Morphometric analysis of facial soft tissue thickness for sexual dimorphism: A cone beam computed tomography study

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Abstract

Introduction: Facial Reconstruction is the final step attempted in forensics for the purpose of human identification wherein the facial structures are recreated over the anonymous skull to make it identifiable by the public. Population-specific facial soft tissue thickness (STT) data is essential to obtain acceptable results in facial reconstruction. Tissue thickness have wide variations owing to the influence of factors such as age, sex and race of the individuals. To this end, the aim of the present study was to provide a set of STT averages for south Indian population and to evaluate the influence of age and sex on STT averages.

Material and Methods: CBCT scans of 307 (142 males and 165 females) south Indian subjects aged 18-80yrs were selected and STT was estimated at 34 landmarks using Ondemand 3D software.

Results: STT averages were obtained. An increasing trend in STTs with advancing age was observed in both males and females. Mean STT was significantly larger in males than females at all the landmarks except at gonion. Seven variables (nasion, subnasale, pogonion, zygion, infraM2, midramus and midmandibular border) were found to be the best predictors of sex and could identify sex of 83% subjects.

Conclusion: Present study has provided mean facial soft tissue thickness values of adult south Indian population at suitable reference points. The derived discriminant function equations will be useful in sex determination of the unknown. STT along with their age and sex related variations will be valuable in forensic facial reconstructions, plastic surgeries and in anthropology.

Keywords: Sex determination, Forensic facial reconstruction, Facial soft tissue thickness, Human identification, Cone beam computed tomography, South Indian population.

Introduction

Human identification is the sine qua non of forensic odontology. Face is the first tool used in this act as this is most visible part of the human body. Under circumstances such as explosions, warfare and mass disasters however, forensic experts are challenged to establish the identity of human remains in mutilated states wherein the face is in the unrecognisable form.[1] Occasionally, parts of the skeleton and skull in particular may be unearthed during archaeological studies.[1] Although Comparative identification is employed in all such situations wherein the post-mortem data of the deceased is matched with his pre-existing medical and dental records, the method is of limited use in the absence / unavailability of antemortem details. Even biological identification through DNA necessitates a known profile for comparison. In all such circumstances when the investigation process reaches a blind end, forensic experts retreat to craniofacial reconstruction, an anthropological technique which aids in the identification of the deceased through recognition by the public.[1,2]

Craniofacial Reconstruction (CFR) is an artistic science of recreating the face of an unknown skull and give the skull a recognisable form to help in its identification during forensic investigations.[3] Occasionally, CFR is employed to sculpt the faces of renowned individuals from the prehistoric times such as Egyptians and Babylonians. Since its inception in the nineteenth century, various two-dimensional and three-dimensional methods have been applied in the process of reconstruction. 2D method superimposes the sketch of the predicted face on to the skull images either manually or by dedicated computer software

for comparison whereas in 3D reconstruction, the entire face is moulded onto the unknown skull or its replica. The procedure employed for 3D reconstruction has varied among the practitioners. Morphoscopic/Russian method rely on the construction of the facial musculature which prerequisites sculptural expertise of certain degree; the morphometric/American method rely on the use of soft tissue depth averages has a more scientific approach whereas the Wilkinson's Manchester method amalgamates both.[3,4] Irrespective of the sequence involved in the procedure, all of the major methods advocate the construction of the soft tissues onto the skull replica under the guidance of tissue depth pegs attached to the skull surface at various points.[5]

Tissue depth markers beacon the anthropologists to establish a near-normal appearance of the face to the skull. The depth of the tissue markers is the averages of the facial soft tissue thickness (STT) measured at specific anatomical landmarks on the face estimated on general population.[6] A variety of measurement techniques have been employed to estimate STT ranging from insertion of needles in cadavers to advanced technologies such as CT-scan and MRI.[7] STT measured on cadavers are severely affected by post mortem changes and also from limited data. In living subjects, STT can be measured using lateral cephalometric radiographs, CT, MRI and ultrasound.[8–11] While cephalometry yields information of the facial thickness along the midline which may also be influenced by superimpositions, ultrasound is technique sensitive wherein the pressure effects from the transducer during examination are likely to underestimate the values. Although CT and MRI are more precise in

evaluating the craniofacial relationship, measurements are taken with subjects in supine position which would introduce gravity induced differences in the measurements.[12] Recently developed Cone Beam Computed Tomography (CBCT) has been exclusively designed for imaging of craniofacial structures and allows the patient to be in upright position during the procedure. Furthermore, the radiation dose is much lower than for CT-scan.[13,14]

