A Study Comparing The Reliability And Accuracy Of Various Cephalometric Softwares To Hand Tracings

Dr. Sudhir Munjal[1], Dr. Jatinder Kaur[2], Dr. Satnam Singh [3], Dr. Harmeet Singh[4], Dr. Jagdeep Singh[5], Dr. Karanpreet [6]

[1]Professor & Head, Department of Orthodontics & Dentofacial Orthopedics, Dasmesh Institute of Research & Dental Sciences, Faridkot (Punjab)
[2,5,6]Post Graduate Student (Final year), Department of Orthodontics & Dentofacial Orthopedics, Dasmesh Institute of Research & Dental Sciences, Faridkot (Punjab)
[3] Professor, Department of Orthodontics & Dentofacial Orthopedics, Dasmesh Institute of Research & Dental Sciences, Faridkot (Punjab)
[4] Professor, Department of Orthodontics & Dentofacial Orthopedics, Dasmesh Institute of Research & Dental Sciences, Faridkot (Punjab)

ABSTRACT

Introduction: Cephalometry is extensively used indiagnosis, planning & evaluation of craniofacial development and growth. Both manual and digital techniques can be used to perform cephalometric tracings.
Material and methods: A sample of 40 pre-treatment lateral cephalograms of the individuals were traced manually on the lead acetate sheets and 23 cephalometric measurements were obtained. The soft copies of the same 40 lateral cephalogramswere imported to three computer-aided softwares i.e. NemoCeph, AutoCEPH, UniCeph; the same landmarks used in manual tracing were marked in the digital tracing softwares and the measurements were computed. The collected data was then tabulated, analyzed and subjected to statistical tests.
Results: All the 23 parameters tested using NemoCeph tracing software showed significant correlation with manual tracings while 22 out of 23 parameters tested using AutoCEPH tracing software showed significant correlationexcept linear measurement i.e. LI to A-Pog line. 22 out of 23 parameters tested using UniCeph tracing software showed significant correlation with manual tracing except angular measurement i.e. UI to SN Angle.
Conclusion: The digital cephalometric tracings using all three cephalometric softwares were as reliable and accurate as manual tracings.

Keywords: Lateral cephalogram, manual cephalometric tracings, digital cephalometric tracings, NemoCeph, AutoCEPH, UniCeph

INTRODUCTION

In 1931, the advent of radiographic cephalometry in orthodontics was facilitated by the historical work of Hofrath in Germany and Broadbent in the United States, who concurrently established methods for collecting standardized radiographs of the head.[10] The use of cephalometry has been widespread for the diagnosis, planning, and evaluation of craniofacial growth and development and the follow up of longitudinal studies for different orthodontic therapies.[9]Lateral cephalometric analysis has been one of the most reliable diagnostic tools in orthodontics since the invention of the lateral cephalogram.[8]
Cephalometric tracings can be performed by manual and/or computerized methods.[10]Conventionally, manual tracing is considered “Gold standard” in cephalometric evaluation.[7] Tracing radiographic landmarks on acetate overlays and measuring linear and angular values is how the traditional cephalometric study is carried out.[13] One of the main causes of inaccuracy in cephalometric evaluation is the magnification of radiographic film, landmark identification, tracing, measuring and recording.[2]
The advent of computerized radiography techniques in the late 1980s and early 1990s led to the display of cephalometric radiographs. These digital cephalometric images created a surge for computer cephalometric analysis software.[6] Digital radiography offers several advantages since it allows improved assessment of the image by using graphic and image processing software, which can reverse color scale, enhance specific areas, provide texture manipulation, and others. According to manufacturers, it also presents approximately 80% radiation dose reduction compared to conventional radiographies.[13]
Ricketts was the first to introduce computerized cephalometrics. He emphasized about the significance

of using computerized cephalometrics in research, treatment planning, case presenting, public relations and result monitoring.[11]There are many programs accessible in both the local and global markets offering a wide array of features and variable prices.[10]Compared to traditional approaches, cephalometric analysis using a computer is quicker in both data collection and analysis. Many cephalometric applications have been created to do cephalometric analysis using a computer by digitizing the landmarks.[2]

