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ORIGINAL ARTICLE

Facial soft tissue thickness database of Gujarati population for forensic craniofacial reconstruction

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Skeletal remains

Abstract The forensic facial reconstruction is a scientific art to construct the ante-mortem face from the human skull. The facial recognition is made by reconstructing the contours of the facial soft tissue thickness (FSTT).These FSTT data are essential for probable face reconstruction but the data of FSTT at particular anthropological landmarks differ in various ethnic groups. Until now several works have been reported on different population but no study exists in which the FSTT of a Gujarati population has been measured. The aim of this study is to compile a set of soft tissue depth data of Gujarati population of India to add to existing literature on FSTT. Computed tomography (CT-scan) has been utilized to measure the 25 different FSTT landmarks of 324 male and 165 female. Present study shows significant differences in certain FSTT of Gujarati population from that of other populations. Our compiled data set of FSTT for the Gujarati population is important in understanding craniofacial characteristics of the Gujarati population and potentially be helpful in forensic identification.

1. Introduction

Personal identification of unknown human skeletal remains is a constant challenge in routine forensic investigation in India. As it is common that a person is murdered and the body is buried, thrown or burnt in remote places and when that body is found after some time, facial features are so distorted, or are absent, that the identity of the deceased cannot be perceived.[1,2] In such cases to fix the identity of the unknown human skeletal remains, ante-mortem medical records are to be compared in the usual practice of forensic investigations.[1–3] These methods are helpful, but do not specifically indicate that the bare skull in question is definitely belongs to a specific person.[2] However, in cases where identification is difficult, efforts are made to reconstruct the face of a bare skull devoid of soft tissue.[2,3] Forensic facial reconstruction or forensic facial approximation is most useful for probable facial recognition by reconstructing the contours of the skull's soft tissues where only skulls are found.[4] Facial reconstruction is a scientific art to construct the ante-mortem face from a human skull. The morphology of the skull is sufficiently distinctive and provides an efficient frame for unique facial appearance. Even small variation in

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the shape, form and proportions of the skull leads to significant variation in facial appearance. Utilizing this presumption, reconstruction of face can be carried out even by applying the average facial soft tissue thickness.[5] Markers of facial soft tissue thickness are the lines projecting from cranial landmarks to facial landmarks. The length of these lines corresponds to the thickness of the soft tissue at that particular location.[5]

A number of methods have been studied out to measure facial soft tissue thickness (FSTT). In earlier time, soft tissue thickness was measured on cadavers by sliding a double edged blade of scalpel or by the needle in which a needle was put through the skin until the bone was encountered by the tip of the needle.[3,9–14] Recently, many medical imagining techniques like RTG-roentgenography, MRI-magnetic resonance imaging, CT-computed tomography and US-ultra sound, were used to study the FSTT.[2,15–25] Of all these methods, CT and MRI are most accurate methods.[2] The utilization of CT and 3D reconstruction offer a more reliable location of soft tissue thickness measurement.[6,15,16] Due to cadaver limitations, the use of clinical facial CT data proved to be the ideal data set for modern living. Due to its accuracy and distinguishability between bone and soft tissue, computed tomography is widely used for measuring the FSTT.[16]

Age, race and sex can be obtained from the skull which is essential for the reconstruction of face as there is not only a wide range of variation depending on the sex, body built, biological group and age of the subject, but also simply on individual differences.[3,6–9] The data of soft tissue thickness at particular anthropological landmarks differ in various ethnic groups and, therefore, other region's tissue thicknesses cannot be applied to any other region's population. And hence, it is important to compile a set of soft tissue depth for each population. A survey of literature reveals that studies have been conducted on American Blacks,[3] American Caucasoid,[9] Australian,[12] Brazilian,[14] Buryat, Korean, Kazakh, Uzbek,[17] Chinese,[18] Colombian adult,[19] Turkish,[20] Portuguese,[13] Egyptian,[21] French,[22] Northwest Indian,[2] Japanese,[10] South African black,[23] Zulu population,[24] mixed racial population[25] etc. to compile the data set of FSTT. It is a fact that the faces vary among the population of Indian states and not any dataset except Northwest Indian is available for facial reconstruction. However, there is no any work done on Gujarati population of India. Reports show that there is a total 38,821 unidentified dead bodies recovered and inquest conducted during 2013 in all over India, from which 2219 is from Gujarat state.[26] Driven by the need to assess the skeletal remains to recognize the cause of death and to identify the unknown remains, recently we developed the sensors for detection of clonazepam and codeine sulfate from skeletal remains[27,28] and utilized CT scan images to determine the craniofacial indices of Gujarati population.[29,30] These[27–32] prompted us to develop the soft tissue depth dataset of Gujarati population. The main aim of this