Reconstructed face attracts public attention and eases recognition only when it depicts the facial features exclusive of the deceased individual. Age, sex and race dependant variations in the craniofacial architecture help to add uniqueness to each individual and differentiate from one another.[3,15] Over the last century, studies have been conducted globally in various ethnic groups as racial variations have been observed in soft tissue thickness data.[7,10,11,16] It is also likely that STT may differ among genders at particular anthropological landmarks. The aims of this study were therefore to measure facial soft tissue thickness of South-Indian population; evaluate if there are sex related differences in the soft tissue thickness and also to assess the influence of age and sex on facial soft tissue thickness.

Materials and Methods

The material for this study consisted of 307 subjects (142 males and 165 females) anonymised cone beam-CT scans of South Indian individuals, aged between 18 and 80 years. Clearance was obtained from Institutional Ethical Committee and patients were subjected to scan for reasons unrelated to the current study. Patients with congenital facial deformities and those treated for head and neck trauma or pathologies, patients who have undergone or in the process of orthodontic treatment or patients with facial asymmetries any of which may compromise the facial soft tissue thickness were excluded from the study. Patients were made to stand within the Planmeca ProMax 3D Mid CBCT scanner with Frankfurt Horizontal plane (FH - plane) parallel to the floor and face in a neutral, relaxed position. Scans were made using a tube current of 8mA, at a tube voltage of 90kV and a scan time of 18secs. With field of view (FOV) of 200 x 170mm, by 360-degree rotation of the x-ray tube, series of images were acquired using amorphous silicon flat panel detector at a resolution of 300μm. All the images were saved in the external hard disc drive in Digital Imaging and Communication in Medicine (DICOM) format. All the DICOM images were exported to ONDEMAND 3D software by CYBERMED INC, KOREA. The maxillofacial 3D images were created from the DICOM data and measurements were done using cephalometric analysis tool of the software. For controlling antero-posterior head rotation and orientation of the images, intracranial reference plane was used with F-H plane oriented horizontal in the sagittal view, mid-sagittal plane oriented vertically in the axial view and transporionic line oriented horizontally in the coronal view.

34 (12 midline and 11 bilateral) hard tissue landmarks and the corresponding soft tissue counterparts were selected for STT measurements. The landmarks were chosen as suggested by Stephan and Simpson[5] who upon their extensive review of 62 studies have opined that these landmarks provide a good basis for a minimum set in STT measurements. To obtain measurements, cephalometric Analysis tool available in the software was used. The landmarks were identified on the 3D reconstructed volumetric image as per the hard tissue landmark definition. The landmark position was further located more accurately using the orthogonal sections. The corresponding soft tissue landmark was established on the soft tissue image according to the landmark definitions. The distance between the two points were automatically calculated by the program as the STT at that anatomical point.

The resulting measurement data were recorded and analysed using IBM SPSS software version 22.0. Released in 2013. Armonk, NY: IBM Corp. The analysis was done for a total of 33 landmarks. Basic descriptive statistics that include mean and standard deviation of FSTT of males and females were calculated. Student Paired t Test was used to compare the mean values of FSTT between right and left Sides in male and female subjects. Independent Student t Test was used to perform gender wise comparison of FSTT and also between the genders in different age groups. Step-wise multivariate Discriminant Function analysis was performed to predict the genders by using different study variables. The level of significance [P-Value] was set at P<0.05.

Results

The name and definitions of various landmarks at which soft tissue thicknesses were estimated in the current study have been adopted from Stephan and Simpson.[5] Facial soft tissue thickness was measured at 12 midline landmarks and 11 bilateral landmarks in CBCT scans from all the 307 study subjects. However, Student Paired t-Test used to compare the mean FSTT values of the right and left sides of the face showed no significant difference at any of the eleven anatomical landmarks among both male and female subjects. Consequently, only right side values were considered for further statistical tests resulting in FSTT values at only 23 landmarks.

Averages of facial soft tissue thickness estimated in both the sexes have been presented in Table 1. STT was larger in males than females as seen in Fig. 1. Independent Student t-Test that was used to compare the mean FSTT values between males and females shows statistically significant differences between the two sexes at all the craniofacial landmarks except at zygion. Differences of ≥ 2mm was noted between males and females at subnasale, midphiltrum, labrale superius, gonion, supracanine and infraM2 with highest sexual dimorphism observed at mid ramus region.