Numerous software programs have been created over time that promise to be just as exact and dependable as manual tracings, if not more so. The majority of research that assessed the accuracy and dependability of various cephalometric measurements using software has found that the variations between the measurements acquired using manual tracing and that from computerized cephalometric softwares were statistically significant, but these differences were found to be clinically insignificant and acceptable.[7]

Considering the importance of cephalometric analysis for orthodontic diagnosis, the precision of computer-based tracing software must be established by comparing them to hand tracing on acetate paper, the current gold standard.[4]

The current study's goal was to evaluate the reliability and accuracy of various cephalometric softwares such as NemoCeph, AutoCEPH and UniCeph with manual tracings so that they can be used in routine cephalometric tracings that would increase the efficiency of diagnosis as digital cephalometric tracing is less time consuming, also as AutoCEPH and UniCeph are cost-effective digital softwares that would further cut down the cost required for clinical set-up.

MATERIAL AND METHODS

A random sample of 40 pre-treatment lateral cephalograms of the patients who reported to the Department of Orthodontics & Dentofacial Orthopedics for an Orthodontic treatment was employed in this study. Cases with no previous orthodontic treatment, good quality radiographs without any artifacts were selected. Radiographs of the patients with craniofacial anomalies like cleft lip and palate and syndromes, cases with history of trauma and marked jaw asymmetries and Temporo-Mandibular abnormality were excluded.

The print of the lateral cephalograms obtained from the extra oral radiographic machine were traced manually on the lead acetate sheet of 0.05mm thickness using tracing table for the illumination. The midpoint of bilateral structures and double images was chosen while tracing. Once the landmark identification was done, the lines and planes were drawn and the cephalometric parameters which included 11 linear, 12 angular measurements were obtained using a ruler and protractor. Out of these parameters, there were 15 skeletal and 8 dental parameters. (Figure 1)

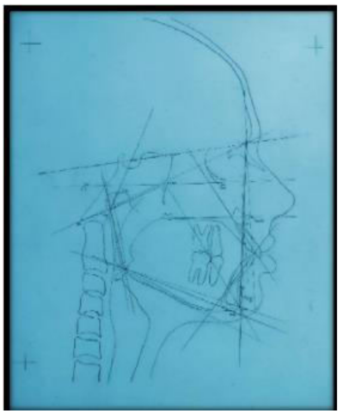

FIGURE 1:Manualcephalogram tracing

The digital copies of the same 40 pre-treatment lateral cephalogram radiographs were used for digital cephalometric tracing.For digital method the soft copies of the same 40 lateral cephalograms used in manual tracing were obtained from Fujifilm FCR Prima Console (CR-IR 391CL) software and imported to three computer-aided softwares i.e. NemoCeph, AutoCEPH, UniCeph and the same landmarks used in manual tracing were marked in the digital tracing softwares using the pointer of that specific software. The images were calibrated by identifying two pin marks 50mm apart. Once the landmark identification was done all the measurements were automatically calculated by the tracing softwares.(Figure 2,3 & 4).

