Evaluation of Repeatability and Reproducibility of Manual and Computerized Methods for Cephalometric Analysis

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Abstract

Manual tracing has been considered as a standard for cephalometric analysis. However, computerized cephalometric analyzing systems are being used widely in orthodontics due to newer advances in computerized systems. Hence, there is a need to evaluate the repeatability and reproducibility of manual and computerized cephalometric analysis techniques.Aim: To determine intra-examiner repeatability and inter-examiner reproducibility of landmarks using manual and computerized cephalometric analyzing techniques. Methods: 30 lateral cephalograms were randomly selected from the archives of the department. Cephalometric tracings of 10 angular and 2 linear values were carried out and measured by 2 operators with the help of manual and computerized method on each cephalogram. Result: Intra-examiner correlation coefficients ranged from 0.80 to 0.982 for manual and 0.28 to 0.99 for computerized tracings. Inter-examiner correlation coefficients (ICC) for conventional method ranged from 0.86 to 0.97. For computerized tracings, the values ranged from 0.24 to 0.97. Conclusion: Intra-examiner repeatability and inter-examiner reproducibility of landmarks with both methods showed high correlation coefficients.

Keywords: *Cephalometrics, Manual, Computerized, Repeatability, Reproducibility*

1. INTRODUCTION

The manual technique is the most commonly used technique for cephalometric analysis since its introduction by Broadbent.[1] In this technique, linear distances and angles formed between cephalometric landmarks are measured and recorded with a ruler and a protractor on an acetate sheet which has been placed over a cephalometric radiograph. But, this method is very tedious and time-consuming and often leads to errors.[2,3]

The leading cause of error in the conventional manual technique is landmark identification.[4,5,6] This usually depends on the visual accuracy, training, and expertise of the clinician, and also the image sharpness and density.[8]

Other errors in reproducibility are due to errors in measurement and image acquisition. Errors in image acquisition depend on the errors that have occurred as a result of faulty exposure or errors in computer processing of the radiographs. Whereas, errors in measurement are often due to defective devices used for measuring or due to the technique used for measuring.[9]

Another method is the computerized technique in which the landmark identification is carried out manually and the analysis is completed by the computer system. Computerized cephalometric method can eliminate errors caused while drawing lines between the landmarks using a ruler and while measuring the angles formed using a protractor.[3] In computer-aided cephalometric method if the landmarks are located manually, the errors occurring during measurements are identical to those found in the manual method.[10] Therefore, the aim of the

present study was to evaluate the intra-examiner repeatability and inter-examiner reproducibility of landmarks between manual and computerized cephalometric analysing techniques.

2. METHODOLOGY

The study was conducted in the Department of Pedodontics and Preventive Dentistry and the Department of Orthodontics, Faculty of Dental Sciences, Ramaiah University of Applied Sciences. Thirty lateral cephalograms that were taken with a Panaromic machine with a cephalometric arm (CS 9300C, Carestream) with kV =82 and mA = 12 exposed for 0.8 seconds, were selected randomly from the existing active patient files in the department. The cephalometric radiographs obtained belonged to patients aged below 18 years old.

The sample size was estimated using the software OpenEpi. Version 3. Considering the power of the study at 80% and the margin of the error at 5%, the total sample size needed was 30 for each group.

The sample included lateral cephalograms wherein the subjects were positioned in the lateral cephalometric machine with their sagittal plane at 90^0 to the path of the X-rays. The FH (Frankfort horizontal) plane was kept parallel to the floor, while occluding the teeth in centric occlusion. The patient was instructed to press the lips lightly together.[11] All the radiographs were of appropriate contrast and clarity with visible landmarks. The exclusion criteria was poor quality damaged or unclear films.

The tracings of the radiographs that were selected were carried out on acetate sheets manually by two examiners (A and B) with a 0.5 mm microtip pencil, on a standard light box in a darkened room. 10 angular and 2 linear measurements were carried out. For bilateral structures, a single landmark was obtained by taking an average of the two structures. All the parameters were measured manually using a ruler and a protractor which were then entered into an Excel spread sheet (Microsoft, Seattle, Washington, USA) for statistical analysis. Digitized radiographs were traced by the same two examiners using the Dolphin Image Software, Version 11.8 (Dolphin Imaging and Management Solutions, Chatsworth, California, USA).

The landmarks were identified manually on the digital images with the help of a mouse-driven cursor.