As shown in Table 2, Independent Student t-Test was used to compare sexual dimorphism in STT values at different age groups. At certain landmarks (nasion, midphiltrum, labrale superius and supracanine) the sex-based differences were significant at all the age groups with

males having larger STT than females. At landmarks mid nasal, rhinion, subnasale, labrale inferius, pogonion, menton, mid supraorbital, alare curvature point and infracanine, the sex-based differences in STT were significant below 30 yrs and above 40 yrs. At supraM2, infraM2, gonion, midramus and mid mandibular border, the differences were statistically significant only beyond 40 yrs of age. At glabella and gnathion however, the differences were significant below 30 yrs and above 50 yrs.

Fig. 2 is a graphical representation depicting an increasing trend in STT with the advancing age of south Indian males. Fig. 3 represents a trend of gradual increase in STT of South Indian females at all the landmarks as the age advances. Facial soft tissues are thinner in the forehead region whereas the STT increases around the cheek and is thickest in the region of the mandible. The trend is similar in both the genders.

As shown in Tables 3 and 4, Step-wise multivariate discriminant function analysis (MDFA) of soft tissue thicknesses was estimated. Seven among the 33 variables (nasion, subnasale, pogonion, zygion, infraM2, midramus and midmandibular border) were chosen as the best landmarks to discriminate the sex. 83.1% of the subjects from the original grouped data and 100% of the subjects (80.5% males and 85.4% females) from cross-validated data were correctly determined. Table 5 shows the discriminant function equations for sex estimations from tissue depth values. By inserting the values at the above mentioned seven anatomical landmarks in the equations given in Table 5, the sex of the unknown can be determined and compared with sex-specific group centroid. If the calculated value lies closer to 1.122, then the subject is male and if the value is closer to -0.909, then the unknown subject is a female.

Table 1: Averages of facial soft tissue thickness (mm) and their variations between two genders

Landmarks	Males	Females	
	Mean ± Std. Dev	Mean ± Std. Dev	P-Value
glabella	5.39 ± 1.17	4.76 ± 1.10	<0.001*
nasion	7.25 ± 1.69	5.81 ±1.45	<0.001*
mid nasal	4.36 ± 1.20	3.63 ±0.95	<0.001*
rhinion	2.51 ± 0.76	2.06 ±0.57	<0.001*
sub nasale	14.11 ± 2.32	11.82 ±2.01	<0.001*
mid philtrum	12.63 ± 2.33	10.40 ±2.18	<0.001*
labrale superius	12.96 ± 2.85	10.82 ±2.37	<0.001*
labrale inferius	14.58 ± 2.94	13.02 ±2.80	<0.001*
mentolabial sulcus	11.51 ± 2.10	10.68 ±1.99	<0.001*
pogonion	12.54 ± 3.15	10.66 ±2.75	<0.001*
gnathion	8.41 ± 2.98	6.79 ±2.32	<0.001*
menton	5.76 ± 2.14	4.91 ±1.50	<0.001*
mid supraorbital	8.39 ± 1.78	6.90 ±1.70	<0.001*
mid infraorbital	5.77 ± 1.57	5.32 ±1.38	0.008*
alare curvature point	9.67 ± 2.15	8.40 ±1.29	<0.001*
gonion	15.33 ± 5.91	13.30 ±4.68	0.001*
zygion	7.54 ± 2.29	7.68 ±1.97	0.58
supracanine	12.70 ± 2.31	10.61 ±2.27	<0.001*
infracanine	13.79 ± 2.97	12.11 ±2.92	<0.001*
supraM2	30.66 ± 4.95	29.00 ±3.90	0.001*
infraM2	27.06 ± 4.88	24.80 ±3.67	<0.001*
mid ramus	21.65 ± 4.51	18.64 ±3.62	<0.001*
mid mandibular border	12.76 ± 4.84	11.64 ±3.67	0.02*

* p-value of ≤ 0.05 is statistically significant

Table 2: Facial Soft Tissue Thickness (mm) variations in males and females in different age groups

