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Original Article

Reliability in Landmark Plotting between Manual and Computerized Method - A Cephalometric Study

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Abstract

Introduction: In orthodontics, cephalometrics plays a key role in diagnosis and treatment planning. Cephalometric radiograph is the product of a two-dimensional image of the skull in lateral view, which helps in enabling the relationship between teeth, bone, soft tissue, and empty spaces in horizontal and vertical planes of space. It also helps in evaluation, diagnosis, treatment results, and prediction of growth.

Aim: The aim of the study is to evaluate the reliability of landmark identification between manual and digital landmark plotting in both X and Y axis.

Materials and Methodology: A total of 50 pre-treatment lateral cephalograms were selected from patients reported for orthodontic treatment. The digital images of each cephalogram were imported directly into Dolphin software for onscreen digitalization, while for manual tracing images were printed using a compatible X-ray printer. After the images were standardized and 10 commonly used hard tissue landmarks were plotted on each cephalogram by six different professional observers and the values obtained were plotted in X and Y axis. Intraclass correlation coefficient was used to determine the intrarater reliability for repeated landmark plotting obtained by both the methods.

Results: The interclass correlation for manual in X and Y axis had a high reliability for all the 10 hard tissue points but when the intraclass correlation was performed, all the hard tissue landmarks showed high reliability both in X and Y axis except Point B which had moderate reliability with less agreement for cephalometric variables in X axis.

Conclusion: The inter- and intraclass correlation in X and Y axis shows high reliability in hard tissue.

Keywords: Cephalometric, Dolphin software, Intraclass correlation, Landmark plotting

INTRODUCTION

In orthodontics, cephalometrics plays a key role in diagnosis and treatment planning. Cephalometric radiograph is the product of a two-dimensional image of the skull in lateral view, which helps in enabling the relationship between teeth, bone, soft tissue, and empty spaces in horizontal and vertical planes of space. It also helps in evaluation, diagnosis, treatment results, and prediction of growth.

The era of radiographic cephalometry began in orthodontics in 1931 by Broadbent and Hofrath; happen to simultaneously present a standardized cephalometric technique for obtaining standardized radiographs of the head.[1]

The major sources of errors in cephalometric analysis are radiographic film magnification, tracing, measuring, and landmark identification. The inconsistency in landmark identification may lead to major error in cephalometric analysis.

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"Dolphin" cephalometric software, which according to manufacturer promises accurate landmark identification, cephalometric analysis, treatment prediction in orthognathic cases, superimposition, and acts as a tool for educating the patient on treatment outcome.

Several studies have been undertaken to compare the accuracy of landmark identification in scanned or digitized lateral cephalogram with the manual methods, whereas studies evaluating the reliability in landmark identification of digitally obtained radiographs with the manual method are scanty in the literature.

Hence, the objective of this study is to evaluate the errors and reliability in cephalometric landmark identification using Dolphin orthodontic software which is commercially available in the market for cephalometric analysis and to compare it with the manual cephalometric landmark identification.

Aims and Objectives

Aim

The aim of the study is to detect errors and reliability of landmark identification between manual and digital plotting for hard tissue landmarks.

Objective

The objective of the study is to conclude the superior method of plotting cephalometric landmarks and their reliability between manual and computerized method (DOLPHIN SOFTWARE) for hard tissue landmark points.

MATERIALS AND METHODOLOGY

A total of 50 pre-treatment digital lateral cephalograms of patients who reported to our department for orthodontic consultation and treatment were taken using digital cephalometer (orthophos XG-SIRONA MODEL NO: D3352), and a written consent form was obtained from all the patients. The criteria for selecting the 50 cephalograms were as follows:

1. Good quality lateral cephalograms with sufficient contrast.
2. The presence of permanent dentition with no missing and impacted teeth.
3. Patients without trauma, syndromes, craniofacial deformity, or gross asymmetry.
4. Lateral cephalograms of patients between 18-25 years of age.