The same 10 angular and 2 linear measurements as the manual method were carried out (Figure 1). Automated calculations of all the measurements were carried out with the help of the computer software.

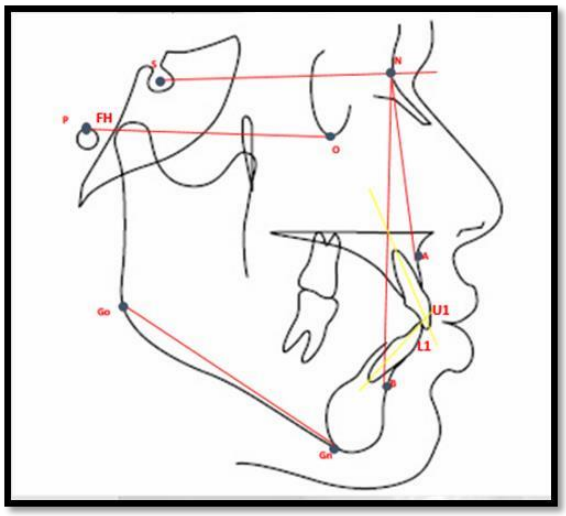

Fig. 1 Parameters used in the study included:Angular parameters: SNA, SNB, ANB, FMA, FMIA, SN – GoGn, IMPA, L1-NB (^{0}), U1 – NA (^{0}), Interincisal angle Linear parameters:U1 – NA (mm), L1 – NB (mm)

For the determination of intra-examiner repeatability, the 30 radiographs were traced and measured again by the same examiner (A), using both conventional and computerized methods, one week after the first tracings.

3. STATISTICAL ANALYSIS

Inferential statistical analysis were performed using the SPSS version 16. Statistical significance was set at $P \leq 0.05$. Means and standard deviations were calculated for all the data. Comparison of means between the first and second measurements was done using paired student's t-test. Intra-class correlation

coefficients (ICC) were calculated to determine intra- and inter-examiner correlation (r value).

4. RESULTS

The mean difference and standard deviations calculated for the 12 measurements taken by the two examiners with both the techniques are shown in Table 2. When the differences in the means obtained for the 2 techniques were compared, the value for ANB, FMA and IMPA ($p \leq 0.05$) measurements showed statistically significant differences.

Intra-class correlation coefficients (r) calculated are shown in Tables 1 and 2.

The highest and lowest ICC obtained for repeated measurements by the same examiner ranged from

0.80 - 0.982 for conventional and 0.28 - 0.98 for digital tracings.

ICC obtained for inter-examiner reproducibility for the manual method showed the highest value for upper incisor to NA (^{0}) (r = 0.97) and the lowest value for IMPA (r =0.86).

For digital tracings, the highest and lowest correlation coefficients for inter-examiner reproducibility were for L1 – NB (mm) (r = 0.97) and SN-GoGn (r = 0.24) measurements, respectively.

Table 1. Differences in cephalometric measurements (n = 30) generated by manual and Dolphin cephalometric analysing methods. *p≤0.05 (statistically significant)

Parameters	Examiner 1				
	Manual		Computerized		Independent samples
	Mean	SD	Mean	SD	t-test
SNA (^{0})	2.8	2.75	2.81	2.79	0.980
SNB (^{0})	2.06	1.40	1.79	1.14	0.410
ANB (^{0})	**0.90**	**1.13**	**1.79**	**1.14**	**0.030***
FMA (^{0})	**3.90**	**3.63**	**0.84**	**0.79**	**0.000***
FMIA (^{0})	1.83	1.73	1.46	1.45	0.379
SN-GoGn (^{0})	2.40	2.27	1.29	0.85	0.160
U1-NA (mm)	1.13	0.93	1.38	1.85	0.518
U1-NA (^{0})	2.50	2.55	3.07	2.70	0.403
IMPA	**5.13**	**7.24**	**1.6**	**1.52**	**0.012**
L1-NB (mm)	0.90	0.62	0.87	0.53	0.870
L1-NB (^{0})	2.10	1.53	1.82	1.34	0.455
Interincisal	4.06	3.33	3.48	2.30	0.431