Landmarks	Sex	17-20 yrs	21-30 yrs	31-40 yrs	41-50 yrs	> 50 yrs
		Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
glabella	M	5.12 ± 0.89	5.16 ± 0.82	5.49 ± 0.87	5.49 ± 1.34	5.64 ± 1.48
	F	4.61 ± 0.64*	4.46 ± 0.91**	4.85 ± 1.02	5.04 ± 1.28	4.83 ± 1.30*
nasion	M	6.88 ± 1.55	7.17 ± 1.13	7.93 ± 1.33	7.50 ± 1.77	7.08 ± 2.12
	F	5.42 ± 0.98**	5.64 ± 0.91**	5.67 ± 1.02**	6.24 ± 1.83**	5.85 ± 1.71**
mid nasal	M	3.99 ± 1.06	4.02 ± 0.84	4.46 ± 1.09	4.72 ± 1.24	4.53 ± 1.44
	F	3.33 ± 0.97*	3.38 ± 0.76**	3.65 ± 0.97	3.83 ± 1.08**	3.82 ± 0.88**
rhinion	M	2.12 ± 0.47	2.20 ± 0.56	2.48 ± 0.65	2.86 ± 0.81	2.68 ± 0.84
	F	1.93 ± 0.40	1.91 ± 0.53*	2.22 ± 0.61	2.12 ± 0.64**	2.17 ± 0.59**

sub nasale	M	14.12 ± 1.57	15.19 ± 1.74	14.95 ± 1.63	13.94 ± 1.88	13.03 ± 3.03
	F	12.57 ± 1.45**	12.32 ± 1.60**	11.93 ± 1.88	11.51 ± 2.36**	11.18 ± 2.11**
mid philtrum	M	12.76 ± 1.31	13.62 ± 1.54	13.77 ± 1.44	12.53 ± 1.82	11.43 ± 3.18
	F	11.33 ± 1.23**	10.83 ± 1.15**	10.70 ± 1.81**	10.11 ± 2.55**	9.63 ± 2.73**
labrale superius	M	13.32 ± 1.47	13.84 ± 2.06	14.10 ± 1.30	12.66 ± 2.73	11.91 ± 3.88
	F	12.01 ± 1.57**	11.15 ± 1.52**	11.80 ± 2.08**	10.11 ± 2.62**	10.17 ± 2.83*
labrale inferius	M	14.18 ± 3.06	15.25 ± 1.98	14.77 ± 1.93	14.15 ± 2.92	14.47 ± 3.80
	F	13.63 ± 1.67	13.41 ± 1.92**	14.20 ± 2.28	12.37 ± 3.18*	12.55 ± 3.52*
mentolabial sulcus	M	11.55 ± 1.63	11.15 ± 1.80	11.59 ± 1.44	11.62 ± 2.47	11.69 ± 2.44
	F	10.57 ± 2.02	10.32 ± 1.32*	11.33 ± 1.18	10.68 ± 2.43	10.86 ± 2.19
pogonion	M	11.56 ± 2.81	12.05 ± 2.53	12.78 ± 2.38	13.06 ± 3.53	12.96 ± 3.60
	F	10.14 ± 2.23	10.70 ± 1.77*	12.59 ± 2.07	10.75 ± 3.33**	10.30 ± 3.14**
gnathion	M	6.71 ± 1.95	8.33 ± 2.83	8.21 ± 2.91	8.45 ± 2.79	9.33 ± 3.39
	F	6.43 ± 1.75	5.97 ± 1.72**	7.39 ± 2.45	7.30 ± 2.69	7.04 ± 2.53**
menton	M	4.57 ± 1.50	5.25 ± 1.35	5.21 ± 1.42	6.22 ± 2.47	6.57 ± 2.47
	F	4.71 ± 1.30	4.63 ± 1.17*	5.33 ± 1.26	5.05 ± 1.68*	5.02 ± 1.74**
mid supraorbital	M	7.86 ± 1.12	8.03 ± 1.26	8.56 ± 1.70	8.98 ± 2.00	8.51 ± 2.23
	F	6.72 ± 1.33**	6.69 ± 1.33**	7.58 ± 1.30	7.06 ± 1.94**	6.86 ± 2.06**
mid infraorbital	M	5.29 ± 1.00	5.14 ± 1.06	5.63 ± 2.07	6.03 ± 1.48	6.38 ± 1.79
	F	5.14 ± 1.02	5.33 ± 1.37	5.28 ± 1.64	5.35 ± 1.50	5.41 ± 1.42**
alare curvature point	M	9.28 ± 1.57	9.83 ± 3.30	9.04 ± 1.63	9.72 ± 1.57	9.89 ± 1.65
	F	8.36 ± 1.12*	7.89 ± 1.24**	8.43 ± 1.67	8.61 ± 1.44**	8.67 ± 1.06**
gonion	M	11.96 ± 4.21	12.80 ± 4.71	14.34 ± 4.90	17.06 ± 5.55	18.02 ± 6.49
	F	10.49 ± 3.38	11.98 ± 4.57	14.84 ± 3.63	14.48 ± 4.73*	14.67 ± 4.77**
zygion	M	7.56 ± 2.33	6.98 ± 2.02	7.34 ± 1.75	8.02 ± 2.17	7.71 ± 2.68
	F	7.33 ± 1.54	7.86 ± 1.89	8.50 ± 1.91	7.87 ± 2.26	7.31 ± 1.95
supracanine	M	12.87 ± 2.45	13.23 ± 1.43	14.27 ± 2.21	12.49 ± 1.81	11.86 ± 2.87
	F	11.93 ± 1.53	11.07 ± 1.39**	11.28 ± 2.14**	10.26 ± 2.17**	9.50 ± 2.80**
infracanine	M	13.55 ± 2.30	13.77 ± 2.75	14.40 ± 2.83	13.78 ± 3.19	13.73 ± 3.39
	F	12.18 ± 2.18*	12.15 ± 2.59*	13.02 ± 3.24	12.17 ± 3.35*	11.71 ± 3.11**
supraM2	M	28.55 ± 3.67	30.11 ± 4.18	29.11 ± 5.24	31.92 ± 5.63	31.85 ± 5.17
	F	28.04 ± 2.57	28.83 ± 4.34	31.45 ± 2.65	29.36 ± 4.27*	28.64 ± 3.97**
infraM2	M	24.26 ± 4.37	26.09 ± 4.19	25.64 ± 4.71	28.23 ± 3.71	28.96 ± 5.68
	F	23.20 ± 2.71	25.20 ± 3.48	27.75 ± 3.04	25.12 ± 3.93**	24.25 ± 3.85**
mid ramus	M	18.88 ± 3.66	19.91 ± 4.05	20.70 ± 3.47	23.28 ± 4.06	23.46 ± 4.71
	F	17.53 ± 2.81	18.23 ± 3.27	21.26 ± 2.89	19.46 ± 3.92**	18.16 ± 3.86**
mid mandibular border	M	9.55 ± 3.95	10.10 ± 3.44	11.52 ± 4.48	14.44 ± 3.85	15.61 ± 4.94
	F	8.98 ± 2.79	10.62 ± 3.57	13.92 ± 3.03	12.27 ± 3.81*	12.94 ± 3.16**

