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Assessing the Reliability of Computer Aided Digital Cephalometric Tracing Versus Manual Cephalometric Tracing- A Comparative Study.

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KEYWORDS

Autoceph, Nemoceph, Oneceph, Down analysis, Steiner's analysis, Tweeds analysis, Manual cephalometrics, Digital cephalometrics.

ABSTRACT:

The aim of this study was to assess the reliability of computer aided digital cephalometric tracing methods versus manual cephalometric tracing method.

MATERIALS & METHODS The study was conducted on pre-treatment lateral cephalograms of 72 subjects which were obtained from Department of Orthodontics & Dentofacial Orthopaedics, Desh Bhagat Dental College & Hospital, Mandi Gobindgarh, Punjab. All the Cephalograms were traced both manually and digitally. The analysis used for study were Steiner's analysis, Down's analysis & Tweed's analysis. Lateral cephalograms of the patients were traced with 3H drawing pencil using standard protocols. For digital tracing cephalometric points and lines were demarcated digitally by using three different softwares that were, Autoceph, Nemoceph & Oneceph. The accuracy and reliability of cephalometric measurements of digital and manual cephalometric tracing was evaluated and the measurements from two methods were also compared. MANOVA followed by Tukey's post hoc test was carried out to determine the difference between the groups. All statistical tests were performed at a significance level of 5% ($p \leq .05$).

RESULTS; Three parameters of Steiner's analysis showed statistical significant difference ($p<0.005$) when compared among the four tracing methods. These parameters were OCCL to SN, S line to UL, S line to LL. The mean value of facial angle measured from Manual tracing and other three softwares were statistically different (p value<0.05), angle of convexity was also significantly different among manual and digital tracing methods (p value is 0.01) ,A-B plane angle and mandibular plane angle were also significantly different (p value is 0.001) among the four tracing methods and the values of Y Axis and cant of occlusion plane were also significantly different among four tracing methods and for cant of occlusion as obtained from manual tracing, Autoceph, Nemoceph and Oneceph tracing method. Statistically significant differences were observed in values of incisor occlusal plane angle and incisor mandibular plane angle (p value 0.01).

CONCLUSION;It was concluded that Autoceph, Nemoceph and Oneceph provided cephalometric measurements as accurate as the manual method in most of the parameters and AUTOCEPH gave the most accurate and reliable result, which was followed by NemoCeph and Oneceph respectively among three digital softwares.

INTRODUCTION

Serial cephalometric radiographs can be used to investigate growth and development of the facial skeleton that can assist in treatment planning and to assess changes between pre- and post-treatment measurements to evaluate the treatment results.The

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introduction of cephalometry by Broadbent (1931) and Brodie in the USA, and by Hofrath in Europe, allowed detailed evaluation of dental and skeletal malocclusions. [1]

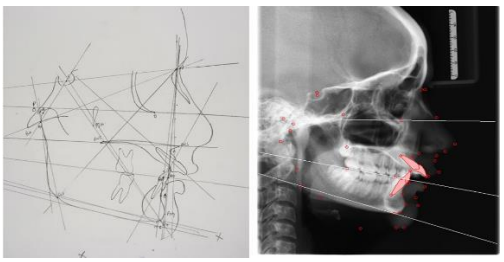
Cephalometric tracings can be performed by-
manual and **digital** tracing Methods.

The **manual** method was previously the only available method used for achieving and procuring cephalometric tracings and angular and linear measurements. The tracings of lateral cephalograms were traced by using a sheet of acetate paper over the radiograph and were done on a view box with the help of ruler, protractor and pencil for the recording of linear and angular measurements .[2]

Despite of its wide use in the field of orthodontics, this technique is time consuming, has disadvantage of being subject errors and systemic errors. The most important source of error includes the variation in landmark identification, errors in measurements and magnification errors.[3]

The **digital** radiographic image is the image obtained from X-rays incidence and is displayed on the computer. There are two methods to obtain digital image that are, **indirect and direct** method.

