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Repeatability of facial soft tissue thickness measurements for forensic facial reconstruction using X-ray images

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The repeatability of facial soft tissue thickness measurements at 10 standard anatomical landmarks was evaluated using lateral X-ray images obtained from 50 adult subjects. The intra-and inter-observer error rates were calculated after four practitioners took measurements using Denta Pacs 8.1 software. The results indicated high inter- and intra-observer repeatability, suggesting X-ray images can be used to measure facial soft tissue thicknesses for the purpose of craniofacial reconstruction and superimposition.

Keywords: facial soft tissue thickness; X-ray images; forensic facial reconstruction; repeatability

Introduction

Forensic facial reconstruction refers to a forensic technique that is used primarily to attempt to recreate the face of a deceased individual, who is no longer identifiable, as authentically as possible. It may be the final option available to gain public attention in forensic cases where the identity of an individual remains unknown. The bases of all forensic facial reconstruction techniques are a thorough knowledge of cranial morphology and facial soft tissue thickness (FSTT) reference databases.

These FSTT databases were established as a result of various different studies. Data were obtained from cadavers utilising needle probes[1−6] and *in vivo* with the aid of medical imaging techniques such as ultrasound[7−12], radiography[13−18], magnetic resonance imaging (MRI)[19−21], computed tomography (CT)[22−26], and cone-beam computed tomography (CBCT)[27−29]. Accurate anthropometric data are important. Stephan and Simpson[30,31] stress the importance of reporting measurement error rates associated with FSTT measurement methods.

Repeatability is an important issue in landmark-based cephalometry[32]. One of the major sources of error in cephalometric analysis is landmark identification. In conventional

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cephalometry, which relies on the experience of the practitioners, it is a significant source of error[33–38]. There have been great efforts made to develop computer-aided cephalometry for the automatic identification of landmarks[39,40]. However, automated systems still do not compete in terms of accuracy[41].

The repeatability of FSTT measurements was tested by Fourie et al.[28], Cavangh and Steyn[22], Hwang et al.[27], Guyomarc′h et al.[25], de Oliveira et al.[42] and Briers et al.[43]. These tests involved computer tomography (CT), cone beam computer tomography (CBCT) and radiography. The purpose of this study is to explore the effect of experience in the repeatability of FSTT measurements obtained from lateral radiographs. By using experienced and inexperienced practitioners, we aim to determine the difference in reproducibility by evaluating the intra- and inter-observer error.

Materials and methods

This study was approved by the Ethics Committee of Diskapi Yildirim Beyazit Training and Research Hospital, Ankara, Turkey. Measurements were taken from diagnostic cephalometric X-ray images obtained from 50 adult individuals without any facial deformities, aged between 18–35 years, who visited the Department of Dento-Maxillofacial Radiology, Faculty of Dentistry, Gazi University, Ankara, Turkey.

Lateral cephalograms were taken in a cephalostat (Orthophos XG 5 DS/Ceph; Sirona Dental System, Bensheim, Germany) in maximum intercuspation, where the - cusps of the teeth of both arches fully interpose themselves with the cusps of the teeth of the opposing arch, and with the head positioned in the Frankfort horizontal plane (FHP).

Measurements

The lateral cephalometric X-ray images were imported into Denta Pacs 8.1 (Garanti Yazilim Inc., Konya, Turkey) software to measure the thickness of ten anatomical landmarks according to the protocol developed by Utsuno et al.[15] (Table 1). Before the measurement process, true measurements were calibrated after a 10% enlargement of the X-ray images[44]. After calibration, FSTTs were measured using the scale tool. The length of the line was then measured by the menu command ‘scale/linear line’.

Table 1. Description of the anatomical landmarks considered in this study.