* p: ≤ 0.05; ** p: ≤ 0.01 - statistically significant

Table 3: Classification functions of Step-wise Multivariate Discriminant Function Analysis for sex discrimination

Variables chosen	Tolerance	F to Remove	Wilks' Lambda	SCDFC	CDFC	Males	Females
subnasale	0.839	25.870	0.544	0.470	0.230	2.702	2.235
nasion	0.722	24.416	0.542	0.494	0.345	1.955	1.254
zygion	0.397	58.413	0.609	-0.972	-0.457	-2.035	-1.108
mid ramus	0.248	26.379	0.546	0.873	0.217	1.366	0.925
mid mandibular border	0.250	13.339	0.520	-0.634	-0.146	-2.125	-1.829
infraM2	0.294	6.632	0.506	0.417	0.098	2.376	2.177
pogonion	0.725	4.839	0.503	0.228	0.080	0.677	0.514
Constant					-7.827	-57.514	-41.404

SCDFC: Standardized Canonical Discriminant Function Coefficients; CDFC: Canonical Discriminant Function Coefficients; Male group centroid = 1.122; Female Group Centroid = -0.909

Table 4: Sex determination table of cross validated results from Step-wise Multivariate Discriminant Function Analysis

Cross Validated	Category	Gender	Predicted Group Membership		Total
			Males	**Females**	
Prediction	n	Males	107	26	133
		Females	22	129	151
	%	Males	80.5	19.5	100
		Females	14.6	85.4	100