Table 2. ICC (r) calculated for intra-examiner repeatability

	Manual (n=30)	Computerized (n=30)
SNA(^{0})	0.91	0.78
SNB(^{0})	0.96	0.95
ANB(^{0})	0.95	0.88
FMA(^{0})	**0.80**	**0.28**
FMIA(^{0})	0.92	0.99
SN-GoGn(^{0})	0.97	0.28
U1-NA(mm)	0.97	0.96
U1-NA(^{0})	0.98	0.96
IMPA(^{0})	0.98	0.421
L1-NB(mm)	**0.982**	**0.98**
L1-NB(^{0})	0.98	**0.98**
Inter Incisal	0.98	0.97

Table 3. ICC (r) calculated for inter-examiner reproducibility

	Manual (n=30)	Computerized (n=30)
SNA(^{0})	0.88	0.89
SBN(^{0})	0.93	0.89
ANB(^{0})	0.87	0.94
FMA(^{0})	0.91	0.26
FMIA(^{0})	0.93	0.88
SN-GoGn(^{0})	0.93	**0.24**
U1-NA(mm)	0.95	0.92
U1-NA(^{0})	**0.97**	0.94
IMPA(^{0})	**0.86**	0.87
L1-NB(mm)	0.89	**0.97**
L1-NB(^{0})	0.94	0.90
Inter Incisal	0.96	0.93

5. DISCUSSION

Traditionally, manual tracings have been thought to be one of the best methods for accurate cephalometric analysis. However, computerized cephalometric analyzing systems are being used widely in orthodontics due to newer advances in computerized systems. Manual tracing technique has favourable results when compared with the results of computerized methods according to Richardson(1981) and Sandler(1988).[12,13] In general, manual identification of landmarks can be carried out in the computerized cephalometric analysis but with the use of automatic landmark identification. However as suggested by Gravely and Benzies if landmark identification has been done manually, measurement errors are same as those from conventional technique.[7] In our study, landmark identification was carried out by hand using a mouse driven cursor on digital images and the measurements were calculated automatically by the software.

If the cephalometric films have been scanned and transferred to digital format, then the quality of the original film is of utmost importance.[14] 75 dpi is sufficient for scanning of the lateral cephalograms.[15,16] A statistical difference was found in low-quality digital and low-quality original cephalograms. Thus, concluding that digital processing did not improve the overall reliability of landmark identification when poorer quality radiographs were used.[17] However, we used digital lateral cephalometric radiographs in our study.

The measurement of angle ANB (point A-nasion-point B) plays an important role in the orthodontic diagnosis since this denotes the relative position of maxilla and mandible to each other. An increase in this angle is suggestive of Class 2 skeletal tendency whereas a lesser than normal angle suggests Class 3 skeletal relationship. When a comparison was done between manual and computerized methods to determine differences between the 1st and 2nd measurements, a statistically significant difference was found for ANB, FMA & IMPA (^{0}) angle. The measurement for ANB is depends on nasion localization. The difficulty in identification of the nasion may have resulted in this statistically significant difference. Various studies have reported that errors in conventional cephalometry is inherently a result of inconsistency in landmark identification.[1,18] In accordance with Sekiguchi and Savara (1972),

there may be difficulty in identifying the nsion when the naso-frontal suture cannot be accurately visualized.[19]

The angle FMA had a wider reliability interval and lower correlation than other parameters tested. FMA measurement related to the Frankfort horizontal plane, which passes through porion and orbitale. Various other publications have reported differences in porion and orbitale loacalization.[20] Porion has also been previously reported to cause problems regarding precision and accuracy.[2] Also, measurements for angles FMA & IMPA requires correct identification of the landmark for gonion. However, gonion identification is challenging due to a poorly defined anatomical outline, a double image and localization away from the midsagittal plane.[21] Also, significant differences were seen in gonion identification showed both vertical and horizontal variations which lead to measurement errors.[22,23,24] This might also be the reason for the wider reliability interval and lower correlation found for the measurements for SN-GoGn.

6. CONCLUSION

Intra-examiner repeatability and inter-examiner reproducibility of landmarks with both methods were highly correlated. When the advantages of computerized technique such as archiving, transmission, time and enhancement are taken into consideration, the computerized method could be preferred in daily use and for research purposes without loss of quality.