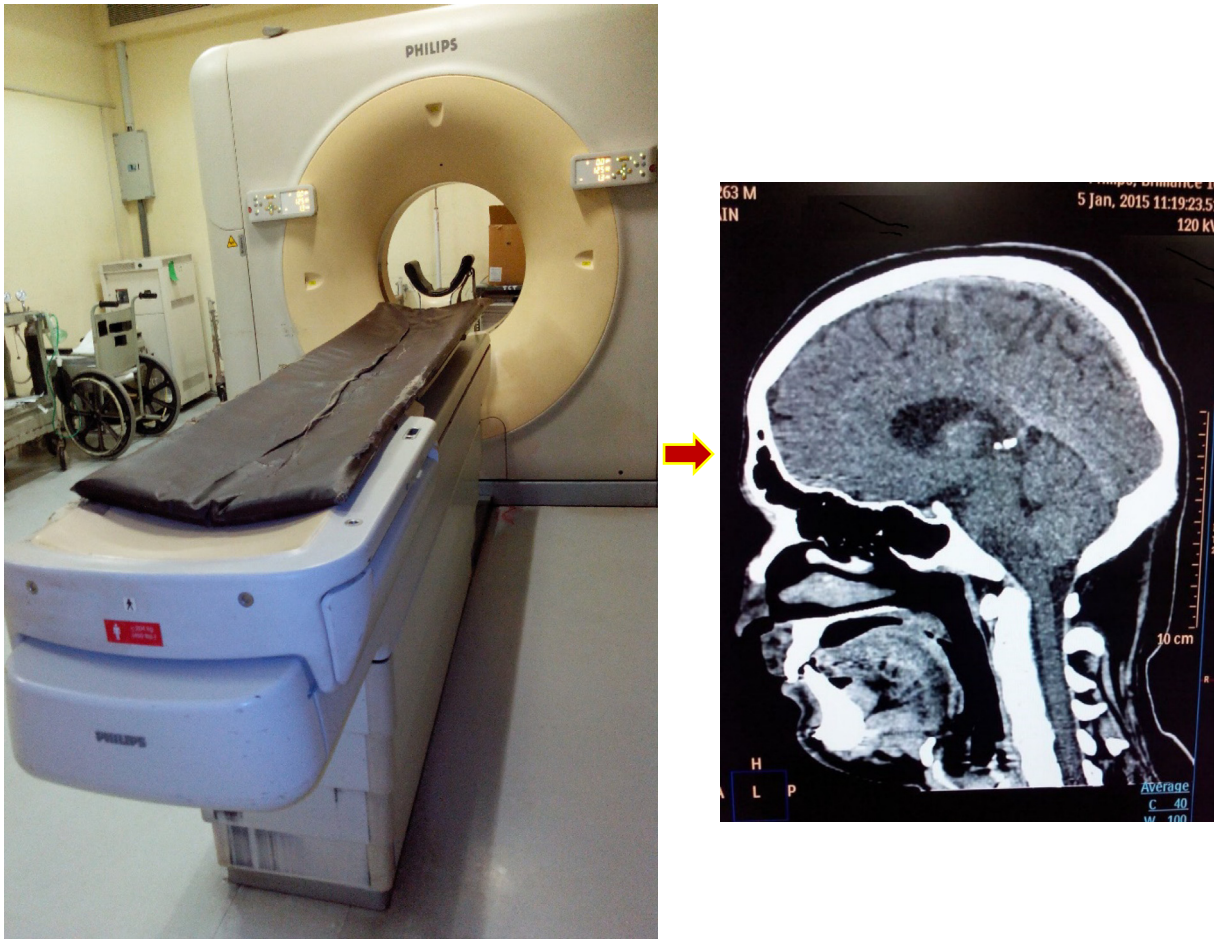

Figure 1 CT-scan machine, Philips Brilliance 16 Slice MDCT at Department of Radiology, Sheth V.S. Hospital, Ahmedabad, Gujarat and the CT-scan images of the subjects.

study is to compile a set of soft tissue depth data of Gujarati population of India to add to existing literature on FSTT. These compiled set of FSTT was compared with other existing datasets to judge whether there are any differences in FSTT which could potentially make a difference when it comes to actual facial reconstruction. Simultaneously age, sex and body mass index (BMI) are considered in the present study since there existed fundamental differences in FSTT between the sexes due to skull morphology, age and BMI.[33,34] Moreover, the wide range of sampling and statistical evaluation data permit accurate analysis of factors affecting the FSTT and could provide the necessary relationship that can be used for computer based forensic facial reconstruction or approximation.[35,36]

2. Method and materials

Computed tomography has been proved to be an accurate and reliable method of measurement and hence the method is chosen as the modality for measuring the soft tissues of the face in this study. The sample comprised 489 Gujarati (324 male and 165 female), ranging in age from 17 to 65 years and in good health. They were selected from patients arriving at Department of Radiology, Sheth V.S. Hospital, Ahmedabad, Gujarat and who required radiographic examination for treatment. As far as could be ascertained all were representatives of a racially and socially homogeneous population, drawn to Gujarat which was confirmed from the history of their forefathers. Subjects with fractures, swellings, malformations, distortions, missing anterior teeth or those who were edentulous and asymmetries were excluded from the sample. After obtaining informed consent, the subject's age, sex, weight and height were recorded separately on a perform. Stadiometer was used for height measurement i.e. the vertical distance from vertex to floor, where vertex is the highest point on the head when the head is held in Frankfurt Horizontal (FH) plane. Subjects were weighed with an Equinox digital weighing scale when point to the zero mark. The average individual rarely maintains a constant weight and it is therefore difficult to collect subjects with ideal height-to-weight ratios. It also has to be considered that a small variation in weight is generally dispersed throughout the body and does not necessarily reflect on the face. The computed tomography scan was done with the machine Philips Brilliance 16 Slice MDCT (Fig. 1). The technical features of the machine include the current of 250 mA and the potential difference of 120 kV. The thickness of the slice was 1 mm. The acquired CT Digital Image and Communications in Medicine (DICOM) images of the subjects were studied on the Philips Brilliance Workspace. The workstation can show the different forms of images on the computer screen on which different landmarks were identified and located manually according to the definitions given in the Table 1. The soft tissue measurements were performed at a total of 25 facial anatomical points, most of which are standard anthropological landmarks. The FSTT recorded is the Euclidean distance between the bony landmark and its homologous cutaneous landmark. The FSTT selected along with their sign and definitions are given in Table 1 and landmarks are represented in Fig. 2. Different facial soft tissue depth anatomical points were measured on the workstation for all the subjects, each measurement was repeated thrice. The resulting data were recorded in Excel Spread Sheet and statistical analysis was done by IBM SPSS 20.00. The intra observer variability was checked by conducting one way ANOVA (Analysis of Variance) test, which is used to determine whether there are any significances between the means

Table 1 Definition of Soft tissue depth markers.