Table 5: Canonical discriminant function equations for sex estimation

Condition	Equation
If sex is Unknown	-7.827 + 0.230 (sn) + 0.345 (n) -0.457 (zy) + 0.217 (mr) -0.146 (mmb) + 0.098 (iM2) + 0.080 (pg)
If sex is Male	-57.514 + 2.702 (sn) + 1.955 (n) -2.035 (zy) + 1.366 (mr) -2.125 (mmb) + 2.376 (iM2) + 0.677 (pg)
If sex is Female	-41.404 + 2.235 (sn) + 1.254 (n) -1.108 (zy) + 0.925 (mr) -1.829 (mmb) + 2.177 (iM2) + 0.514 (pg)

sn: subnasale; n: nasion; zy: zygion; mr: mid ramus; mmb: mid mandibular border; iM2: infraM2; pg: pogonion

Fig. 1: Facial Soft Tissue Thickness variations in males and females
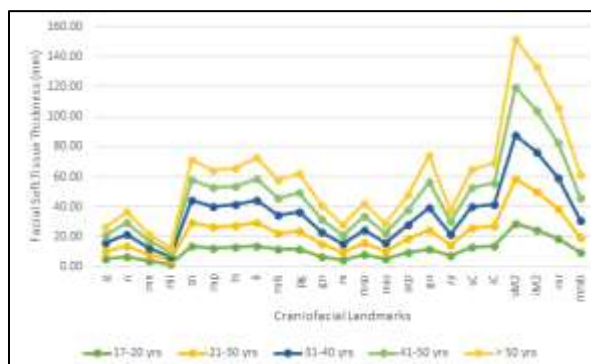
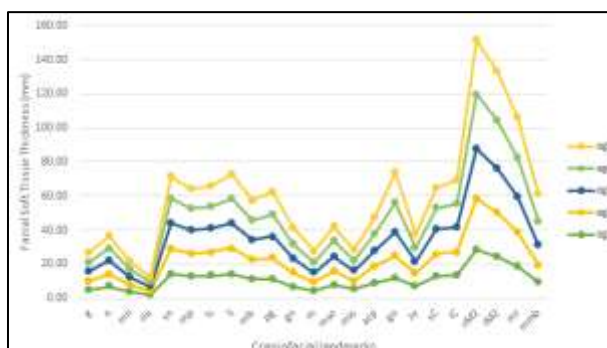**Fig. 2:** Facial Soft Tissue Thickness variations with advancing age in males

Fig. 3: Facial Soft Tissue Thickness variations with advancing age in females

Discussion

Establishing the identity of skeletonised human remains is a challenging task for both forensic investigators and anthropologists.[1] Distinguishing the gender will reduce the search population for identification by half thus simplifying further procedures. Sex determination is 98% accurate when the whole skeleton is available. Skull possesses 90% accuracy and has the second highest sex discriminant potential, first being the pelvis.[17] The present study evaluated whether the facial soft tissues overlying the skull shows significant gender-based differences in its thickness analogous to the skull.

Facial reconstruction in forensics is a scientific art of recreating the face on the anonymous skull to facilitate its identification. The Technique relies heavily on the average facial soft tissue thickness measurements at pre-determined anatomical landmarks to improve the likeness of the rebuilt face. Although various studies across the globe have measured on a range of 10[18] to 52[11] landmarks, measurements in the present study Was done only at 34 landmarks as per Stephan and Simpson who from the systematic review suggested that measuring at 34 landmark sites would be sufficient enough for reconstruction of the face to a recognisable degree.[5] The results of the current study provide a set of average STT measurements measured at 34 anatomical landmarks for South Indian males and females.

Since the 18th century, STT has been measured by using invasive techniques such as needle puncture method to non-invasive ones like radiographs. The present study used cone beam computed tomography; a technique intended specifically for maxillofacial imaging. Being a three - dimensional imaging technique, it provides a good representation of soft tissues and facilitates a comparative assessment of both hard and soft tissues simultaneously.[19] Since the machine is reasonably priced when compared to CT, smaller in size requiring smaller foot size and hence the space, and images at par with CT imaging,[19] it is more likely to be easily available in forensic caseworks for postmortem scanning and virtopsies of body parts.