The originally saved digital cephalographic images are retrieved from the computer in which they were stored. As suggested by Alexander[2] among the selected images 3 registration crosses for orientation were marked, 2 in cranium and 1 in cervical vertebrae region for reorientation and 2 fiduciary points were chosen on the rulers that were imaged with the patients. Y axis was constructed by the software connecting the two fiduciary points as the vertical reference for landmark coordination, the X axis was constructed perpendicular to this line that served as horizontal reference,[3] and they were printed to 100% of the original size. The prints were obtained in Fuji Medical Dry Imaging Film of size 20×25 cm (8"×10" inches).[4]

These printed lateral cephalograms were subjected to manual plotting, and the digital images cephalograms were imported to computer aided cephalometric software Dolphin imaging V.11.8 to perform the landmark plotting.

A total number of 10 landmarks (Figure 1) were identified by 6 qualified investigators, each observer was to perform landmark plotting per each cephalogram 3 times manually and 3 times digitally, at a 2 week interval as performed by Yu *et al.*[5] These were the most commonly used landmarks which play a significant role in routine orthodontic diagnosis and treatment planning. Not more than two radiographs were plotted at a given time to avoid errors due to operator fatigue in both the methods.

Manual Plotting

The 50 samples[5,6] were manually plotted in a dark room over an x-ray view box (Figure 2) on acetate sheet of thickness 0.003"[6-8] with a 0.5 mm[8,9] lead pencil by 6 qualified investigators. All plotted sheets by investigators were collected and each landmark, was separately transferred to graph sheet, and the values of the landmarks were evaluated in X and Y axis.[8]

Digital Plotting

Digital plotting was performed by the same 6 investigators using Dolphin imaging V.11.8 software. The images were calibrated by dpi settings and viewed in a 15" LCD flat screen monitor (Figure 3). The landmarks were manually identified using cursor controlled mouse.[10] After plotting, each image was printed in 20×25 cm (8"×10" inches) and landmarks were transferred to the graph sheet to get values in X and Y axis.[6]

Statistical Analysis

A total of 12,000 values were obtained of which 6,000 X-component and 6,000 Y-component. It includes 600 reading for an individual landmark; the analysis was performed using Statistical Package for Social Sciences version 16.0. Average values of each landmark plotting were calculated and presented as mean ± standard deviation (Table 1). Differences in mean were analyzed using analysis of variances. The level of significance was set at $P < 0.05$. Intraclass correlation coefficient (ICC) is used to determine

the intrarater reliability for both the techniques. According to Landis and Koch,[11] the following ICC interpretation scale was used: Poor to fair (below 0.4), moderate (0.41-0.60), excellent (0.61-0.80), and almost perfect (0.81-1).

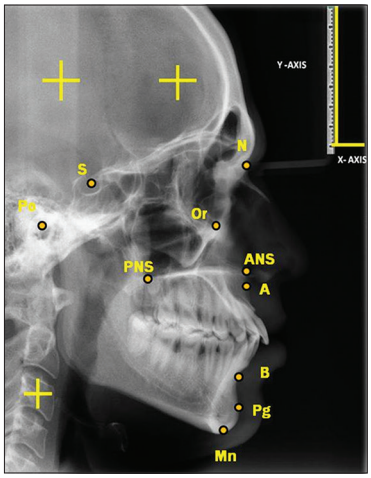

Figure 1: 3 Orientation marks-X and Y axis along the rulers.10 hard tissue landmarks. S-Sella, N-Nasion, Po-Porion, Or-Orbitale, ANS-Anterior nasal spine, PNS-Posterior nasal spine, A-Point A,B-Point B, Pg-Pogonion, Mn-Menton