Sr. No.	Soft tissue landmarks	Sign	Definitions
1.	Supraglabella	SUG	Most anterior point on midline
2.	Glabella	G	It is the point which lies on the root of the nose and between the supra-orbital ridges of the forehead
3.	Nasion	Na	It is the point where the frontonasal suture meets the sagittal plane
4.	Rhinion	Rh	It is the lowest point on the internasal suture in the midsagittal plane
5.	Sabnasal	SaN	It is that point which is situated at the junction of the lower edge of the nasal septum and the upper lip in the median sagittal plane
6.	Sab Alare	SaA	A point on the outer curvature of the maxilla halfway between inner points of sub-zygomatic and Lat. upper-lip margin
7.	Upper Lip Margin	ULM	The mid-line between maxillary central incisors, at the level of the cementum–enamel junction
8.	Lower Lip Margin	LLM	Midline on the lower lip
9.	Chin Lip Fold	CLF	Deepest midline point in the groove superior to the mental eminence
10.	Pogonion	PGo	Most anterior midline point on the mental eminence of the mandible anterior
11.	Gnathion	Gn	Most inferior midline point at the mental symphysis of the mandible inferior
12.	Supraorbital	SOr (L&R)	Most anterior point of the supraciliary arch in the axe of the center of the orbit
13.	Infraorbital	InOr (L&R)	Point of the zygomaxillary suture on the orbital rim anterior
14.	Gonion	Go (L&R)	It is the most downward, backward and upward point of the angle of the lower jaw made by the basal margin of the body and posterior margin of ramus
15.	Endocanthion	EnCa (L&R)	It is that point in the medial corner of eye where upper and the lower eyelid margin meet
16.	Lateral Orbit	LaOr (L&R)	Most antero-inferior point on the posterior border of the zygomatic bone
17.	Submaxillar curvature	SUBMAX (L&R)	Most supero-medial point on the maxillary inflexion between the zygomaxillare and the ectomolare
18.	Ectomolare Supram2	SUPRAM2 (L&R)	Point on superior alveolar ridge superior to the crown of the maxillary second molar

of two or more independent groups or samples, and the result is shown in Table 2. The discriminant function analysis was done with the use of IBM SPSS 20.00 to find out the ability of all these parameters to differentiate between sexes. Population data were further differentiated in five age groups, which are Group A: 17–25, Group B: 26–35, Group C: 36–45, Group D: 46–55 and Group E: more than 55 and 3 major BMI ($\frac{\text{Weight(kg)}}{\text{Height}^2(\text{m}^2)}$) groups which are Group A: $\leqslant$15–18.5 (underweight), Group B: 18–25 (normal), Group C: 25–$\geqslant$40 (overweight to obese) to check the influence of BMI, age and sex individually and combined on soft tissue depth within the groups & between the groups and results are tabulated.

In present study, *z*-scores used to compare a measurement to a reference value of different population. The *z*-score is the number of standard deviations away from the average or mean value of the reference groups. From the reference population standard deviation and mean value *z*-score were calculated. The *t*-test was performed to determine if there is a significant difference between the mean or average scores of two groups. The p value which is calculated probability were calculated to estimate probability of rejecting the null hypothesis of a study question when that null hypothesis is true. In present investigation, 5% a threshold value or significance level is chosen for performing the test to derive the *p*-value.

3. Results and discussion

To check the intra observer error among the three observations of each variable a one way ANOVA study was per-

Table 2 Mean value and standard deviation for male and female, *t* score and *p* value.

Name of the variable	Mean value ♂	Mean value ♀	*t* score	*p* value
SUG	4.6 ± 0.93	4.3 ± 1.5	2.418	0.016*
G	6.3 ± 0.8	5.0 ± 1.2	12.147	0.000*
Na	6.4 ± 0.7	6.5 ± 0.5	−2.153	0.032*
Rh	2.6 ± 0.7	2.8 ± 0.3	−4.495	0.000*
SaN	14.2 ± 3.2	12.9 ± 2.7	4.847	0.000*
SaA	12.9 ± 2.5	12.7 ± 2.4	1.008	0.314
ULM	10.5 ± 0.6	11.4 ± 1.6	−7.492	0.000*
LLM	12 ± 0.9	11.7 ± 1.5	2.419	0.016*
CLF	9.3 ± 0.9	9 ± 1.5	2.419	0.016*
PGo	9.1 ± 0.6	10.03 ± 1.6	−7.484	0.000*
Gn	8.3 ± 0.95	8.9 ± 1.5	−4.953	0.000*
SOrL	7.1 ± 0.71	6.8 ± 0.7	5.125	0.000*
SOrR	7.1 ± 0.71	6.8 ± 0.7	5.532	0.000*
InOrL	5.4 ± 0.9	5.8 ± 1.4	−3.361	0.001*
InOrR	5.1 ± 0.6	6.1 ± 1.6	−7.495	0.000*
GoL	15.8 ± 1.2	15.3 ± 0.8	4.989	0.000*
GoR	15.4 ± 1.2	14.9 ± 0.8	5.096	0.000*
EnCaL	6.6 ± 0.96	7.2 ± 1.5	−5.022	0.000*
EnCaR	6.6 ± 0.95	7.2 ± 1.5	−5.076	0.000*
LaOrL	7.9 ± 0.93	8.4 ± 2	−3.385	0.001*
LaOrR	7.6 ± 0.94	8.1 ± 2	−3.426	0.001*
SubmaxL	15.7 ± 0.62	15.2 ± 0.25	13.826	0.000*
SubmaxR	15.6 ± 0.62	15.04 ± 0.24	14.243	0.000*
SupraM2L	22.3 ± 2.5	22 ± 2.4	1.110	0.268
SupraM2R	22.1 ± 2.5	21.8 ± 2.4	1.079	0.281

* Indicates significant difference at 5% level of significance ($p < 0.05$).