If the image is captured directly through a charged coupled device while eliminating the use of radiographic film and darkroom, is a direct method whereas in the indirect method, also called hybrid system, a conventional radiograph is obtained by a video camera or scanner and is digitalized in a computer through a software program.[4]



Some of the commonly used softwares are: Dentofacial Planner, Dolphin Imaging, NemoCeph, Quick Ceph, OneCeph ,AutoCEPH & Blue sky bio. Howerever no study has been done by using the three softwares in comparision to Manual & among themselves in order to evaluate the reliability and accuracy.

AutoCEPH is two dimensional (2D) computerized cephalometric analysis software designed and developed in the context of Indian Orthodontic clinical practices by CSIR-Central Scientific Instruments Organization (CSIO).[5]

NemoCeph software is the most complete Orthodontic tool for diagnosis, treatment planning and case presentation to the patient. This software really is best tool for cephalometric analysis in clinics.[6]

It is simple, customizable, communicable and comprehensive. The images are calibrated by identifying two crosshairs 10 mm apart and the enhancement features of the software, like brightness, contrast adjustment and magnification can be used as needed to identify individual cephalometric landmark as precisely as possible with the help of mouse/cursor.

OneCeph is one of the few easily available software that is easy and best to use which can be downloaded from the Google Play store app in any of the current smart phones which run on the Android operating systems.[7]

Therefore it can be used as an aid in diagnosing, planning, monitoring, and evaluating orthodontic treatment both in clinical and research settings. So, the aim of present study was to analyze and compare the linear and angular measurements obtained from manual tracing & digital cephalometric tracing software programmes which were Autoceph, Nemoceph & OneCeph.

AIM AND OBJECTIVES

The aim of this study was to assess the reliability of computer aided digital cephalometric tracing methods versus manual cephalometric tracing method.

OBJECTIVES

- To compare the digital cephalometric tracing with manual cephalometric tracing.
- To check the accuracy & relaibility of digital tracings of different softwares (Autoceph, Nemoceph & Oneceph) against manual tracing.

MATERIAL AND METHODS

- The study was conducted on pre-treatment lateral cephalograms of 72 subjects.
- All the Cephalograms were traced both manually and digitally.
- The analysis used for study were Steiner's analysis, Down's analysis & Tweed's analysis.
- Lateral cephalograms of the patients were traced with 3H drawing pencil using standard protocols.

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For digital tracing cephalometric points and lines were demarcated digitally by using three different softwares that were, Autoceph, Nemoceph & Oneceph.

INCLUSION CRITERIA

- All subjects should be in age group of 16-30 years.
- No history of previous orthodontic treatment.
- No craniofacial syndromes.
- No history of facial trauma.
- Lateral cephalogram with proper contrast.

EXCLUSION CRITERIA

- Subjects with cleft palate and lip
- Poor contrast of lateral cephalogram
- Incorrect Head position of patients.
- Presence of radiographic distortions

ARMAMENTARIUM USED

I. MANUAL TRACING (Fig.No.1)

a) Lateral cephalograms
b) Acetate tracing sheet of 0.003-inch thickness
c) 0.5 mm lead pencil (3H)
d) Tracing table
e) Measuring devices – ruler, set square, protractor

II. Digital Tracing

a) Autoceph software
b) Nemoceph software
c) One ceph software
d) Windows 10 Laptop
e) Window system 10 pro
f) Samsung Tab
g) jpg images of cephalogram.

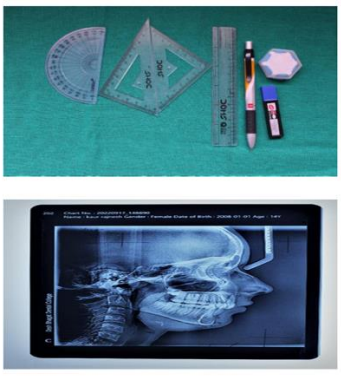

Fig.No 1: Armamentarium: 3H drawing Pencil, Eraser, Scale, Set Square and Protractor. Lateral cephalogram with acetate matte tracing sheet.

CONSTITUTION OF TEST GROUPS

- Group I – **Manual** hand tracing
- Group II – Tracing performed using computerized software **Autoceph**
- Group III – Tracing performed using computerized software **Nemoceph**
- Group IV – Tracing performed using computerized software **OneCeph**

Lateral cephalograms were taken in standardized manner using cephalostat by **Vatech** Digital X-ray imaging system manufactured by **Vatech**, Korea Ltd. Each Cephalometric radiograph was taken in standardized position maintaining the subject's head in a constant relationship to the film. This in turn standardized the distance of the subject to the film, the X-ray exposure as well as the magnification.