Figure 2: Manual plotting over an X-ray view box

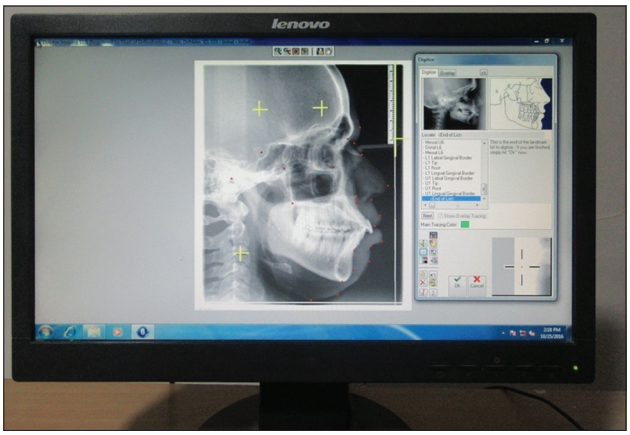

Figure 3: Landmark plotting with dolphin imaging V.11.8 (Dolphin imaging and management solutions, Chatsworth, CA 91311) software

DISCUSSION

To evaluate the reliability of landmark identification by using manual and computerized plotting, the results obtained for the hard tissue landmarks (Table 2) were as follows:

Sella on evaluation in X axis, complete homogeneity was achieved between manual and computerized plotting. When compared both the techniques, ICC indicates good homogeneity. And also in Y axis, the manual landmark plotting indicates high reliability and in digital plotting with an ICC value of 1.000 which denotes complete homogeneity. On direct comparison between both the methods, ICC denotes very high reliability of the cephalometric variable. Chang *et al.*[3] stated that sella is consistent and reliable which supports the values obtained for our study. According to Liu *et al.*,[12] their study stated that sella was the most accurately identified landmark. According to Chen *et al.*[13] stated that the errors in sella were smaller than 1mm in both horizontal and vertical directions. Chen *et al.*[14] stated that the landmarks with minimal difference were sella, and the values obtained were statistically significant. McClure *et al.*[9] also described sella as the most accurately defined landmark in both film and digital methods.

Nasion in X axis denotes complete homogeneity. On comparing both the technique, ICC is 0.863 which is a good indicator for cephalometric reliability. On Y axis nasion intraclass correlation indicates excellent reliability in landmark plotting. Uysal *et al.*[15] suggested that nasion identification was difficult. Several other studies showed inconsistency in nasion identification such as Baumrind and Frantz,[16] McClure *et al.*[9] suggested that nasion point was considered accurate for both digital identification and film based landmark identification, which supports the results obtained from our study. Chen *et al.*[13] study stated that the landmarks with minimal location difference were the point nasion, compared to all the landmark points, he has studied. Chang *et al.*[3] in his study of landmark identification errors by CBCT image mode suggested that errors were rated for nasion, orbitale, ANS compared to other landmark identification points.

Porion in X axis ICC is close to homogeneity. When compared directly between manual and digital ICC value is 0.881, indicates good reliability. Along Y axis, ICC is 0.980 in manual and 0.999 in dolphin. When comparing both methods, the ICC value is 0.912, which are closest

Table 1: Results obtained by manual plotting of hard tissue landmarks

Hard tissue landmarks	Mean±SD				Manual ICC		Computerized ICC	
	Manual		Computerized					
	X	Y	X	Y	X	Y	X	Y
Sella	111.08±20.8	34.92±21.69	111.31±18.5	32.48±19.68	0.994	0.979	1.000	1.000
Nasion	42.31±7.02	19.95±7.62	42.4±6.36	19.04±7.15	0.981	0.963	0.991	0.994
Porion	134.47±23.8	54.01±22.00	134.41±21.4	51.93±20.10	0.991	0.980	0.996	0.999
Orbitale	56.09±5.6	47.20±6.34	56.21±6.17	46.90±5.84	0.982	0.956	0.992	0.989
ANS	38.90±9.5	68.59±11.13	37.99±9.40	68.77±8.7	0.989	0.760	0.998	0.981
PNS	90.07±8.5	73.97±7.31	90.07±8.96	72.72±8.36	0.819	0.845	0.997	0.995
Point A	42.98±10.6	73.77±11.65	41.74±9.68	74.03±9.4	0.990	0.927	0.998	0.973
Point B	50.76±18.9	109.13±23.8	48.59±16.63	112.68±15.5	0.985	0.962	0.999	0.995
Pogonion	51.21±22.4	124.49±25.3	48.75±19.56	126.6±18.99	0.928	0.846	0.998	0.995
Menton	57.75±22.5	132.04±24.0	55.82±19.52	136.97±32.9	0.967	0.789	0.917	0.912