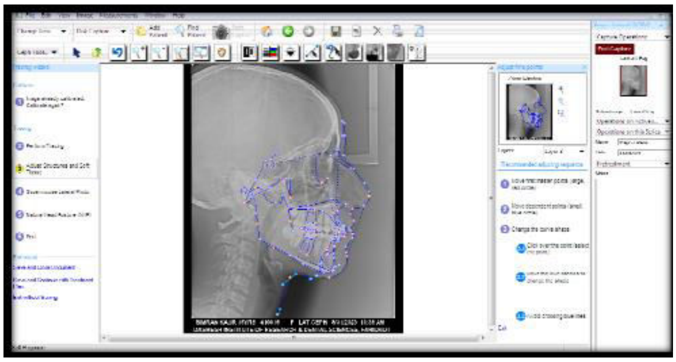

FIGURE 2:Digital cephalometric tracing using NemoCephSoftware

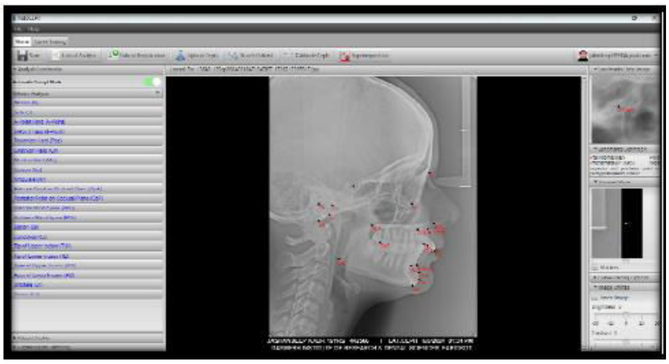

FIGURE 3: Digital cephalometric tracing using AutoCEPHSoftware

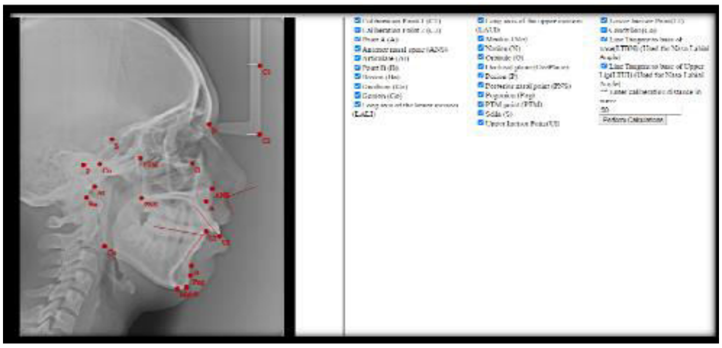

FIGURE 4: Digital cephalometric tracing using UniCeph Software

STATISTICAL ANALYSIS

The values obtained from the manual and digital cephalometric tracing were tabulated, analyzed and subjected to statistical tests to evaluate the reliability and accuracy of digital cephalometric softwares to manual tracing. The statistical analysis was done using Statistical Package for the Social Sciences (SPSS Inc.). Intra-class Correlation Coefficient (ICC) was performed to compare the values of the digital cephalometric softwares to values obtained from hand tracings. Intra-class correlation was calculated using absolute agreement.

RESULTS

The statistical analysis was done using Statistical Package for the Social Sciences (SPSS Inc.). Intraclass Correlation Coefficient (ICC) was performed to compare the values of the digital cephalometric softwares to values obtained from hand tracings (Table 2, 3 & 4). Absolute agreement was used to calculate Intraclass Correlation Coefficient (ICC). All the parameters showed ICC ranging between 0.75 to 0.90 except for LI to A-Pog line and Upper Incisor to Sella Nasion Plane Angle which showed insignificant correlation.

All the 23 parameters tested using NemoCeph tracing software showed significant correlation with manual tracings. 22 out of 23 parameters tested using AutoCEPH tracing software showed significant correlation with manual tracing except linear measurement i.e. LI to A-Pog line that showed a wider reliability interval and lower correlation. 22 out of 23 parameters tested using UniCeph tracing software showed significant correlation with manual tracing except angular measurement i.e. Upper Incisor to Sella Nasion Angle that showed a wider reliability interval and lower correlation.Basal Plane Angle measurement using NemoCeph software had the lowest Intra-class Correlation with the manual reading in comparison with AutoCEPH and UniCeph.LI to A-