The present study provides average STT measurements of South Indian population. Observations of the values indicate that Facial soft tissue thickness values are lower in the upper facial region when compared to other regions of the face possibly because the soft tissues of the region are tightly adherent to the underlying skull.[20] The values are comparable to those of Kotrashetti and Mallapur[8] done on South Indian population at all the common landmarks except at gonion where the values differ more than 2mm. The authors have measured tissue thickness at gonion using antero-posterior radiograph which is inherent with superimpositions. Additionally, it being a two-dimensional radiograph, visualisation of the landmark in all the three planes is restricted thus compromising on the accuracy of landmark identification. CBCT overcomes such limitations wherein the structures can be better visualised on 3D reconstructed images which enhance identification of craniometric landmarks with precision. Being an isotropic

imaging modality, CBCT is devoid of magnification which ensures that the measurements made are accurate and reliable. As observed in Northwest Indians[10] and Chinese subjects,[21] STT of South Indian population in the current study showed an increasing trend in the values at upper and middle third of the face and decreasing trend at the lower facial points along the midline.

Insignificant differences noted in the STT values between the right and left sides of the face support no facial asymmetry. The results are in concordance with that observed in Spanish population[22] and German adults.[9] Even Sahni et al. did not find any statistically significant difference between right and left STT among northwest Indian adult males and females.[10]

Measured data was analysed on the basis of age and sex. STT was compared at five progressive age groups within the same sex and between sexes. Variations in STT with advancing age was negligibly small within the same gender. However, the values vary significantly between the genders. In the regions around the upper lip (midphiltrum, labrale superius, supracanine), the differences were significant at all age groups whereas at areas around the cheek and the mandible (supraM2, infraM2, gonion, mid ramus and mid mandibular border), the differences were significant only beyond 40 yrs. Since the age and sex of the skull will be assessed prior to the start of the reconstruction process, these observations may be utilised for improved results. Wilkinson observed no definite relation in the STT values and the advancing age although there is a trend of decrease in STT around the mouth and cheek areas while STT being increased at the chin as age advances.[15] Similar pattern is observed in the current study which is noticeable evidently in females than in males.

The results of the present study demonstrated higher STT in males than females at all the facial areas except at zygion. Craniometrically, male skulls are larger and more robust than female skulls. In addition, due to the differences in the hormonal influences, males have stronger and larger musculature as compared to females.[23] However, the landmark zygion which is the point on the lateral most curvature of the zygomatic arch lies in the cheek region where females possess thicker soft tissues than males due to presence of subcutaneous fat in abundance.[10] Several studies have found that males have thicker soft tissues at majority of the facial regions than females which is in concordance with the results of the current study.[8,10,16,24]

Multivariate Discriminant Function Analysis showed higher predictive value (80.5% in males and 85.4% in females) in determination of sex accurately. Kaur et al. in their study on STT of northwest Indians observed similar results wherein the STT was analysed using CT and MRI.[24] This emphasise that sexual dimorphism play a vital role and hence should be taken into account during facial reconstruction. In addition, the discriminant function equation that has been derived assist in the estimation of gender whenever necessary.

Apart from age and sex, multiple factors including race, ethnicity and nutritional status influence the STT. Studies

have shown that soft tissue thickness measurements increases with increased BMI and these changes are common to both genders alike.[25,26]Nevertheless, since the present study utilised the pre-existing CBCT scans which were done for purposes not intended for this study, the data of height and weight of not all the subjects were available for calculating BMI. Remaining small subject cohort with average BMI showed no noteworthy relationship between the BMI and STT.

Variation in the STT values when compared to other population may be attributed to racial and regional diversities apart from the impact of local factors such as nutrition. As future work, the authors of the current research intend to evaluate facial soft tissue thickness among other racial groups and also estimate BMI to understand the interplay of age, sex and BMI of the individual in forming facial soft tissue thickness. Apart from this, estimating STT in younger adults is important which will be beneficial during orthognathic surgeries apart from finding its application in forensic facial reconstruction.

Conclusion
The present study has provided a set of average facial soft tissue thickness for adult South Indian population using CBCT; explored facial soft tissue thickness of male and female at different age groups and evaluated the statistical significance of STT measurements between the genders at different age groups. Results of the analysis show sexual dimorphism with a significantly higher STT in males of all ages than in females. In both men and women, there is an increasing trend in STT values noted at all the points with advancing age. Facial soft tissue thicknesses were lower in the regions of upper face and chin while its larger in the regions around the mandible. Present study can provide valuable information for facial reconstruction of south Indian population with insights on influence of age and sex on facial soft tissue thickness.

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