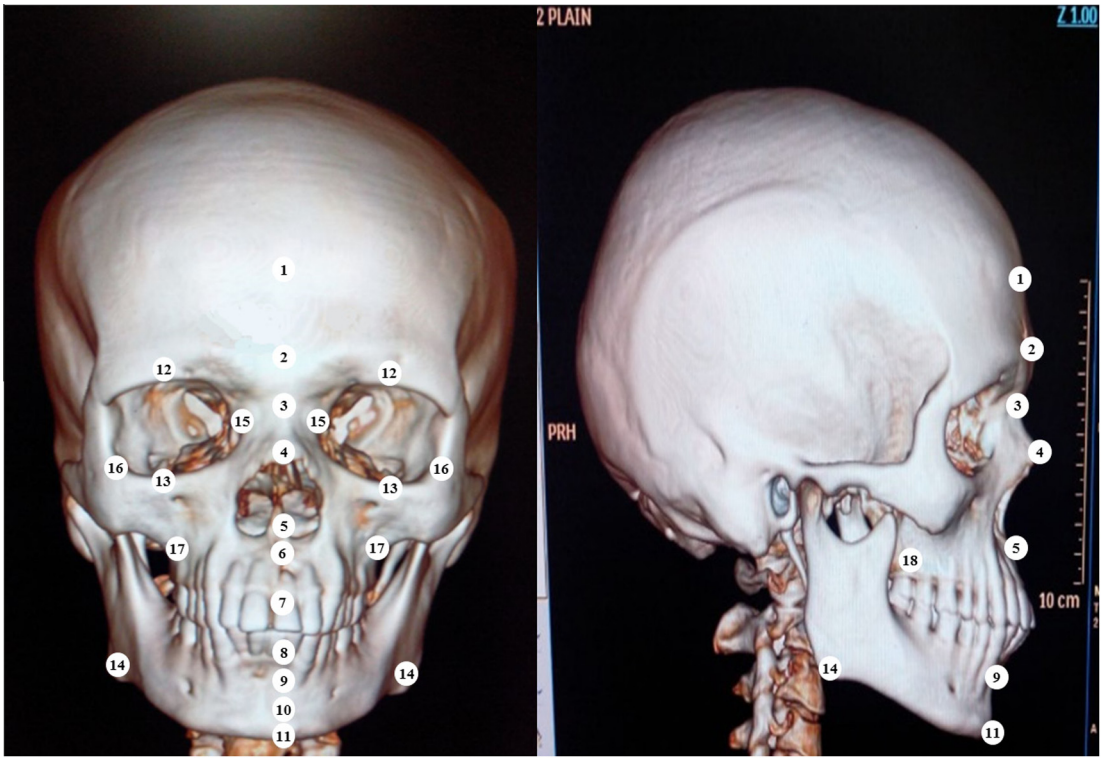

Figure 2 Anatomical landmarks of the skull.

formed that shows there is no significant difference among these three observations for all the variables. It confirms that measurements were repeated with high accuracy and confident enough for the further analysis. The mean value and standard deviation with t score from independent t-test and p values for significance level of all the variables for male and female are derived and results are tabulated in Table 2. It shows that all the variables are having significant differences between the mean values of male and female except SaA, supraM2L and supraM2R. In general males have thicker FSTT than females because they have larger skulls and larger muscle attachments. Many studies have shown that the majority of

Table 3 Correlation of facial soft tissue thickness of different landmarks to BMI for male and female.

Name of the variables	Sex	R	R^2	p value	Constant	Coefficient
SUG	♂	0.355	0.126	0.000*	2.782	0.081
	♀	0.037	0.061	0.641	4.586	−0.015
G	♂	0.348	0.121	0.000*	4.790	0.068
	♀	0.021	0.000	0.787	5.178	−0.007
Na	♂	0.037	0.001	0.512	6.535	−0.006
	♀	0.167	0.028	0.032*	6.996	−0.021
Rh	♂	0.122	0.015	0.028*	2.082	0.022
	♀	0.198	0.039	0.011*	2.410	0.016
SaN	♂	0.188	0.035	0.001*	11.005	0.147
	♀	0.500	0.250	0.000*	4.057	0.387
SaA	♂	0.127	0.016	0.022*	11.287	0.078
	♀	0.489	0.329	0.000*	5.203	0.332
ULM	♂	0.251	0.063	0.000*	9.723	0.034
	♀	0.196	0.038	0.012*	9.391	0.090
LLM	♂	0.356	0.127	0.000*	10.227	0.082
	♀	0.035	0.001	0.655	12.017	−0.015
ClF	♂	0.356	0.127	0.000*	7.527	0.082
	♀	0.035	0.001	0.655	9.317	−0.015
PgO	♂	0.253	0.064	0.000*	8.319	0.035
	♀	0.196	0.038	0.012*	7.998	0.090
Gn	♂	0.005	0.000	0.935	8.308	−0.001
	♀	0.174	0.030	0.026*	10.610	−0.074
SOrL	♂	0.0228	0.052	0.000*	6.348	0.040
	♀	0.065	0.004	0.406	7.067	−0.013
SOrR	♂	0.236	0.056	0.000*	6.219	0.042
	♀	0.057	0.003	0.464	7.033	−0.011
InOrL	♂	0.078	0.006	0.161	5.781	−0.018
	♀	0.328	0.108	0.000*	8.760	−0.131
InOrM	♂	0.251	0.063	0.000*	4.420	0.034
	♀	0.196	0.039	0.011*	4.091	0.090
GoL	♂	0.187	0.035	0.001*	14.544	0.057
	♀	0.136	0.018	0.082	16.040	−0.033
GoR	♂	0.187	0.035	0.001*	14.145	0.057
	♀	0.130	0.017	0.096	15.599	−0.031
EnCaL	♂	0.003	0.000	0.960	6.567	0.001
	♀	0.164	0.027	0.036*	8.812	−0.070
EnCaR	♂	0.001	0.000	0.982	6.539	0.000
	♀	0.183	0.033	0.019*	8.912	−0.077
LaOrL	♂	0.078	0.006	0.159	7.465	0.018
	♀	0.204	0.042	0.008*	11.012	−0.115
LaOrR	♂	0.072	0.005	0.198	7.202	0.017
	♀	0.205	0.042	0.008*	10.759	−0.116
Submax L	♂	0.082	0.082	0.000*	14.747	0.044
	♀	0.060	0.004	0.447	15.242	−0.004
Submax R	♂	0.289	0.083	0.000*	14.648	0.044
	♀	0.060	0.004	0.446	15.135	−0.004
Supra M2L	♂	0.129	0.017	0.020*	20.549	0.079
	♀	0.496	0.246	0.000*	14.394	0.335
Supra M2R	♂	0.129	0.017	0.020*	20.355	0.079
	♀	0.490	0.340	0.000*	14.325	0.330