Pog line measurement using AutoCEPH had the lowest Intra class Correlation with the manual reading in comparison with NemoCeph and UniCeph. (Graph 1)Effective Maxillary Length measurement using UniCeph had the lowest Intra-class Correlation with the manual reading in comparison with NemoCeph and AutoCEPH (Graph 2). Mandibular Body Length measurement using UniCeph had the lowest Intra-class Correlation with the manual reading in comparison with NemoCeph and AutoCEPH (Graph 4). UI to SN Angle measurement using UniCeph had the lowest Intra-class Correlation with the manual reading in comparison with NemoCeph and AutoCEPH. Most unreliable parameter was UI to SN plane Angle using UniCeph as it showed low level of agreement with manual tracings as ICC was (-0.145). (Graph 3)

Out of three cephalometric tracing softwares NemoCeph was found to have high level of agreement in comparison with manual tracings as out of 23 parameters analyzed ICC values for 22 parameters exceeded 0.9 indicative of very high level of agreement. AutoCEPH software also showed high level of agreement upon comparison with manual tracings as 21 out of 23 parameters had ICC above 0.9 and UniCeph software showed ICC above 0.9 for 20 out of 23

parameters.So, based on statistical values NemoCeph showed greater reliability and accuracy when compared with manual tracings followed by AutoCEPH and then UniCeph.

Table 1: Cephalometric measurements used inmanual and digital cephalometric analysis

Measurements	Definitions
Skeletal parameters	
SNA angle	Angle determined by points S, N, and A
SNB angle	Angle determined by points S, N, and B
ANB angle	Angle determined by points A, N, and B
Go-G n-SN angle	Angle between the Go-Gn and SN lines
Sum of posterior angles	Sum of saddle, articular, and gonial angle
Gonial angle	Angle formed by tangents to the body of the mandible and posterior border of the ramus of the mandible
Facial axis angle	Angle formed by a line constructed from the posterosuperior aspect of the pterygomaxillary fissure (PTM) to anatomic Gnathion (G n) and a line perpendicular to the cranial base (represented by a line joining basion [Ba] and nasion [N])
Basal plane angle	Angle between palatal and mandibular planes
N perpendicular point A	The linear distance between nasion-perpendicular and point A (the posteriormost point of the anterior contour of the maxilla)
N perpendicular pogonion	Distance between pogonion point and a line drawn perpendicular to FH from point N
Lower anterior facial height	Distance between ANS and Me
Effective maxillary length	Distance between condylion and point A
Effective mandibular length	Distance between condylion and gnathion
Mandibular ramus length	Distance between articulare and gonion
Mandibular body length	Distance between gonion and pogonion
Dental Parameters	
Upper incisor to NA (°)	Angle formed between the long axis of upper central incisor and NA plane
Upper incisor to NA (mm)	Distance between the labial point of U1 and NA plane
Lower incisor to NB (°)	Angle formed by the intersection L1 to the plane between points N and B
Lower incisor to NB (mm)	Perpendicular distance from the tip of the mandibular incisor to the plane between points N and B
Upper incisor to point A	Distance between a vertical line drawn through point A parallel to N-perpendicular to the facial surface of the maxillary incisors
Lower incisor to A-Pog line	The distance between the long axis of lower incisor and A point-Pogonion
Upper incisor to SN plane angle	Angle between the upper incisor axis and S-N posteriorly
Lower incisor to mandibular plane angle	Angle formed between Go – Me and the mandibular incisor axis

TABLE 2: Manual Tracings versus Nemo Ceph Software Tracings Intra class Correlation Coefficient