Manual hand tracing method

Manual hand tracing was performed in a darkened room using an illuminated tracing table. The x-ray was secured to the surface of the tracing table and a sheet of fine transparent acetate paper of 0.003 inches thickness was secured over the x ray. Tracing was carried out using 0.5 mm 3 H lead pencil, landmarks were identified by a single point, in a predetermined order. For bilateral structures and double images the mid-point was chosen by construction. After landmark identification linear and angular measurements were made & measured **(Fig.No.2)**

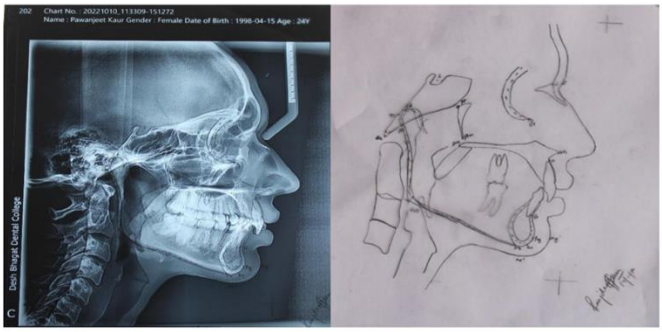

Fig No. 2 . Landmarks marked on tracing sheet for manual tracing

Planes Used In the Study: (Fig.No.3)[8]

S-N PLANE: It is the cranial line between the center of sella tursica (sella) and the anterior point of the fronto-nasal suture (nasion). It represents the anterior cranial base.

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FRANKFORT HORIZONTAL PLANE: This plane connects the lowest point of the orbit (orbitale) and the superior point of the external auditory meatus (porion).

PALATAL PLANE : It is a line connecting the anterior nasal spine of the maxilla and the posterior nasal spine of the palatine bone.

OCCLUSAL PLANE: Line joining midpoint of overlap of mesiobuccal cusps of upper and lower first molars with point bisecting overbite of incisiors.

MANDIBULAR PLANE (STEINER)– **1:** A line connecting gonion and gnathion.

MANDIBULAR PLANE (TWEED) – **2:** Tangent to the lower border of the mandible.

MANDIBULAR PLANE (DOWNS) – **3:** A line connecting gonion and menton.

S- LINE : It is drawn from pog' to the midpoint of the S- shaped curve between Subnasale and Pronasle (nose tip).