Table 2: Results obtained on comparing ICC values of hard tissue landmark plotting between manual and computerized method

Landmarks	ICC-manual		ICC-computerized		ICC-manual versus computerized	
	X	Y	X	Y	X	Y
Sella	0.994	0.979	1.000	1.000	0.858	0.895
Nasion	0.981	0.963	0.991	0.994	0.863	0.858
Porion	0.991	0.980	0.996	0.999	0.881	0.912
Orbitale	0.982	0.956	0.992	0.989	0.835	0.671
ANS	0.989	0.760	0.998	0.981	0.741	0.750
PNS	0.819	0.845	0.997	0.995	0.616	0.941
Point A	0.990	0.927	0.998	0.973	0.771	0.749
Point B	0.985	0.962	0.999	0.995	0.737	0.469
Pogonion	0.928	0.846	0.998	0.995	0.754	0.665
Menton	0.967	0.789	0.917	0.912	0.759	0.718

to homogeneity. Lai *et al.*[17] suggested that the difficulty in identifying porion on images of superimposed structures results in variation of Frankfort horizontal plane. Bruntz *et al.*[18] showed porion had lower reliability in landmark identification, thus leading to significant unreliability of Frankfort horizontal plane. Chen *et al.*[19] suggested that the reliability of porion in digital images was inferior in our radiographs. Chang *et al.*[3] had a difficulty in identifying porion due to overlapping structures, thus increase in identification error. Chen *et al.*[13] had a very small error which is less than 1mm in both horizontal and vertical directions stating that porion point was accurately plotted. This study supports our study for high identification reliability of porion landmark. The other reason for identification of porion may be due to the conscious effort of the observers while plotting as the literature suggests otherwise.

Orbitale - in X axis ICC values indicate complete homogeneity. And when both are directly ICC is 0.835 which indicates excellent reliability. When assessed along Y axis ICC value are reliable but when compared directly the ICC value is 0.671, indicating excellent agreement. Celik *et al.*,[20] Sayinsu *et al.*,[21] Chen Yi *et al.*,[19] Uysal *et al.*,[15] and Bruntz *et al.*[18] suggested that orbitale sometimes is not clearly identified in a cephalogram. Chen *et al.*[13] suggested that orbitale point had a maximum error difference compared to other landmarks he had studied in both X and Y axis. Chang *et al.*,[3] in his study, he expressed those identification errors were greater for orbitale even with CBCT derived cephalograms. The explanation given for this later identifies errors was because of superimposed bilateral structures and maybe blurred images. Broch *et al.*[22] suggested that the landmark if in blurred area of facial structures like orbitale errors will be larger. Chen *et al.*[13] suggested that significant location difference of porion and orbitale can lead to alteration in FH plane.

ANS in X axis has an ICC value are reliable but when compared directly ICC value is 0.741, which shows excellent agreement. In Y axis ICC for ANS, the digital plotting has a very higher value; it is very close to complete homogeneity. On comparing directly between manual and digital, ICC is 0.750 which indicates excellent agreement for the cephalometric variable. Baumrind and Frantz,[16] Santoro *et al.*,[23] Polat-Ozsoy *et al.*,[24] Ongkosuwito *et al.*,[25] Gregston *et al.*,[26] and Houston *et al.*[27] found difficulty in locating ANS. Chen *et al.*[19] suggested that the reliability of ANS was inferior that of which original radiograph, and hence it was difficult to compare absolute value of reliability between different studies.

