Original Article

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Comparison of Conventional Cephalometric Method of Landmark Identification with Digital Monitor Image and Film-based Digital Image

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Abstract

Introduction: After the standardization of the technical procedures, radiography has become one of the most frequently applied aids in human biometric research. While using this method, it is necessary to make a careful check of the accuracy of the reproduction of cephalometric landmarks.

Purpose: The purpose of this study was a comparison of the conventional cephalometric method of landmark identification with digital monitor image and film-based digital image.

Materials and Methods: Eight observers, all orthodontists, recorded 8 landmarks twice on 10 conventional cephalograms, 10 digital hard copy, and 10 monitor images that were obtained from 10 human skulls in standardized fashion. Digital images were displayed on 15 inches, thin-film-transistor monitor. Recordings were transferred into standardized coordinate systems and evaluated separately for each coordinate. After correcting for magnification, precision was assessed with Maloney-Rastogi tests; intra-observer and inter-observer reproducibility was calculated from squared differences.

Results: Effective magnification was larger for the digital images. Significantly different ($P < 0.05$) precision was found for nasion (N), posterior nasal spine (PNS), sella (S), supraspinale (A), and orbitale (Or), but average standard errors were within the confidence interval. Intra-observer and inter-observer reproducibility did not differ significantly among the three image modes. Squared differences were largest for PNS in three modalities.

Conclusion: Results indicate comparable errors in landmark recording for three evaluated modalities.

Key words: Conventional cephalometry, Digital radiography, Landmark identification, Monitor image, Precision, Reproducibility

INTRODUCTION

The assessment of radiography as a diagnostic aid in orthodontics was proclaimed by W. A. Price in 1900 just 5 years after the invention of X-rays.[1] Thereafter, many investigators produced radiographs for evaluation of the craniofacial measurements, but it was only in the year 1931, that Hofrath in Germany and Broadbent in America concurrently and independently developed standardized technique for the production of cephalometric radiographs using cephalostat.[2] Since its inception in early thirties, cephalometry has gained sufficient popularity for clinical use as well as for research in field of growth and estimation of treatment response through measurement of anatomic landmarks in number of various analysis. However, to quantify the precision of measurements, the errors and their sources should be pointed out. According to Baumrind and Frantz,[3] variations or errors in the angular and linear measurements are of three basic types: Errors in projection, errors in landmark location, and mechanical errors in drawing lines between points on tracing and in measuring with ruler or protractor. Whereas, Chen *et al*.[4] points out that the major sources of error in the cephalometric analysis include radiographic

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film magnification, tracing, measuring, recording, and landmark identification.[5] Identification and reproduction of the landmarks precisely are one of the most effective means of avoiding this inconsistency.

Today with the application of computers in orthodontics, digital enhancement of the images can be done to get precision and accuracy in landmark identification, which resulted in the replacement of conventional film-based radiographic machines with digital systems.[6] Digital X-rays have many advantages over film-based X-rays. Despite these advantages, however, the diagnostic performance of the new digital systems must be evaluated in comparison with that of the established film-screen combination. Various studies have been published comparing digitized and conventional cephalometric radiographs with respect to validity and reproducibility of angular and linear measurements or accuracy of landmark identification.[6]

The aim of our study was to compare conventional cephalograms with digital hard copy cephalograms and digital monitor image for precision and reproducibility of the landmark identification with the images from both modalities obtained from the corresponding radiographic machines of one manufacturer.[6]

MATERIALS AND METHODS

About 10 dry skulls were selected randomly for film-based digital cephalograms, digital monitor images, and conventional cephalograms. Criteria included while collecting data as follows.

1. Skulls without mandible were selected randomly
2. Three dimensional stabilization of skull was done by ear rods in acoustic meatus and nasal pointer at the frontonasal suture area
3. Internal references for the calculation of magnification were provided by three steel balls (diameter 1.0 mm) that were glued to each skull mid-sagittally in three anatomic regions, namely, glabella, maxilla above the anterior spine, and dorsal part of the palatine raphae
4. Eight observers marked 8 landmarks on transparent film placed on conventional, digital monitor image, and digital film-based cephalograms
5. Same size (10 × 8 inch) was maintained for conventional, digital, and monitor images. Adobe photoshop (7.1 Version) and PowerPoint stretch options were used to get the same size on flat screen (thin-film-transistor monitor)
6. Statistical presentation was done by Maloney-Rastogi test and graphical representation by Bland-Altman plots. The difference between the methods were plotted against the mean ([CO+DH+MO]/3), where CO = Conventional, DH = Digital hard copy, and MO = Monitor image[6]
7. Consequently, the following landmarks were selected for evaluation: Sella, nasion, anterior nasal spine (ANS), posterior nasal spine (PNS), orbitale, supraspinale, porion, and basion.