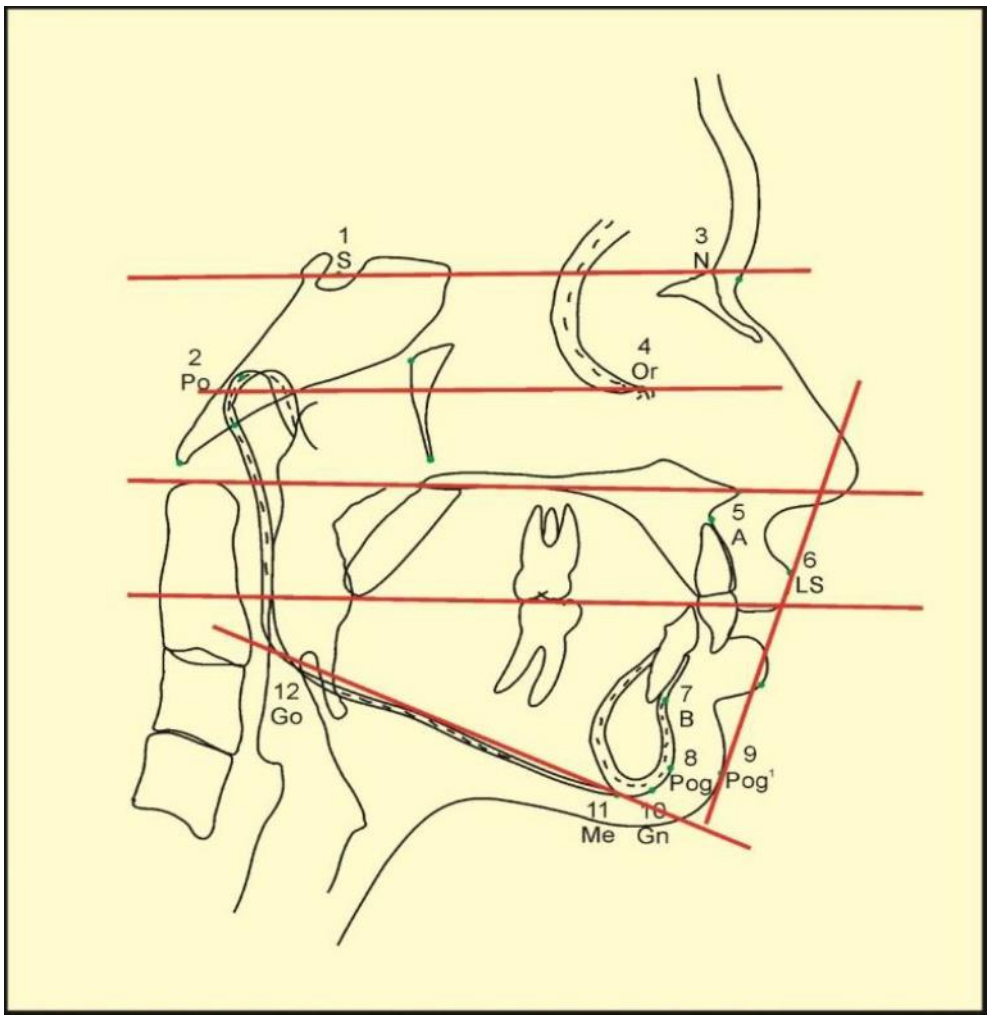

Fig. No. 3. Planes used in the study.

DIGITAL TRACING

The digital radiographic image, obtained from X-rays incidence and is displayed on the computer and is digitalized through the inbuild software programme. After that we converted the image into jpg file and then transfered into the 3 tracing softwares (Autoceph,Nemoceph & Oneceph).The following three digital computerized tracing software were used:

a) Autoceph
b) NemoCeph
c) OneCeph

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AUTOCEPH (CSIOR-CSIO chandigarh and AIIMS New Delhi,Version 1.1.3.(Fig.No. 4.)

Configuration of the system used:
OPERATING SYSTEM - Windows 10
PROCESSOR - Intel core i3 processor
RAM - 4 GB

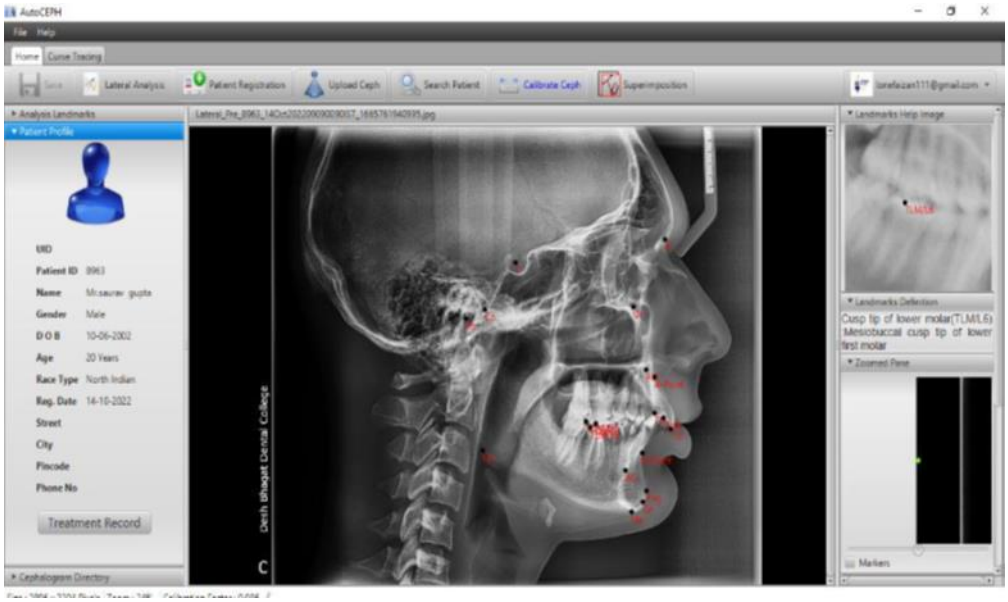

Fig. No. 4. AUTOCEPH TRACING

NEMOCEPH NX 2006 (Nemotec,version 6.0 Madrid, Spain) (Fig.N0.5)
Configuration of the system used:
OPERATING SYSTEM - Windows 10 pro
PROCESSOR - 11th Gen Intel(R) core(TM) i5 processor
RAM - 8.00 GB