Variable	Intraclass Correlation(a)	95% Confidence Interval		F Test with True Value 0			
		Lower Bound	Upper Bound	Value	df1	df2	Sig
SNA Angle	.985	.954	.994	91.787	39.0	39	.000
SNB Angle	.989	.978	.994	91.285	39.0	39	.000
ANB Angle	.977	.954	.989	49.315	39.0	39	.000
Go-Gn-Sn Angle	.976	.956	.988	42.060	39.0	39	.000
Sum of Post.	.981	.965	.990	52.668	39.0	39	.000
Gonial Angle	.976	.946	.988	49.843	39.0	39	.000
Facial Axis Angle	.980	.962	.989	48.448	39.0	39	.000
Basal Plane Angle	.854	-.154	.962	22.560	39.0	39	.000
N perp. Point A	.946	.897	.971	18.953	39.0	39	.000
N perp. Point Pog	.973	.950	.986	36.708	39.0	39	.000
LAFH	.974	.947	.987	43.336	39.0	39	.000
EL. Max	.939	.673	.978	27.678	39.0	39	.000
EL. Mand	.967	.849	.988	48.464	39.0	39	.000
Ar-Go	.939	.884	.967	16.527	39.0	39	.000
Go-Pog	.927	.533	.976	25.367	39.0	39	.000
UI to NA Angle	.991	.980	.995	121.890	39.0	39	.000
UI to NA (mm)	.939	.885	.968	16.299	39.0	39	.000
LI to NB Angle	.965	.935	.982	29.319	39.0	39	.000
LI to NB (mm)	.981	.964	.990	54.568	39.0	39	.000
UI to Point A	.935	.877	.965	15.404	39.0	39	.000
LI to A-Pog Line	.632	.311	.804	2.834	39.0	39	.001
UI to SN Angle	.988	.935	.996	144.209	39.0	39	.000
LI to Mand. Angle	.955	.134	.989	81.105	39.0	39	.000

TABLE 3: Manual Tracings versus AutoCEPH Software TracingsIntraclass Correlation Coefficient

Variable	Intraclass Correlation(a)	95% Confidence Interval		F Test with True Value 0			
		Lower Bound	Upper Bound	Value	df1	df2	Sig
SNA Angle	.985	.954	.994	91.787	39.0	39	.000
SNB Angle	.989	.978	.994	91.285	39.0	39	.000
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UI to SN Angle	.988	.935	.996	144.209	39.0	39	.000
LI to Mand. Angle	.955	.134	.989	81.105	39.0	39	.000

TABLE 4: Manual Tracings versus UniCeph Software TracingsIntra-class Correlation Coefficient

Variable	Intraclass Correlation(a)	95% Confidence Interval		F Test with True Value 0			
		Lower Bound	Upper Bound	Value	df1	df2	Sig
SNA Angle	.985	.954	.994	91.787	39.0	39	.000
SNB Angle	.989	.978	.994	91.285	39.0	39	.000
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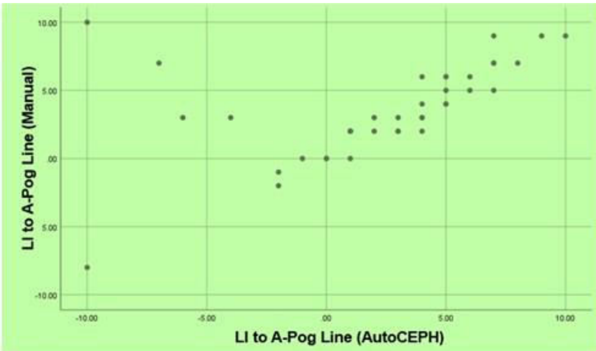
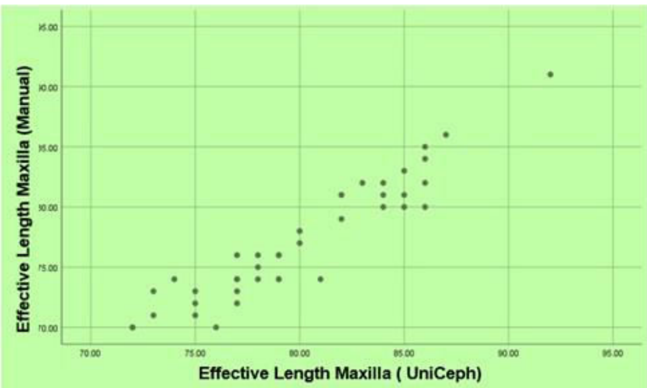
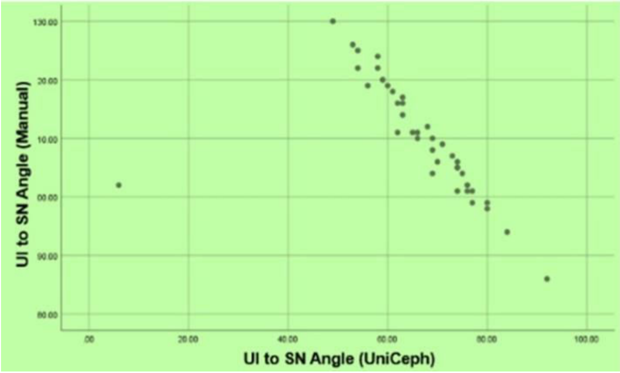


