | 24.02  | 19.43    | 4.78 |
| Left mmb                       | 12.33  | 4.59   | 24.70  | 20.11    | 4.69 |

SD: Standard deviation, mso: Mid-supraorbital, mio: Mid-infraorbital, acp: Alare curvature point, go: Gonion, zy: Zygion, sC: Supracanine, IC: Infraorbinate, sM<sup>2</sup>: Supramolar 2, IM<sub>2</sub>: Inframolar 2, mr: Midramus, mmb: Mid-mandibular border

Figure 1: Clinical images of three-dimensional reconstructed skull showing hard tissue landmarks used in the present study. (a) Frontal view showing g: glabella; n: nasion; mn: midnasal; rhi: rhinion; sn: subnasal; mp: midphiltrum; ls: labrale superius; li: labrale inferius; mls: mentolabial sulcus; pg: pogonion; gn: gnathion; m: menton. (b) Right (R) profile view showing mso: mid-supraorbital margin; mio: mid-infraorbital margin; acp: alare curvature point; go: gonion; zy: zygion; sC: supracanine; IC: infraorbinate; sM<sub>2</sub>: supramolar 2; IM<sub>2</sub>: inframolar 2; mr: midramus; mmb: mid-mandibular border.
had significantly thicker soft tissues than the females at all landmarks, especially along the midline [Figure 2].

The mean value and standard deviation between landmarks of the right and left sides in both the sexes were compared, and paired $t$-test was used to test the significant difference between the mean values as shown in Table 5. There were no significant differences between the right and left side measurements except at mid-supraorbital margin and alare curvature point, suggesting no facial asymmetry. Further, correlation test carried out yielded significantly high and positive correlation between right and left sides in both males and females [Table 5].

To understand population diversity, gender-specific comparisons were made between the FSTT of the current study and the Korean data.[19] Statistically significant differences were observed between the two at almost all the anatomical sites [Table 6].

The mean and standard values of tissue depth of South Indian population with the values of other population of the Indian subcontinent were compared as shown in Table 7. Because the landmarks used in other studies varied in terms of number as well as nomenclature, abbreviations and definitions, only those values at the landmarks same or similar to the ones used in the current study were considered for comparison. The values differed among all the studies at all the landmarks. The differences are marked

### Table 3: Sex-based comparison of midline facial soft tissue thickness (mm) using Student’s $t$-test

| Landmarks | Males | Females | $t$ | $P$ |
|-----------|-------|---------|-----|-----|
| g         | 5.66±1.30 | 4.56±0.88 | 4.408 | 0.000 |
| n         | 7.74±1.70 | 5.82±1.12 | 5.952 | 0.000 |
| mn        | 4.3±1.21 | 3.62±0.98 | 2.915 | 0.005 |
| rhi       | 2.54±0.69 | 2.15±0.76 | 2.367 | 0.020 |
| sn        | 15.05±5.22 | 12.20±2.24 | 5.336 | 0.000 |
| mp        | 13.50±2.48 | 10.50±1.54 | 6.669 | 0.000 |
| ls        | 13.80±2.81 | 10.49±1.90 | 6.147 | 0.000 |
| li        | 14.96±3.03 | 12.98±2.71 | 3.076 | 0.003 |
| mls       | 12.22±3.30 | 10.62±1.66 | 3.547 | 0.001 |
| pg        | 12.87±5.57 | 10.57±2.59 | 3.299 | 0.001 |
| gn        | 9.72±3.35 | 7.21±2.88 | 3.543 | 0.001 |
| m         | 6.71±2.73 | 5.13±1.37 | 3.219 | 0.002 |

q: Glabella, n: Nasion, mn: Midnasal, rhi: Rhinion, sn: Subnasal, mp: Midphiltrum, ls: Labrale superius, li: Labrale inferius, mls: Mentolabial sulcus, pg: Pogonion, gn: Gnathion, m: Menton