Fig. No. 5. NEMOCEPH TRACING

ONECEPH Fig.No.6)
Configuration of the system used: Tablet and windows 11

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Model name - Galaxy Tab A7
Model number - SM-T500

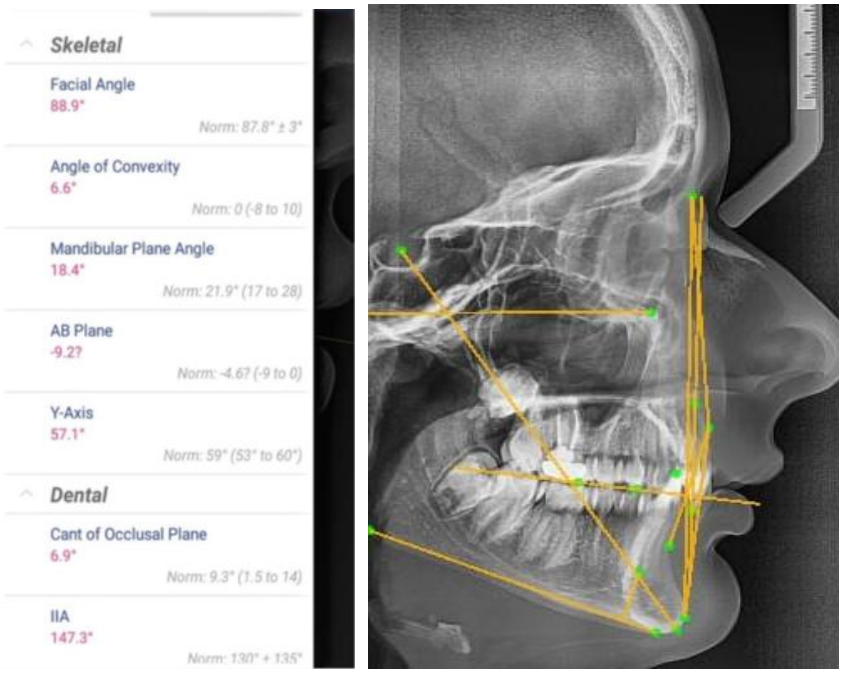

Fig. No. 6. ONECEPH TRACING

RESULTS

Mean values of FMA measured by manual tracing were 25.9 º, while 24.4º, 24.4º and 24.2 º measured from Autoceph, Nemoceph and Oneceph respectively. There was no statistically significant difference in FMA values obtained from four tracing methods. Similarly no significant difference was reported among the four tracing methods for mean values of IMPA and FMIA angles.

Three parameters of Steiner's analysis showed statistical significant difference ($p<0.005$) when compared among the four tracing methods. These parameters were OCCL to SN,S line to UL, S line to LL.

The mean values of Occl to SN as obtained from manual tracing, Autoceph, Nemoceph and OneCeph were 15.31º, 12.96º, 22.81º&17.13º respectively. Linear measurement from S line to UL was1.32 mm as measured from manual tracing and 1.73 mm, -0.55 mm and 4.15 mm obtained from Autoceph, Nemoceph and Oneceph respectively. Mean value of S line to LL measured from manual tracing was 1.99 mm, 0.62 mm from Autoceph, 0 mm obtained from Nemoceph and Oneceph showed 2.64 value for this parameter.

The mean value of facial angle measured from Manual tracing was 82.1^0, from Autoceph it was 84.9º, from Nemoceph it was 83.4º& from Oneceph it was 86.2º.These values were statistically different (p value<0.05).The mean value of angle of convexity was also significantly different among manual and digital tracing methods (p value is 0.01) Mean values of angle of convexity obtained from manual tracing, Autoceph, Nemoceph, Oneceph were 5.09º,7.23º, 8.16º and 8.21º respectively.