Landmarks	Description	
1	Glabella	Crosspoint between midline and supraorbital line
2	Nasion	Midpoint of frontonasal suture
3	Rhinion	Junction between bone and cartilage of nose
4	Subnasal	The middle of the inferior border of the anterior nasal aperture at the base of the nasal spine.
5	Labrale superius	Midline on upper lip
6	Stomion	The midpoint of the oral fissure determined with the lips closed
7	Labrale inferius	Midline on lower lip
8	Labiomentale	Depression between the lower lip and the chin
9	Pogonion	Centred on most anteriorly projecting point of chin
10	Gnation	The vertical measure of soft tissue on the most inferior point of chin

After setting the FHP, soft tissue thicknesses were measured at the following anatomical landmarks: (1) glabella; (2) nasion; (3) rhinion; (4) subnasale; (5) labrale superius; (6) stomion; (7) labrale inferius; (8) labiomentale; (9) pogonion; and (10) gnathion (Figure 1). These FSTTs were measured perpendicular to the bony surface. Two experienced and two inexperienced practitioners performed FSTT measurements, once for each of the 20 subjects, to evaluate inter-observer error. The FSTTs at each landmark were measured twice by the experienced practitioners, with a six-week interval to evaluate the intra-observer error.

Statistical analysis

The normality of the distribution of the variables was tested using the Kolmogorov-Smirnov test. To calculate the inter-observer repeatability, a one-way variance analysis (ANOVA) and intra-class correlation (ICC) analysis were performed. A Tukey's *post hoc* test – a parametric test used in one-way variance analysis that makes corrections when testing the difference between groups – was used to perform multiple comparisons between the pairs of practitioners and to determine differences between the sample groups.

A paired *t*-test was then used to calculate intra-observer repeatability. Correlation coefficients were calculated using Pearson correlation and reliability coefficient analyses. Statistical data analysis was carried out using SPSS software, Version 14 for Windows (SPSS Inc., Chicago, IL). A value of $p<0.05$ was considered statistically significant.

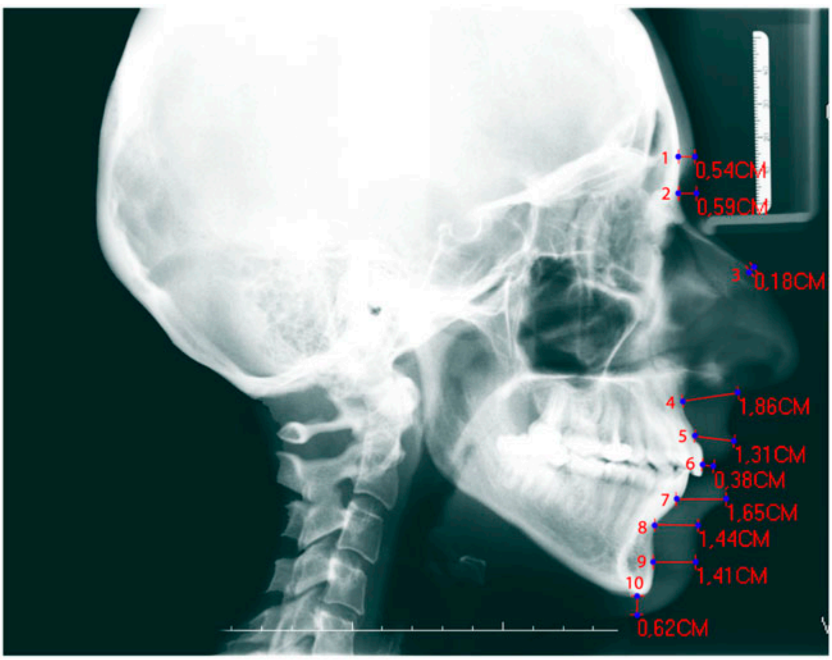

Figure 1. Anatomical landmarks of the skull.

Results

Table 2 illustrates the results of the one-way ANOVA and intra-class correlation analysis including the inter-observer error. Of the 10 landmarks in the measurements of the four practitioners, statistically significant differences ($p<0.05$) were only observed for glabella (g) and subnasale (sn). Intra-class correlation analysis indicated high repeatability for FSST measurements as all reliability coefficients were over 0.89 (Table 2).