REFERENCES

1. Broadbent BH. A new x-ray technique and its application to orthodontia. The Angle Orthodontist. 1931 Apr;1(2):45-66.
2. Chen YJ, Chen SK, Chung-Chen Yao J, Chang HF. The effects of differences in landmark identification on the cephalometric measurements in traditional versus digitized cephalometry. The Angle orthodontist. 2004 Apr;74(2):155-61.
3. Liu JK, Chen YT, Cheng KS. Accuracy of computerized automatic identification of cephalometric landmarks. American Journal of Orthodontics and Dentofacial Orthopedics. 2000 Nov 1;118(5):535-40.
4. Houston WJ. The analysis of errors in orthodontic measurements. American journal of orthodontics. 1983 May 1;83(5):382-90.
5. Houston WJ, Maher RE, McElroy D, Sherriff M. Sources of error in measurements from cephalometric radiographs. The European Journal of Orthodontics. 1986 Aug 1;8(3):149-51.
6. Mitgård J, Björk G, Linder-Aronson ST. Reproducibility of cephalometric landmarks and errors of measurements of cephalometric cranial distances. The Angle Orthodontist. 1974 Jan;44(1):56-61.
7. Baumrind S, Frantz RC. The reliability of head film measurements: 1. Landmark identification. American journal of orthodontics. 1971 Aug 1;60(2):111-27.
8. Björk A, Solow B. Measurement on radiographs. Journal of Dental Research. 1962 May;41(3):672-83.
9. Ongkosuwito EM, Katsaros C, Van't Hof MA, Bodegom JC, Kuijpers-Jagtman AM. The reproducibility of cephalometric measurements: a comparison of analogue and digital methods. The European Journal of Orthodontics. 2002 Dec 1;24(6):655-65.
10. Gravely JF, Benzies PM. The clinical significance of tracing error in cephalometry. British Journal of Orthodontics. 1974 Apr 1;1(3):95-101.
11. Uysal T, Baysal A, Yagci A. Evaluation of speed, repeatability, and reproducibility of digital radiography with manual versus computer-assisted cephalometric analyses. The European Journal of Orthodontics. 2009 May 14;31(5):523-8.
12. Richardson A. A comparison of traditional and computerized methods of cephalometric analysis. The European Journal of Orthodontics. 1981 Jan

1;3(1):15-20.
13. Sandler PJ. Reproducibility of cephalometric measurements. British journal of orthodontics. 1988 May 1;15(2):105-10.
14. Sayinsu K, Isik F, Trakyali G, Arun T. An evaluation of the errors in cephalometric measurements on scanned cephalometric images and conventional tracings. The European Journal of Orthodontics. 2007 Feb 1;29(1):105-8.
15. Held CL, Ferguson DJ, Gallo MW. Cephalometric digitization: a determination of the minimum scanner settings necessary for precise landmark identification. American Journal of Orthodontics and Dentofacial Orthopedics. 2001 May 1;119(5):472-81.
16. Rogers MB. Duplication of x-rays by scanning. Journal of clinical orthodontics: JCO. 2002 Apr;36(4):208.
17. Macri V, Wenzel A. Reliability of landmark recording on film and digital lateral cephalograms. The European Journal of Orthodontics. 1993 Apr 1;15(2):137-48.
18. Baumrind S, Frantz RC. The reliability of head film measurements: 2. Conventional angular and linear measures. American Journal of Orthodontics and Dentofacial Orthopedics. 1971 Nov 1;60(5):505-17.
19. Sekiguchi T, Savara BS. Variability of cephalometric landmarks used for face growth studies. American journal of orthodontics. 1972 Jun 1;61(6):603-18.
20. Bruntz LQ, Palomo JM, Baden S, Hans MG. A comparison of scanned lateral cephalograms with corresponding original radiographs. American Journal of Orthodontics and Dentofacial Orthopedics. 2006 Sep 1;130(3):340-8.
21. Santoro M, Jarjoura K, Cangialosi TJ. Accuracy of digital and analogue cephalometric measurements assessed with the sandwich technique. American Journal of Orthodontics and Dentofacial Orthopedics. 2006 Mar 1;129(3):345-51.
22. Chen YJ, Chen SK, Chang HF, Chen KC. Comparison of landmark identification in traditional versus computer-aided digital cephalometry. The Angle orthodontist. 2000 Oct;70(5):387-92.
23. Altuna G, Clar E, Freisfeld M, Schmuth G. Errors in determination of landmarks in connection with methodological problems in roentgenographic growth studies. Transactions. European Orthodontic Society. 1971:373.
24. Graber TM, Orthodontics principles and practices. 4th edition. Elsevier Health Sciences.