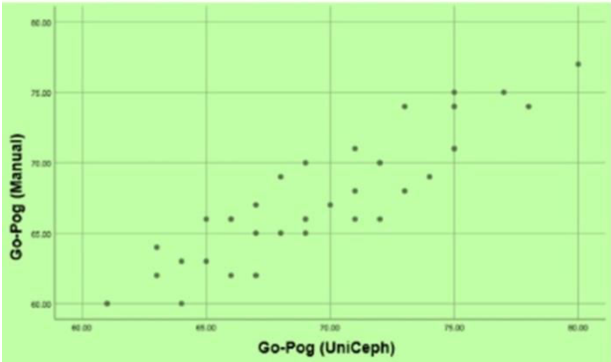
GRAPH 1: Scatter plot of correlation between AutoCEPH readings and manual readings (LI to A-Pog line)



GRAPH 2: Scatter plot of correlation between UniCeph readings and manual readings (Effective Length Maxilla)



GRAPH 3: Scatter plot of correlation between UniCeph readings and manual readings (UI to SN Angle)



GRAPH 4: Scatter plot of correlation between UniCeph readings and manual readings (Go-Pog)

DISCUSSION

In orthodontics, cephalometric radiography is a vital tool for diagnosing, planning and assessing treatment outcomes as well as for researching the growth and development of the dentofacial skeleton. In cephalometric analysis, manual tracing is traditionally regarded as the “Gold standard”. Tracing radiographic landmarks on acetate overlays and utilizing them to measure the required linear and angular values is how manual analysis is carried out. Nevertheless, it is time consuming, tedious and prone to a number of mistakes.[7]Systematic mistakes and random errors, which include measurements, landmark identification and tracing, make up cephalometric analysis errors. [3]

To do cephalometric analysis directly on screen-displayed digital film, numerous commercially available or specially designed programs have been created. Furthermore, the substantial reduction in radiation exposure that can be achieved when direct digital cephalogram methods are used is one additional reason for the gradual transition from analogue to digital cephalometrics.[15]

Some conflicting results were found by Thurzo et al. (2010) who confirmed lower accuracy in manual method of tracing.[14] Another author Navarro et al. (2013) also confirmed the greater reliability of cephalometric analysis from CBCT as compared with manual tracing and digitized lateral cephalograms.

The present study compared the manual tracings of 40 pre-treatment lateral cephalograms with three cephalometric tracing softwares named NemoCeph, AutoCEPH and UniCeph. A total of 23 skeletal and dental parameters commonly used cephalometric variables for Orthodontic diagnosis, treatment planning and evaluation of treatment results were compared.

The use of NemoCeph software in many Orthodontists work and diagnosis is a fact and it is a confirmed quality program.

AutoCEPH is an indigenous 2D computerized cephalometric analysis software designed and developed by pioneer institutes of the country.[7]Similarly, UniCeph is designed and developed by our Department of Orthodontics & Dentofacial Orthopedics. This browser based cephalometric analysis software is cost effective and easy to operate.