* Indicates significant difference at 5% level of significance ($p < 0.05$).

Table 4 Correlation of facial soft tissue thickness of different landmarks to age for male and female.

Name of the variables	Sex	R	R^2	p value	Constant	Coefficient
SUG	♂	0.039	0.002	0.480	4.643	−0.003
	♀	0.568	0.323	0.000*	2.141	0.053
G	♂	0.117	0.014	0.035*	6.531	−0.007
	♀	0.269	0.072	0.000*	5.812	−0.020
Na	♂	0.166	0.028	0.003*	6.722	−0.008
	♀	0.150	0.023	0.054*	6.681	−0.004
Rh	♂	0.246	0.061	0.000*	2.039	0.013
	♀	0.032	0.001	0.685	2.785	−0.001
SaN	♂	0.105	0.011	0.060	15.138	−0.025
	♀	0.613	0.376	0.000*	8.710	0.104
SaA	♂	0.277	0.077	0.000*	14.950	−0.051
	♀	0.546	0.298	0.000*	9.508	0.081
ULM	♂	0.137	0.019	0.013*	10.682	−0.006
	♀	0.585	0.342	0.000*	9.098	0.059
LLM	♂	0.037	0.001	0.504	12.086	−0.003
	♀	0.569	0.324	0.000*	9.589	0.053
ClF	♂	0.037	0.001	0.504	9.386	−0.003
	♀	0.569	0.324	0.000*	6.889	0.053
PgO	♂	0.133	0.618	0.020*	9.278	−0.005
	♀	0.584	0.341	0.000*	7.702	0.059
Gn	♂	0.256	0.065	0.000*	8.988	−0.018
	♀	0.327	0.107	0.000*	7.705	0.031
SOrL	♂	0.020	0.000	0.714	7.158	−0.001
	♀	0.094	0.009	0.230	6.609	0.004
SOrR	♂	0.009	0.000	0.868	7.139	0.000
	♀	0.094	0.009	0.230	6.611	0.004
InOrL	♂	0.286	0.082	0.000*	6.163	−0.020
	♀	0.004	0.000	0.957	5.810	0.000
InOrR	♂	0.136	0.019	0.014*	5.381	−0.006
	♀	0.584	0.341	0.000*	3.803	0.059
GoL	♂	0.084	0.007	0.133	16.068	−0.008
	♀	0.462	0.213	0.000*	16.266	−0.024
GoR	♂	0.083	0.007	0.135	15.667	−0.008
	♀	0.466	0.217	0.000*	15.864	−0.025
EnCaL	♂	0.253	0.064	0.000*	7.285	−0.018
	♀	0.337	0.114	0.000*	5.974	0.032
EnCaR	♂	0.254	0.064	0.000*	7.222	−0.018
	♀	0.339	0.115	0.000*	5.929	0.031
LaOrL	♂	0.062	0.004	0.265	8.019	−0.004
	♀	0.222	0.919	0.004*	7.316	0.027
LaOrR	♂	0.066	0.004	0.235	7.738	−0.005
	♀	0.222	0.919	0.004*	7.021	0.028
Submax L	♂	0.163	0.027	0.003*	15.403	0.007
	♀	0.088	0.008	0.260	15.201	−0.001
Submax R	♂	0.163	0.027	0.003*	15.209	0.007
	♀	0.090	0.008	0.251	15.095	−0.001
Supra M2L	♂	0.275	0.075	0.000*	24.211	−0.050
	♀	0.546	0.298	0.000*	18.787	0.081
Supra M2R	♂	0.272	0.074	0.000*	23.995	−0.050
	♀	0.544	0.295	0.000*	18.624	0.080

* Indicates significant difference at 5% level of significance ($p < 0.05$).

Table 5 Comparison of tissue depth of different landmarks among different population.