The entire tracing evaluation procedure was repeated for the entire data material consisted of 10 images of 10 skulls acquired in 3 modalities (CO, DH, and MO) with 8 landmarks recorded twice by 8 observers. The time gap between the first and second registration was at least 1 week.

In our study, the transparent films obtained from all images were placed on millimeter-scaled graph paper, and an X, Y coordinate system was constructed with reference ball number 1 and 2 (X-axis) and the reference ball number 3 and 2 (Y-axis). Precision was assessed by including 95% confidence interval (CI) of the differences.[6] Intra-observer reproducibility was calculated from squared differences between both observations averaged over all skulls, and inter-observer reproducibility was expressed as squared differences between observers averaged for each skull and observation. Differences were compared with Maloney-Rastogi test with $P < 0.05$ considered to be significant.

For digital image processing and enhancement, Multiscale Image Contrast Amplification software was used. This enables the implementation of subsets of specific image processing algorithms such as detail contrast enhancement, edge contrast enhancement, latitude reduction, and noise reduction.

RESULTS

Conventional lateral cephalograms of 10 skulls and their digitally enhanced hard copy and monitor images were compared with 8 different landmarks for location. Location of each landmark was denoted by (X, Y) coordinates.

Mean and standard deviation were calculated. All values were analyzed statistically and compared using Maloney-Rastogi test and Bland-Altman plots. The mean significant disparity of all 8 observers for locating point sella, ANS, and PNS with X-coordinate and nasion, basion, supraspinale, orbitale, and porion with Y-coordinate.

The mean, standard deviation, and P value for all 8 landmarks for all 3 modalities are compared in Table 1. The mean of the sum of the squared differences for different methods was calculated to show the squared difference value with respect to X and Y coordinates

Table 1: Comparison of mean, standard deviation, and significance of all 8 landmarks for all 3 modalities (CO, DH, and MO)

Landmark	Coordinates	CO-DH			DH-MO			MO-CO		
		Mean	SD	*P* value	Mean	SD	*P* value	Mean	SD	*P* value
ANS	X	0.2625	0.7201	<0.05	0.0375	0.6412	<0.05	−0.300	0.8426	<0.05
	Y	0.0139	0.5110	>0.05	−0.0750	0.3800	>0.05	0.0375	0.6214	>0.05
Nasion	X	0.825	1.5064	>0.05	−0.8500	1.4841	>0.05	0.0250	0.6341	>0.05
	Y	0.3000	0.0416	<0.05	−0.5875	1.0331	<0.01	0.2875	1.3341	<0.001
Orbitale	X	−0.2250	1.9169	>0.05	0.1875	1.5976	>0.05	0.0375	2.2105	>0.05
	Y	0.2250	2.2582	>0.05	−0.4125	2.7554	<0.05	0.1875	2.4854	<0.01
PNS	X	−0.2250	3.5951	<0.001	0.0125	2.9601	<0.01	0.2125	3.2737	<0.05
	Y	0.1500	3.4896	>0.05	−0.1375	2.6160	>0.05	−0.012	3.1630	>0.05
Sella	X	0.3625	0.8695	<0.05	−0.0250	0.6888	>0.05	−0.337	1.1613	>0.05
	Y	0.3051	0.8000	>0.05	−0.1500	1.0618	>0.05	0.0500	1.2237	>0.05
Supraspinale	X	1.0500	1.6576	>0.05	−0.6625	1.2937	>0.05	1.1750	6.3871	>0.05
	Y	0.7875	1.5628	>0.05	−0.6250	1.3544	<0.05	−0.162	1.1559	>0.05
Porion	X	−0.2350	1.8169	>0.05	0.1975	1.4976	>0.05	0.0475	2.2405	>0.05
	Y	0.2350	2.3582	>0.05	−0.3125	2.8554	<0.05	0.1975	2.4954	<0.01
Basion	X	0.735	1.4064	>0.05	−0.8800	1.4641	>0.05	0.0350	0.7341	>0.05
	Y	0.3010	0.05526	<0.05	−0.6875	1.0231	<0.01	0.2876	1.4341	<0.001

ANS: Anterior nasal spine, PNS: Posterior nasal spine, SD: Standard deviation

(Table 2). Higher the value, lesser will be the precision and reproducibility of that particular landmark. Hence, we can precisely reproduce ANS than sella and nasion, orbitale, supraspinale in decreasing order and most difficult point to reproduce was the PNS. The calculated mean values of the sum of the squared differences taking different landmarks to evaluate the intra-observer deviation on X and Y coordinates shows how much each observer deviated while locating all 8 landmarks in all 3 modalities (Table 3). As the value of X and Y coordinate increases, more the person deviated from mean.