In the *post hoc* comparison, each practitioner was compared with the others (AB, AC, AD, BC, BD and CD) to reveal the difference between them (Table 3). No significant differences occurred between the experienced observers (A and B). In contrast, two landmarks showing significant differences occurred between the inexperienced observers (C and D) (Table 3). These statistically significant differences may originate from the difficulty of identifying glabella (g) and subnasale (sn) landmarks due to the difficulty of delineating landmarks on a curved anatomical boundary. Reproducibility can therefore be increased by experience and repetition. However, the present study did not reveal a general trend regarding the effect of observer experience on the repeatability of landmark placement.

The results of the paired t-tests and correlation analyses showed the intra-observer repeatability of the measurements performed by experienced practitioners A (Table 4) and B (Table 5). All FSTTs were identified without statistically significant differences between the first and second measurements, indicating high intra-observer repeatability for both experienced practitioners. Pearson correlations and reliability coefficients show the close relationship between the first and second FSTT measurements.

Discussion

FSTT studies have been conducted using lateral radiographs for quite some time. The advantages of this method are that subjects are scanned in an upright position and the facial soft tissues are not distorted. One of the disadvantages is the exposure to radiation. The X-ray images were taken for reasons not related to the current study.

Table 2. Results of the ANOVA and intraclass correlation analysis showing the inter-examiner repeatability of the FSTT measurements (*n*: 50).

Measurements (mm)	A Mean ± SD	B Mean ± SD	C Mean ± SD	D Mean ± SD	ANOVA (*p*-value)	ICC
g	5.43 ± 0.75	5.29 ± 0.76	5.53 ± 0.81	4.84 ± 0.84	0.000**	0.893
n	6.58 ± 1.07	6.20 ± 0.99	6.54 ± 0.97	6.27 ± 1.07	NS	0.934
rhi	2.21 ± 0.52	2.29 ± 0.56	2.38 ± 0.67	2.24 ± 0.56	NS	0.911
sn	16.57 ± 2.10	16.26 ± 1.94	16.58 ± 2.06	15.33 ± 1.81	0.005*	0.931
ls	15.03 ± 1.93	15.01 ± 2.17	15.17 ± 1.87	14.57 ± 2.01	NS	0.976
sto	5.58 ± 1.52	5.46 ± 1.44	5.44 ± 1.63	5.68 ± 1.64	NS	0.976
li	15.24 ±1.25	15.11 ± .21	15.40 ± 1.42	15.55 ± 2.06	NS	0.912
labm	10.65 ±1.19	10.73 ±1.34	10.79 ± 1.17	10.61 ± 1.30	NS	0.924
pog	11.37 ±1.59	11.15 ±1.59	11.37 ± 1.71	11.22 ± 1.78	NS	0.978
gn	6.78 ± 1.14	6.54 ± 1.11	6.78 ± 1.26	6.49 ± 1.26	NS	0.965

ICC, intraclass correlation coefficient; NS, not significant.
*$p < 0.01$; **$p < 0.001$.

Table 3. Tukey's Post hoc comparison for the FSTT measurements between examiners using X-ray images.

measurement	*AB*	*AC*	*AD*	*BC*	*BD*	*CD*	mean thickness(mm) *A*	*B*	*C*	*D*
g	-	-	**	-	**	**	5.43	5.29	5.53	4.84
sn	-	-	*	-	-	*	16.57	16.26	16.58	15.33

*$p < 0.01$; **$p < 0.001$.

Table 4. Results of the t-test and correlation analysis showing the intra-examiner repeatability of the FSTT measurements (*n*: 50) performed by practitioner A.

Measurements (mm)	1st measure Mean ± SD	2nd measure Mean ± SD	Significance	Pearson correlation coefficient	Reliability coefficient
g	5.43 ± 0.75	5.41± 0.93	NS	0.779*	0.864*
n	6.58 ± 1.07	6.63 ± 1.07	NS	0.841*	0.914*
rhi	2.21 ± 0.52	2.19 ± 0.60	NS	0.796*	0.882*
sn	16.57 ± 2.10	16.43 ± 1.91	NS	0.955*	0.975*
ls	15.03 ± 1.93	14.95 ± 1.96	NS	0.965*	0.982*
sto	5.58 ± 1.52	5.67 ± 1.63	NS	0.899*	0.946*
li	15.24 ± 1.25	15.08 ± 1.31	NS	0.823*	0.903*
labm	10.65 ±1.19	10.56 ±1.41	NS	0.875*	0.805*
pog	11.37 ±1.59	11.36 ±1.71	NS	0.904*	0.948*
gn	6.78 ± 1.14	6.74± 1.28	NS	0.920*	0.955*

NS, not significant.
*$p < 0.001$.