Name of the landmarks	Origin/population	Mean ± SD		z Score		p value	
		Male ♂	Female ♀	Male ♂	Female ♀	Male ♂	Female ♀
SUG	Gujarati population present work	4.6 ± 0.93	4.3 ± 1.5	–	–	–	–
	Chinese	3.98 ± 0.71	3.59 ± 0.60	7.78	5.29	0.000*	0.000*
	North Indian population	3.44 ± 0.36	3.57 ± 0.40	15.14	4.9	0.000*	0.000*
	Mixed racial population	5.36 ± 1.44	4.88 ± 1.02	−3.6	−1.8	0.000*	0.07
	South African black population	–	4.7 ± 1.19	–	−3.3	–	0.001*
	Zulu population	5.21 ± 0.92	–	−5.1	–	0.000*	–
G	Gujarati population present work	6.3 ± 0.8	5.02 ± 1.2	–	–	–	–
	Chinese	5.43 ± 0.71	5.32 ± 0.56	12.9	−3.1	0.000*	0.002*
	French population	6.5 ± 1.2		−9.57		0.000*	
	North Indian population	5.18 ± 0.66	5.24 ± 0.74	16	−2.2	0.000*	0.03*
	Mixed racial population	5.47 ± 0.68	5.64 ± 1.42	4.2	−2	0.000*	0.05
	South African black population	–	6.3 ± 1.29	–	−9.3	–	0.000*
	Zulu population	5.21 ± 0.92	–	−5.1	–	0.000*	–
	Koreans	5.1 ± 0.8	5.4 ± 0.89	13.3	−2.71	0.000*	0.007*
	Buryats	5.4 ± 0.75	5.6 ± 0.88	12.9	5.8	0.000*	0.000*
	Kazakhs	5.3 ± 0.79	5.6 ± 0.86	11.11	5	0.000*	0.000*
	Uzbeks	5.4 ± 0.75	5.5 ± 0.77	4.5	5	0.000*	0.000*
Na	Gujarati population present work	6.4 ± 0.7	6.5 ± 0.5	–	–	–	–
	French population	8.2 ± 1.6		−24.4		0.000*	
	North Indian population	5.86 ± 0.65	5.76 ± 0.76	9	10.6	0.000*	0.000*
	Mixed racial population	4.00 ± 2.42	4.68 ± 2.35	11.4	8.3	0.000*	0.000*
	South African black population	–	6.0 ± 1.55	–	4.2	–	0.000*
	Zulu population	5.21 ± 0.92	–	−5.1	–	0.000*	–
	Koreans	4.5 ± 0.79	4.4 ± 0.86	2.4	26.25	0.02*	0.000*
	Buryats	4.8 ± 0.85	4.5 ± 0.89	1.98	25	0.05*	0.000*
	Kazakhs	4.8 ± 0.91	4.6 ± 0.7	20	24.4	0.000*	0.000*
	Uzbeks	5.7 ± 0.87	5.3 ± 0.77	6.36	10.26	0.000*	0.000*
Rh	Gujarati population present work	2.6 ± 0.7	2.8 0.3	–	–	–	–
	Chinese	2.64 ± 0.52	2.40 ± 0.58	−1.33	7.2	0.184	0.000*
	French population	2.0 ± 0.9		−7.4		0.000*	
	Zulu population	3.08 ± 0.58	–	−4.4	–	0.000*	–
SaN	Gujarati population present work	14.2 ± 3.2	12.9 ± 2.7	–	–	–	–
	Chinese	11.85 ± 1.43	10.64 ± 1.17	10.59	0.99	0.000*	0.322
SaA	Gujarati population present work	12.9 ± 2.5	12.7 ± 2.4	–	–	–	–
	North Indian population	11.84 ± 1.119	10.68 ± 1.56	5.95	8.8	0.000*	0.000*
	Mixed racial population	12.25 ± 2.97	10.13 ± 2.48	1.14	4.2	0.25	0.000*
	South African black population	–	10.9 ± 1.41	–	8.2	–	0.000*
	Zulu population	12.10 ± 1.63	–	2.42	–	0.02*	–
ULM	Gujarati population present work	10.5 ± 0.6	11.4 ± 1.6	–	–	–	–
	North Indian population	10.44 ± 1.21	10.01 ± 1.13	0.75	9.3	0.45	0.000*
	Mixed racial population	13.16 ± 2.51	13.63 ± 3.70	−14	−4.6	0.000*	0.000*
	Koreans	12.6 ± 1.73	10.6 ± 1.57	−6.2	3.8	0.000*	0.000*
	Buryats	13.5 ± 1.9	11.7 ± 1.81	−25	−1.6	0.000*	0.11
	Kazakhs	12.4 ± 1.7	11.1 ± 1.53	−17.3	1.4	0.000*	0.1615
	Uzbeks	13.1 ± 2.02	12.1 ± 1.51	−18.6	−3.3	0.000*	0.001*
LLM	Gujarati population present work	12.0 ± 0.9	11.7 ± 1.5	–	–	–	–
	North Indian population	11.56 ± 0.96	11.07 ± 1.23	4.8	4.2	0.000*	0.000*
	Mixed racial population	10.43 ± 1.69	12.45 ± 2.31	6.24	−1.8	0.000*	0.07
	Koreans	13.8 ± 1.51	12.3 ± 1.49	−15	−3	0.000*	0.003*
	Buryats	14.5 ± 1.63	13.1 ± 1.73	−27.8	−6.7	0.000*	0.000*
	Kazakhs	13.7 ± 1.61	12.4 ± 1.42	−13.1	−3.5	0.000*	0.000*
	Uzbeks	14 ± 1.98	13.1 ± 1.52	−11.8	−2.3	0.000*	0.02*
CLF	Gujarati population present work	9.3 ± 0.9	9.0 ± 1.5	–	–	–	–
	North Indian population	8.80 ± 1.04	8.65 ± 1.10	5.6	2.36	0.000*	0.02*
	Mixed racial population	12.02 ± 2.07	11.70 ± 1.66	−10.88	−6.97	0.000*	0.000*
PGo	Gujarati population present work	9.1 ± 0.6	10.03 ± 1.6	–	–	–	–
	Chinese	9.42 ± 1.62	9.12 ± 1.52	−3.3	5.4	0.001*	0.000*

(*continued on next page*)

Table 5 (*continued*)