Table 2: Comparison of intra-observer squared differences between observations for CO, DH, and MO averaged for all skulls

Landmark	CO-DH		DH-MO		MO-CO	
	X	Y	X	Y	X	Y
ANS	5.875	2.625	4.125	1.5	8	3.875
Nasion	29.5	11.75	29.25	14.125	34	18.625
Orbitale	37.25	51.5	25.875	77.625	48.875	62.125
PNS	129.75	122	87.625	68.625	107.63	252.625
Sella	8.875	6.5	4.75	11.5	14.625	15
Supraspinale	38.5	30.625	21.125	22.25	11.625	13.625
Porion	38.25	512.5	26.875	78.625	47.875	61.125
Basion	30.5	12.75	30.25	15.125	35	17.625

ANS: Anterior nasal spine, PNS: Posterior nasal spine

Table 3: Comparison of inter-observer squared differences for CO, DH, and MO averaged over all skulls (P=Person)

Person	CO-DH		DH-MO		MO-CO	
	X	Y	X	Y	X	Y
P1	97.33	9.50	88.33	65.33	87.67	64.17
P2	86.33	99.67	66.00	57.33	63.00	224.33
P3	37.33	82.00	17.83	61.50	26.83	114.83
P4	32.83	20.67	18.17	22.17	35.67	24.17
P5	28.83	29.67	20.17	12.00	26.67	27.67
P6	18.00	9.33	8.00	7.00	25.67	9.00
P7	17.33	8.17	4.50	13.83	17.17	11.00
P8	15.00	41.00	7.33	21.67	17.00	12.67

DISCUSSION

After the standardization of the technical procedures, radiography has become one of the most frequently applied aids in human biometric research. While using this method, it is necessary to make a careful check of the accuracy of the reproduction of cephalometric landmarks. Furthermore, interpretation of cranial radiographs of living subjects can involve a factor of uncertainty. This is especially true in details of the cranial base. For this reason, the study was made on human skulls from which brain had been removed to permit proper inspection and location of landmarks, like in the present study, it was point sella of the cranial base.[7]

The present study compared 3 modalities of landmark identification to check the precision and reproducibility. Furthermore, the comparison of conventional method with digital hard copy and monitor image was performed and statistically analyzed.

To the best of our knowledge, many researchers have compared digital and conventional cephalometry, but very few studies exist on digital hard copy comparison with conventional cephalogram and monitor image.

Schulze *et al*. did the comparison of direct landmark identification study on monitor images on conventional cephalogram.[6] Since 1995, Chen *et al*. have conducted serial studies on landmark identification, but all their studies were mainly concerned with the digitization of landmarks using various software that were available in market at that particular time.[4,8,9]

In our study, the mean significant disparity for locating point sella was only with x-coordinate. This result favors the study of Schulze *et al*.[6] but contrasts the observation of Chen *et al*.[9] The mean significant difference for locating point nasion was with Y-coordinate while comparing all 3 modalities ($P < 0.05$). This is in accordance with Richardson[10] and Liu *et al*.[11]

The mean significant disparity for locating point supraspinale was with Y-coordinate, which favors the findings of Richardson,[10] who concluded that point A was difficult to reproduce vertically. The mean significant inconsistency for locating point ANS was mainly with X-coordinate. Similar findings were noted by Schulz *et al*,[6] Liu *et al*.,[11] and Turner and Weerakone[12] in their study.

The mean significant disparity for reproducing point PNS was with X-coordinate ($P < 0.05$). It was observed that PNS was more difficult to locate in young individuals due to the presence of developing third molars in this region. This finding is in favor of the study of Turner and Weerakone[12] and partly in favor of Schulz *et al*.[6.] The mean significant disparity for precise reproduction of point orbitale was with Y-coordinate, i.e., vertical direction. This finding is similar to that observed by Chen *et al*.[11] There was slight difficulty in accurately locating point porion, which could be due to superimposition of other anatomical structures of the inner cranium. This was also noticed by Midtgård *et al*.[13] There was slight difficulty in locating basion on the y-axis ($P < 0.05$) which shows a vertical pattern of distribution, as noted by Baumrind and Frantz[3] in his study.

The mean of the sum of the squared differences for different methods was calculated to show the squared difference value with respect to X and Y coordinate. The increase in value indicates less precision and reproducibility of that particular landmark. So, we can precisely reproduce ANS, sella, nasion, basion, orbitale, porion, and supraspinale in decreasing order and most difficult point to reproduce was the PNS.

In the present study, we found that compared to conventional and monitor tracing it was very easy to precisely reproduce the landmarks on a digital hard copy, but still we did not find statistically significant difference between all 3 modalities as far as accuracy in landmark identification and reproduction is concerned.

CONCLUSION

Based on the results of this study, we can make the following conclusions.

1. Precision and reproducibility in landmark identification on conventional, digital hard copy, and monitor image were almost similar
2. It is extremely easy and convenient to locate landmarks in digital hard copy than conventional and monitor image
3. ANS was the most consistent and PNS was the least consistent landmark.

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