FSTT measurements may be taken at anatomical landmarks on the midline of the face[14], and the measurements taken from X-ray images deviate from actual measurements by approximately 10%[14,44]. However, the repeatability of FSTT measurements taken from lateral cephalographs has not been tested previously, except by Briers et al.[43]. Nonetheless, the importance of reporting measurement error rates has been emphasised[30,31]. The aim of the current study was to evaluate measurement error rates using X-ray images.

The repeatability of FSTT measurements derived from lateral cephalographs has been studied previously. In the current study, Denta Pacs 8.1 software was used to measure facial soft tissue depths perpendicular to the surface of the bone at 10 anatomical landmarks, using X-ray images. ANOVA and intra-class correlation analyses were performed to evaluate the repeatability of facial soft tissue depth measurements.

Every practitioner tends to place anatomical landmarks in a slightly different position. Nevertheless, there were no statistically significant (p>0.05) differences between the measurements recorded by the two experienced practitioners, indicating low intra-observer error rates. The differences were significant (p<0.01) between the two inexperienced observers, but only at two of the 10 measurement sites. This suggested that measurement error rates might be reduced with practice and long-term experience.

The differences between inexperienced observers occurred at the glabella (g) and subnasale (sn), which suggested that the two practitioners possibly interpreted the definitions of the landmarks slightly differently. The poor repeatability was mainly due to

Table 5. Results of the t-test and correlation analysis showing the intra-examiner reproducibility of the FSTT measurements (*n*: 50) performed by practitioner B.

Measurements (mm)	1st measure Mean ± SD	2nd measure Mean ± SD	Significance	Pearson correlation coefficient	Reliability coefficient
g	5.29 ± 0.76	5.36 ± 0.80	NS	0.627*	0.770*
n	6.20 ± 0.98	6.00 ± 1.27	NS	0.653*	0.779*
rhi	2.29 ± 0.56	2.30 ± 0.69	NS	0.734*	0.836*
sn	16.26 ± 1.94	16.14 ± 2.01	NS	0.919*	0.957*
ls	15.01 ± 2.16	14.87 ± 1.94	NS	0.935*	0.963*
sto	5.46 ± 1.43	5.58 ± 1.39	NS	0.896*	0.945*
li	15.11 ± 2.20	15.29 ± 1.70	NS	0.837*	0.895*
labm	10.73 ±1.34	10.85 ±1.41	NS	0.877*	0.934*
pog	11.15 ±1.70	11.10 ±1.71	NS	0.963*	0.981*
gn	6.54 ± 1.11	6.66 ± 1.13	NS	0.847*	0.917*

NS, not significant.
*$p < 0.001$.

the difficulty of placing those points accurately. More precise definitions of cranial landmarks may hence be necessary to decrease measurement error rates. Plooij et al.[45] have proved that defining some of the cranial landmarks more accurately results in more accurate FSTT measurements using 3D stereophotogrammetry. Labiale superius (ls) and pogonion (pog) were the most repeatable landmarks. This was due to the well-defined contours at this area of the upper lip and chin, making it easier to identify the exact positions of these points on the face.

Tukey's *post hoc* comparison revealed significant ($p<0.001$) differences between experienced and inexperienced practitioners, which suggested that a learning curve exists. With training and repetition, the repeatability of FSTT measurements may therefore be increased. Conversely, however, de Oliveria et al.[42] found that the practitioner's experience only had a minimal effect on landmark placement error – a conclusion that is congruent with our results. The differences only occurred at two landmarks, indicating that the redefinition of some cranial landmarks will be helpful in decreasing measurement error rates.

In conclusion, the FSTT measurements of the X-ray images showed high inter- and intra-observer repeatability. The results of the study suggest that X-ray images can be used reliably for the purpose of facial reconstruction and superimposition.

Disclosure statement

No potential conflict of interest was reported by the authors.

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