Name of the landmarks	Origin/population	Mean ± SD		z Score		p value	
		Male ♂	Female ♀	Male ♂	Female ♀	Male ♂	Female ♀
	North Indian population	8.95 ± 1.22	8.85 ± 1.10	1.1	7.4	0.2713	0.000*
	Mixed racial population	8.94 ± 2.42	9.57 ± 2.36	0.4	1.20	0.6892	0.23
	South African black population	–	10.6 ± 1.91	–	−2.27	–	0.023*
	Koreans	10.6 ± 1.85	11.1 ± 1.71	−13.6	−5.1	0.000*	0.000*
	Buryats	11.4 ± 1.93	11.9 ± 1.82	−19.2	−9.8	0.000*	0.000*
	Kazakhs	10.9 ± 1.66	11.4 ± 1.53	−16.4	−6.5	0.000*	0.000*
	Uzbeks	11.2 ± 1.9	10.6 ± 1.52	−15	−2.6	0.000*	0.000*
Gn	Gujarati population present work	8.3 ± 0.95	8.9 ± 1.5	–	–	–	–
	Chinese	5.57 ± 1.03	5.36 ± 1.01	32.77	24.9	0.000*	0.000*
	French population	9.5 ± 3.3		−6.8		0.000*	
	North Indian population	7.74 ± 1.13	6.65 ± 1.15	6.2	15	0.000*	0.000*
	Mixed racial population	6.61 ± 1.71	6.47 ± 1.57	6.76	6.3	0.000*	0.000*
SOr	Gujarati population present work	7.1 ± 0.71	6.8 ± 0.7	–	–	–	–
	Chinese	5.95 ± 1.05	5.96 ± 0.83	16.4	9.33	0.000*	0.000*
	Egyptian	5.13 ± 0.94	5.69 ± 0.85	24.63	11.1	0.000*	0.000*
	North Indian population	7.08 ± 0.69	6.59 ± 0.78	0.3	2.6	0.764	0.009*
	Mixed racial population	5.46 ± 1.31	5.79 ± 1.89	8.6	4.4	0.000*	0.000*
InOr	Gujarati population present work	5.4 ± 0.94	5.8 ± 1.39	–	–	–	–
	Chinese	5.27 ± 0.94	5.47 ± 1.17	1.6	2.4	0.11	0.016*
	Egyptian	4.17 ± 0.64	4.31 ± 0.46	13.7	9.3	0.000*	0.000*
	North Indian population	4.61 ± 0.45	4.56 ± 0.41	11.4	10.33	0.000*	0.000*
	Mixed racial population	5.97 ± 2.87	6.42 ± 3.83	−2.04	−1.41	0.041*	0.16
Go	Gujarati population present work	15.8 ± 1.23	15.3 ± 0.84	–	–	–	–
	Chinese	14.98 ± 3.73	14.72 ± 2.98	3.91	2	0.000*	0.046*
	French population	18.5 ± 6.9		−10.4		0.000*	
	North Indian population	15.67 ± 2.03	15.30 ± 2.13	0.93	0.00	0.352	1.000
	Mixed racial population	14.20 ± 6.08	13.50 ± 6.60	3.6	3.3	0.000*	0.001*
	South African black population	–	17.9 ± 4.35	–	−7.02	–	0.000*
SubMax	Gujarati population present work	15.7 ± 0.62	15.2 ± 0.25	–	–	–	–
	French population	28.2 ± 3.9		−70.55		0.000*	
SuparaM2	Gujarati population present work	22.2 ± 2.48	21.9 ± 2.37	–	–	–	–
	Mixed racial population	12.68 ± 2.10	12.99 ± 4.45	15.11	13.10	0.000*	0.000*
	South African black population	–	30.1 ± 4.43	–	−20.5	–	0.000*

* Indicates significant difference at 5% level of significance ($p < 0.05$).

the facial soft tissue landmarks of males have thicker tissues than females, specifically at the brow, mouth, and jaw;[37] the present study also shows the similar pattern in Gujarati male and female FSTT. One way ANOVA test of all the variables for different BMI groups shows that the mean values of different variables have significant differences among different BMI groups except for the variables namely G, Gn, SOrL, SOrR, EnCaL, LaOrL, LaOrR, SUBMAXL and SUBMAXR. The results of one way ANOVA test of all the variables for different age groups indicate that the mean values of different variables have significant differences among different age groups except for the variables namely SOrL and SOrR. Results also show the effect of sex*age interactions on the tissue depth at different landmarks where most of the landmarks, except Na and SubmaxL, show significant differences for sex*age interactions.

Further, to know the correlation of male and female BMI to FSTT, all the variables were statistically evaluated and results are recorded in Table 3 and it shows that in case of male most of the variables are having significant correlation with BMI except Na, Gn, InOrL, EnCaL, EnCaR, LaOrL and LaOrR whereas in the case of female, variables namely SUG, G, LLM, CLF, SOrL, SOrR, GoL, GoR, SUBMAXL and SUBMAXR are not having significant correlation with BMI. From Table 3, it is somewhat intuitive that, weight gain can be reflected in the face thereby affecting a FSTT. Table 4 shows correlation of facial soft tissue thickness of different landmarks to age for male and female. In the case of male, all variables are having significant correlation with age except SUG, SaN, LLM, CLF, SOrL, SOrR, GoL, GoR, LaOrL and LaOrR whereas in the case of females, all variables are having significant correlation with age except Rh, SOrL, SOrR, InOrL GoL, GoR, SUBMAXL and SUBMAXR. Both age and BMI shows the significant correlation with different landmarks and hence it can be used for the approximate different FSTT landmarks. If there is availability of the average age or antemortem BMI of the deceased, by using following formula derived from collected FSTT data set of different landmarks of Guajarati population (Tables 3 and 4), approximate FSTT of particular landmark for particular sex can be computed:

$$\text{Landmark/Variable} = (\text{BMI} \times \text{Coefficient}) + \text{Constant}$$

$$\text{Landmark/Variable} = (\text{Age} \times \text{Coefficient}) + \text{Constant}$$

Table 6 Comparison of tissue depth for bilateral landmarks.