ICC for PNS in X axis shows good agreement for manual plotting but for digital it is near to complete homogeneity but when both techniques are compared the ICC is 0.616 which shows good reliability for cephalometric variables. In Y axis intraclass correlation value is closest to complete homogeneity. Ralf Kurt Willy-Schulze *et al.*,[28] in his journal, observed that PNS was least reliable landmark in the X and Y direction both for inter and intraobserver reliability. Forsyth *et al.*[29] suggested that PNS is a poorly defined

structure that is disguised by surrounding noise. Bruntz *et al.*[18] suggested that PNS had low reliability in landmark identification as observed from interobserver error. Huja *et al.*[30] observed in his study indicating the value as more than 1 mm while taking upper 95 interval consideration suggesting that PNS identification was reliable during superimposition. McClure *et al.*[9] suggested that PNS seems to be more reliably identified in vertical than in horizontal directions.

Point A on digital plotting along X axis has a higher value compared to manual method; a significant difference between both the values is not present. But on direct comparison, the ICC value is 0.771 which suggests good reliability as a cephalometric variable. In Y axis digital plotting has a higher value than in manual method, but both are near to homogeneity. And in comparison of both manual and digital, the ICC value is 0.749 indicating excellent reliability as the value is within 0.61 and 0.80. McClure *et al.*,[9] in his study, indicated that Point A was accurate in horizontal direction. Trpkova *et al.*[28] found Point A to be accurate vertically. Shaheed *et al.*[31] had a problem in accurately identifying the A point. Jacobson *et al.*,[32] in his landmark article where he revisited Point A, suggested this point is obscured by prominent cheeks, and rare earth identifying screens for enhancement of soft tissue visualization which makes it difficult to locate accurately. Kazandjian *et al.*[33] suggested that intraoperator reliability was decreased for Point A, in Y axis. Guedes *et al.*[34] had a difficulty in locating Point B in both manual and computer assisted methods.

Point B with ICC values in X axis is near to complete homogeneity. On direct comparison, the ICC is 0.737 in X axis which denotes good reliability. For Y axis, both the methods indicate complete homogeneity. On direct comparison between manual and digital methods intraclass correlation value is 0.469 which shows moderate agreement. Kazandjian *et al.*[33] suggested that interoperator reliability was included using computer assisted method for Point B in both X and Y axis. McClure *et al.*[9] suggested that identification of Point B was accurate among the horizontal plane. Shah *et al.*[7] suggested that Point B lies on a poorly defined outline or low contrast areas. Guedes *et al.*[34] had a difficulty in reproducing Point B in both manual and computer assisted methods.

POGONION in X axis ICC values are in complete homogeneity. When compared directly the intraclass correlation value is 0.754, indicating good reliability. Along Y axis intraclass correlation values indicate complete homogeneity, as they range between 0.81 and 1. But when compared directly, the ICC is 0.665 which indicates good agreement. Agarwal *et al.*[8] have indicated location of POGONION was difficult. Chang *et al.*[3] indicated that identification of POGONION in horizontal direction was relatively consistent and reliable in both imaging modes. The results of this study correlated with the results of our study.

MENTON when subjected to ICC in X axis both the values are near to complete homogeneity. On direct comparison, the ICC is 0.759 which is a good reliability of landmark plotting. Manual plotting in Y axis manual values shows good reliability, and digital value indicates complete homogeneity, but when directly compared between both the techniques the ICC value is 0.718 indicating good reliability. Chen *et al.*[13] suggested that the error for MENTON point were smaller than 1mm in both vertical and horizontal direction suggesting reliability. Kazandjian *et al.*[33] indicated that intraoperator reliability improved for MENTON point when compared to other points both in X and Y axes. The results of these studies support our findings. Chen *et al.*[13] explained that the uncertainty in locating MENTON point may be caused by the difficult of delineating landmark on a curved anatomical boundary. According to Chang *et al.*,[3] landmark identification of MENTON in the vertical direction was the most reliable point.

CONCLUSION

The inter- and intraclass correlation in X and Y axes shows high reliability in hard tissue.

The results obtained for manual and digital was almost similar, but the digital landmark plotting has an added advantage in archiving, retrieval, transmission and can be enhanced during plotting of lateral cephalograms so that the digital method of landmark plotting could be preferred for both daily use and research because of the advantages.

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