### Table 4: Sex-based comparison of bilateral facial soft tissue thickness (mm) using Student’s $t$-test

| Landmarks | Males | Females | $t$ | $P$ |
|-----------|-------|---------|-----|-----|
| Right mso | 8.94±1.52 | 7.17±1.39 | 5.387 | 0.000 |
| Left mso  | 8.63±1.51 | 6.83±1.21 | 5.838 | 0.000 |
| Right mio | 5.97±1.54 | 5.46±1.62 | 1.422 | 0.159 |
| Left mio  | 6.07±1.60 | 5.56±1.70 | 1.484 | 0.142 |
| Right acp | 10.34±1.48 | 8.45±1.47 | 5.702 | 0.000 |
| Left acp  | 10.68±1.64 | 8.79±1.60 | 5.207 | 0.000 |
| Right go  | 15.69±6.36 | 12.30±4.60 | 2.728 | 0.008 |
| Left go   | 15.95±6.74 | 12.31±4.45 | 2.841 | 0.006 |
| Right zy  | 8.18±2.40 | 7.75±2.21 | 0.834 | 0.407 |
| Left zy   | 8.29±2.17 | 7.49±2.19 | 1.651 | 0.103 |
| Right sc  | 13.24±2.53 | 10.59±1.83 | 5.355 | 0.000 |
| Left sc   | 12.97±2.13 | 10.57±1.72 | 5.200 | 0.000 |
| Right IC  | 14.06±2.11 | 12.34±2.92 | 2.775 | 0.007 |
| Left IC   | 13.90±2.92 | 12.30±2.98 | 2.423 | 0.018 |
| Right Sm²  | 30.58±5.39 | 29.21±4.48 | 1.199 | 0.234 |
| Left Sm²  | 30.17±5.16 | 28.97±3.81 | 1.134 | 0.261 |
| Right IM₂ | 27.19±4.74 | 25.43±4.07 | 1.756 | 0.083 |
| Left IM₂  | 26.52±4.93 | 24.91±4.44 | 1.521 | 0.132 |
| Right Mr  | 21.93±4.65 | 18.29±3.87 | 3.804 | 0.000 |
| Left Mr   | 22.06±4.64 | 17.92±3.68 | 4.424 | 0.000 |
| Right mmb | 13.12±5.37 | 11.85±4.07 | 1.194 | 0.236 |
| Left mmb  | 13.27±5.10 | 11.39±4.08 | 1.825 | 0.072 |

mso: mid-supraorbital, mio: Mid-infraorbital, acp: Alare curvature point, go: Gonion, zy: Zygion, sc: Supracanine, IC: Infracanine, Sm²: Supramolar 2, IM₂: Infraorbital 2, m: Menton, mmb: Mid-mandibular border

### Table 5: Comparison and correlation of facial soft tissue thickness (mm) for facial asymmetry

| Landmarks | Right | Left | $t$ | $P$ | Correlation | Significance |
|-----------|-------|------|-----|-----|-------------|--------------|
| mso       | 8.04±1.70 | 7.72±1.63 | 3.933 | 0.000 | 0.908 | 0.000 |
| mio       | 5.72±1.59 | 5.82±1.17 | -0.669 | 0.511 | 0.642 | 0.000 |
| acp       | 9.39±1.74 | 9.73±1.87 | -3.137 | 0.002 | 0.859 | 0.000 |
| go        | 13.99±5.77 | 14.13±5.96 | -0.406 | 0.686 | 0.871 | 0.000 |
| zy        | 7.97±2.30 | 7.89±2.20 | 0.617 | 0.539 | 0.885 | 0.000 |
| sc        | 11.91±2.56 | 11.77±2.27 | 0.909 | 0.366 | 0.846 | 0.000 |
| IC        | 13.20±2.88 | 13.10±3.04 | 0.597 | 0.552 | 0.859 | 0.000 |
| Sm²       | 29.70±4.89 | 29.56±4.54 | 0.317 | 0.752 | 0.871 | 0.000 |
| IM₂       | 26.27±4.53 | 25.82±4.70 | 1.834 | 0.071 | 0.894 | 0.000 |
| Mr        | 20.11±4.62 | 19.99±4.65 | 0.777 | 0.439 | 0.953 | 0.000 |
| Mmb       | 12.48±4.78 | 12.33±4.69 | 0.811 | 0.420 | 0.936 | 0.000 |