Manual tracings were done using standard protocols. Using a millimeter ruler and protractor all linear and angular measurements were taken to the nearest 0.5mm and 0.5° respectively. Midpoint of all the bilateral anatomical structures and double images was used. For computerized cephalometric measurements, digital images of same cephalograms were directly imported to the computerized cephalometric softwares. These direct digital images were standardized and calibrated in millimeters using markings present on cephalogram. The bilateral structures for the selected landmarks were averaged to make a single landmark. All the tracings (manual as well as digital) were done by a same examiner.[7]

To evaluate the reliability and reproducibility for all the methods of cephalometric measurement, Intraclass Correlation Coefficient (ICC) was calculated. All the parameters showed ICC ranging between 0.75 to 0.90 except for LI to A-Pog line using AutoCEPH digital cephalometric software and Upper Incisor to Sella Nasion Plane Angle using UniCeph cephalometric software which showed insignificant correlation.

LI to A-Pog line measurement was found to be least reliable using AutoCEPH software upon comparison with manual tracings while the comparison of the same measurement using NemoCeph and UniCeph cephalometric tracing software demonstrated accuracy and dependability as with manual tracing.

Several reports found LI to A-Pog using various cephalometric softwares unreliable when compared with manual tracings as study by Tanwani et al. (2014) found a significant difference in Nasolabial angle and L1-A Pog variables of McNamara analysis. This is because of difficulty in locating Point Pog and because of variability in the sample population, the soft tissue variability is observed.[13]

Gregston et al. (2004) found high coefficient of variation for L1-APog for most of the scanned and digital images and concluded it due to difficulties in landmark identification that could be related to the lack of contrast in the areas of incisor apices.[5]

UI to SN Angle was found to be least reliable using UniCeph digital tracing software upon comparison with manual tracings while the comparison of the same measurement using NemoCeph and AutoCEPH cephalometric tracing software proved to be reliable and accurate.

Santoro, Jarjoura & Cangialosi (2006) upon comparison of cephalometric measurements obtained with digital tracing software with equivalent hand tracings found the correlation coefficients of most variables above 0.95with the exception of the Wits (0.82), upper incisor to sella-nasion plane angle (0.92) and lower incisor to A-pogonion (0.93) for conventional tracings and reported the tracing issues with the position of the incisors and differences in incisor angular measurements between tracing techniques.[12]Similarly, Gregston et al. (2004) conducted a study that used manual tracings and three software programs (Dolphin Imaging v. 6.7, Vistadent v. 7.33 and Vistadent v. 8.01) to compare conventional images, scanned conventional images and stored phosphor images and found differences of more than 2mm or 2° from hand tracing of U1 SN angle parameter along with NBa-PTGn, IMPA.[5]

Sekiguchi and Savara indicated that Nasion (N) may be difficult to identify when the nasofrontal suture is not accurately visualized so landmark identification is considered the major source of error.[1]

In comparative analysis of hand tracings with 3 different cephalometric tracing softwares (NemoCeph, AutoCEPH and UniCeph) using 23 cephalometric parameters very few parameters showed statistically significant differences. NemoCeph cephalometric tracing software was found to be most reliable upon comparison with the hand tracings as out of 23 parameters analyzed 22 parameters were in high level of agreement followed by AutoCEPH as 21 parameters were in high level of agreement with the manual tracings then UniCeph as 20 out of 23 parameters were in high level of agreement with manual tracings. The inferiority of the digital image in terms of landmark reliability in 2 out of 23 parameters may have a little impact in our application of digital cephalometry, because besides the lateral cephalometric analysis there are several sources of diagnostic information. However, it is preferable to carefully interpret the subtle differences found in digital cephalometry in order to assess growth change or therapy effect. These landmarks with significant lower reliability in digital images should be scrutinized more carefully while taking potential advantages of the use of digital cephalometry.

CONCLUSION

Computerized cephalometric measurement using direct digital imaging is inherently preferable for its user-friendly and time saving characteristics, thus making this method preferable to hand tracing for cephalometric analysis of radiographs used in diagnosis, treatment planning and the evaluation of treatment outcome. The digital approach may be favoured for everyday usage and study without sacrificing quality when the benefits of digital imaging - such as archiving, transmission and enhancement - are taken into account.

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