Name of the variable	Gujarati population present study		North Indian population					
	Mean ± S.D. ♂	Mean ± S.D. ♀	Mean ± S.D. ♂	Mean ± S.D. ♀	*z* score ♂	*z* score ♀	*p* value ♂	*p* value ♀
SOrL	7.1 ± 0.71	6.8 ± 0.7	7.08 ± 0.69	6.59 ± 0.78	0.3	2.6	0.7642	0.009
SOrR	7.1 ± 0.71	6.8 ± 0.7	6.90 ± 0.70	6.42 ± 0.77	3.3	4.75	0.001*	0.000*
InOrL	5.4 ± 0.9	5.8 ± 1.4	4.61 ± 0.45	4.56 ± 0.41	11.3	9.5	0.000*	0.000*
InOrR	5.1 ± 0.6	6.1 ± 1.6	4.47 ± 0.45	4.40 ± 0.42	1.46	12.3	0.1443	0.000*
GoL	15.8 ± 1.2	15.3 ± 0.8	15.67 ± 2.03	15.30 ± 2.13	0.93	−0.05	0.3524	0.9601
GoR	15.4 ± 1.2	14.9 ± 0.8	15.34 ± 2.27	15.05 ± 2.11	0.2	−0.8	0.8415	0.4237
SupraM2L	22.3 ± 2.5	22.0 ± 2.4	20.46 ± 1.51	19.73 ± 1.61	9.2	7.6	0.000*	0.000*
SupraM2R	22.1 ± 2.5	21.8 ± 2.4	20.13 ± 1.53	19.73 ± 1.58	9.85	7.8	0.000*	0.000*

* Indicates significant difference at 5% level of significance ($p < 0.05$).

Although this method is easy to carry out it is by no means accurate, however the method gives approximate values of FSTT for each landmarks studied in the present work which can be utilized for facial approximation of skull of Guajarati origin.

The mean and standard deviation (SD) values of tissue depth of Gujarati population with the values of other population like Chinese, Egyptian, French, North Indian, mixed racial population, South African black, Zulu, Korean, Buryats, Kazakhs, Uzbeks in terms of *z* scores and *p* values are compared in Table 5. While comparing the FSTT values with results from other studies, it should be taken into consideration that not all the measurements were included by other researchers, thus due to absence of the variability of the measurements not all the statistical comparisons could be performed. It is clearly seen that Gujarati females have a thinner FSTT at G as compared to French, Chinese, North Indian, Mixed Racial, South African Black, Korean, Buryats, Kazakhs and Uzbeks Females whereas it is found contrary for Gujarati males as they have thicker FSTT at G with significant difference. FSTT at Na of Gujarati male and female is thicker than the other North Indian, Mixed racial, South African Black, Zulu, Koreans, Buryats, Kazakhs and Uzbeks population whereas it is thinner than French population. From the resulted dataset it can be concluded in general that Rh, SaA, ULM, LLM, CLF, PGo, InOr and SubMax show the thinner FSTT of Gujarati population as compared to other compared populations whereas SuG, Na, SaA, Gn and SOr have thicker FSTT. Chinese population have thinner FSTT as compared to Gujarati population except the Rh, PGo of Chinese males. However, FSTT landmarks of mixed racial population show both thicker and thinner types of FSTT with significant difference and similarity with the Guajarati population which is as per the hypothesis and expectation. South African Black female population have significantly thicker FSTT as compared to Gujarati females except Na and SaA which show thinner FSTT than Gujarati females. Zulu male population have significant differences in their FSTT landmarks except the SaA from the Gujarati males. Korean, Buryats, Kazakhs and Uzbeks population show significant differences as compared to Gujarati population. Dataset of Gujarati population FSTT significantly differ from French population as results of comparison show French population having thicker FSTT. Table 6 shows comparison of mean values of tissue depth of both sides of lateral landmarks with North Indians. North Indian males and females show significant differences of the landmarks SOrR, InOrL, InOrR(female), SupraM2L and SupraM2R in males, while SOrL, InOrL, InOrR (male), GoL and GoR are not having significant differences between Gujarati and North Indian population. This resulted dataset supports our hypothesis that Gujarati population have different FSTT from that of other population, even from the North Indian population of India. The statistically significant values confirms this hypothesis and proves the significance of present study for Gujarati population.

4. Conclusion

In conclusion, this study provides the facial soft tissue thickness of Gujarati population from measurements obtained through CT scan. General descriptive analysis was performed including consideration of age and BMI of the individuals. The 22 of the 25 landmarks showed sex based differences where the males have thicker FSTT except for two landmarks SaA and Supra M2 which shows smaller values in male than in female subjects. Simultaneously, it is also observed that all the three BMI groups have significant differences among them for all the variables except G, Gn, SOr, EnCa, LaOr and Submax. The derived formula can be utilized for computing the average FSTT of Guajarati population from BMI or age of the deceased. The results of the present study suggest the significant difference in FSTT of Gujarati population compared to the Chinese, Egyptian, French, North Indian, mixed racial population, South African black, Zulu, Korean, Buryats, Kazakhs and Uzbeks population. Through this investigation, we have provided the first data set on FSTTs of Gujarati population. Present study can provide valuable information for facial reconstructions of Guajarati population as this information has heretofore been unavailable.

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Conflict of interest

None declared.

Ethical approval

Necessary ethical approval was obtained from "Sheth V.S. Hospital, Ahmedabad, Gujarat" and informed consent were obtained from each subject as per the guidelines.

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