mso: mid-supraorbital, mio: Mid-infraorbital, acp: Alare curvature point, go: Gonion, zy: Zygion, sc: Supracanine, IC: Infracanine, Sm²: Supramolar 2, IM₂: Infraorbital 2, m: Menton, mmb: Mid-mandibular border

Figure 2: Graph showing gender-based differences in facial soft tissue thickness
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between those derived from the radiographic assessment to the ones from the advanced imaging techniques. However, the measurements obtained from CT and CBCT were comparable and the differences are statistically insignificant at most of the points: glabella, rhinion, midphiltrum, labrale inferior, pogion and gnathion.

**DISCUSSION**

FSTT measurements have been recorded using a number of invasive and noninvasive techniques. Needle puncture method employed in the past had certain limitations such as limited subject availability and problems while skin puncture.[16] Feasibility of tissue penetration dictated the selection of anatomical sites. To overcome some of these limitations, various noninvasive imaging modalities such as lateral cephalograms, USG, MRI and CT evolved. Lateral cephalograms[17] reveal only midline FSTT values. While USG analysis is an appropriate alternative especially for large-scale studies,[18] anatomical sites chosen for the measurements are limited. Because it is a real-time imaging, new measurements cannot be incorporated at a later date.[19] Measurement errors are likely due to indentation of facial tissues with the transducer. This compels the investigators to repeat measurements which are likely due to indentation of facial tissues with the transducer.

Further, transducer orientation will reveal only midline FSTT values. While USGFeasibility of tissue penetration dictated the selection of anatomical sites. To overcome some of these limitations, various noninvasive imaging modalities such as lateral cephalograms, USG, MRI and CT evolved. Lateral cephalograms[17] reveal only midline FSTT values. While USG analysis is an appropriate alternative especially for large-scale studies,[18] anatomical sites chosen for the measurements are limited. Because it is a real-time imaging, new measurements cannot be incorporated at a later date.[19] Measurement errors are likely due to indentation of facial tissues with the transducer. This compels the investigators to repeat measurements which are likely due to indentation of facial tissues with the transducer.
CT and MRI minimized these limitations.\(^{[12,13]}\) Unlike USG, the measurement sites can be added at a later date according to the research requirements and the problems associated with transducer is eliminated. However, patient is in supine position during both the procedures, which results in gravity induced reduction in midline FSTT measurements while increasing the lateral ones.\(^{[21]}\)

CBCT system designed specifically for head and neck imaging has emerged as an effective tool for measuring FSTT. The dose of CBCT is almost 100 times less when compared to CT scans\(^{[22]}\) ranging from 102 to 298 μSv at lower resolution settings and exposures parameters. The mean effective doses for large and medium FOVs is 212 μSv and 177 μSv, respectively, which is far lower than the effective dose of approximately 860 μSv in CT.\(^{[22,23]}\)

CBCT gives a good representation of the facial soft tissues. Farman and Scarfe reported that the clarity in soft tissue definition with CBCT is sufficient to determine air/soft boundaries and also the patient’s profile.\(^{[24]}\) By integration of flat panel detectors, visualization of soft tissues has further improved.\(^{[25]}\)

The scans used in the current study were in the voxel size of 0.3–0.4 mm in accordance with Fourie et al.\(^{[14]}\) Small voxel size of 0.2 mm results in a very large surface mesh model, which makes it difficult to process an accurate 3D surface model apart from increasing patient radiation exposure while the use of bigger voxel sizes will cause loss of some relevant details.\(^{[29]}\) Patients in the current study were positioned upright with FH plane parallel to the floor to standardize patient positioning. This will avoid gravity-related measurement errors. Although Hoogeveen et al.\(^{[26]}\) have demonstrated negligible differences,\(^{[27]}\) Munn and Stephan demonstrated that posture variation affect the average FSTT measurements, especially in the cheeks, eyes and nasolabial fold area.\(^{[21]}\)

All the hard tissue and their homologous soft tissue landmarks in the present study were identified manually on volume rendered image at first and then was precisely defined on MPR slices for increasing the accuracy. The volume-rendered image was reoriented to make FH plane and transorbital plane horizontal although Gupta et al.\(^{[28]}\) opined that such reorientations does not enhance the precision of landmark plotting.\(^{[29]}\) CBCT allows clinically accurate and reliable 3D linear measurements of the craniofacial complex\(^{[28]}\) and allows addition of new parameters postscan unlike USG.\(^{[13]}\) Both hard and its homologous soft tissue images can be visualized simultaneously. The 3D reconstructions along with transplanar cross-sections help in accurate identification of the landmark.\(^{[28]}\)

The present study showed significantly higher soft tissue thickness means in males as large as up to 2–3 mm compared to the females at all the midline and certain bilateral (mid-supraorbital margin, alare curvature point, gonion, supracanine, infracanine and mid-ramus) landmarks which correspond to nose–lip and the mandibular angle areas. De Greef et al.\(^{[13]}\) on Caucasians and Utsuno et al.\(^{[14]}\) on Japanese children observed a similar pattern. This implies that soft tissues in the lip areas are distinctly thicker in men than in women, irrespective of the race. However, Stephan and Simpson insisted that this difference is of little practical implications during craniofacial reconstruction.\(^{[29]}\)

To evaluate facial asymmetry, FSTT measurements of the right side were compared with the left. The differences were negligible and insignificant at all the landmarks except mid-supraorbital margin and alare curvature point. The differences were below 0.4 mm and never exceeded 1.2 mm. Researchers with similar results have chosen either to measure FSTT only on the right side of the or to average the bilateral values.\(^{[12,13,18]}\)

To evaluate racial variations in FSTT values as have been reported in the literature,\(^{[14,19]}\) the data of the present study were compared with the mean values of the Korean population.\(^{[13]}\) These two datasets were comparable as both had similar sample size and both used CBCT for measurements. Significant differences in FSTT values were observed at 11–13 landmarks in both the genders emphasizing interpopulation variations in the FSTT and consequently the need for population-specific datasets. Stephan and Simpson opine that such differences occur due to the noise in the data created by measurement errors.\(^{[20]}\)

To understand whether the choice of technique affects the measurements, the data of the current study were compared with three other Indian studies\(^{[17,18,30]}\) wherein the researchers have used various noninvasive techniques such as lateral cephalogram,\(^{[17]}\) MRT\(^{[18]}\) and CT.\(^{[30]}\) The midline FSTT values of all the four studies differed from one another, the differences being statistically significant between the radiographic study\(^{[17]}\) and all the other three. In spite of lateral cephalograms clearly demonstrating the profile soft tissue outlines and facilitating midline measurements, the accuracy of 2D radiographic techniques is limited when compared to the advanced imaging owing to technique related errors such as superimposition. On the contrary, the differences between CT\(^{[30]}\) and CBCT
(current study) derived values are negligible and statistically insignificant at majority of the landmarks. CBCT provides high-quality images at a lower radiation dose using less expensive equipment. In addition, cases are not in supine position during the procedure unlike CT, which will eliminate gravity-induced effects on the FSTT values.[21]

CONCLUSION

Using CBCT scans, FSTT averages for South Indian Adults were obtained. Males had significantly thicker facial tissues than females. Negligible differences were noted in the soft tissue thickness between the right and left sides of the face. The measurements obtained in this study can be used as a database for the forensic facial reconstruction of South Indian adults. The values may also find its applications in archeology, maxillofacial and plastic reconstructive surgeries.

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Conflicts of interest

There are no conflicts of interest.

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