The mean values of A-B plane angle and mandibular plane angle were also significantly different (p value is 0.001) among the four tracing methods**.** A-B Plane angle values were -4.2º, -7.9º,8.2º, -8.5ºand mandibular plane angle values were 26.4º, 24.5º, 23.2º,20.2º and the values of Y Axis and cant of occlusion plane were also significantly different among four tracing methods, which were 62.0º,60.1º, 90.1º and 58.9º for Y axis and 10.31º, 6.62º, 15.02º and 8.96º for cant of occlusion as obtained from manual tracing, Autoceph, Nemoceph and Oneceph tracing method.

Statistically significant differences were observed in values of incisor occlusal plane angle and incisor

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mandibular plane angle (p value 0.01). The mean values of incisor occlusal plane angle were 31.47º, 57.2º, 21.22º, and 25.88º as measured from manual tracing method, Autoceph, Nemoceph, and Oneceph respectively. Values of incisor mandibular plane angle were 21.25º, 103.88º,100.87º and 13.54º

Table 1 shows the correlating the values of cephalometric parameters as obtained from manual and Autoceph software, the mean values of FMA, IMPA, FMIA, SNA, SNB, ANB, upper incisor to N-A (linear mm) , upper incisor to N-A (angle), lower incisor N-B (linear mm), lower incisor to N-B (angle), interincisal angle, 1 to A -pog showed high correlation between two tracing methods with ICC value > 0.80 The values of Angle of Occlusal to SN,Y axis, Cant of occlusal plane, showed moderate correlation with ICC value in the range of 0.75 – 0.80. Poor correlation was indicated by some parameters which are GOGN to SN, S line to UL, S line to LL, Facial Angle, Angle of convexity, A-B plane angle, Incisor Occlusal plane angle & Incisor mandibular plane angle with ICC value less than 0.75.

Group	ICC	95% Confidence Interval	
		Lower Bound	Upper Bound
FMA	.813[c]	0.70	0.88
IMPA	.906[c]	0.85	0.94
FMIA	.874[c]	0.80	0.92
SNA	.938[c]	0.90	0.96
SNB	.936[c]	0.90	0.96
ANB	.847[c]	0.76	0.90
GOGNSN	.672[c]	0.48	0.80
N-A (mm)	.862[c]	0.78	0.91
N-A (angle)	.927[c]	0.88	0.95
N-B (mm)	.924[c]	0.88	0.95
N-B (angle)	.883[c]	0.81	0.93
1 to 1	.947[c]	0.92	0.97
occlusal to SN	.750[c]	0.60	0.84
s line to UL	.571[c]	0.31	0.73
s line to LL	.713[c]	0.54	0.82
Facial angle	.533[c]	0.25	0.71
Angle of convexity	.638[c]	0.42	0.77
AB plane angle	.404[c]	0.05	0.63
Mandibular plane angle	.877[c]	0.80	0.92
y -growth axis	.788[c]	0.66	0.87
cantt of occlusion	.754[c]	0.61	0.85
Interincisal angle	.891[c]	0.83	0.93
incisor occlusal plane angle	-1.592[c]	-3.14	-0.62
incisor mandibular plane angle	-.050[c]	-0.68	0.34
1 to A-pog line	.872[c]	0.80	0.92

Table 1 correlation coefficient (ICC) between Manual &AutoCeph tracing method.

Table 2 shows correlation of cephalometric measurements between Manual & Nemoceph software tracing methods.
Out of 25 parameters, 17 values showed high level of correlation between the two methods. These parameters were FMA, IMPA, FMIA , SNA, SNB, ANB, GOGNSN, upper incisor to N-A (linear mm), upper incisor to N-A (angle), lower incisor to N-B (linear mm

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), lower incisor to N-B (angle), S line to LL, Mandibular plane angle , interincisal angle, I to A- pog line but the AB Plane angle showed moderate reliability with ICC value of -0.736. (Table 2). Poor correlation was observed for some parameters such as OCCL to SN, Facial angle, Angle of convexity , y-growth axis. Cant of occlusion, Incisor occlusal plane angle, Incisor mandibular plane angle with ICC < 0.75.

Group	ICC	95% Confidence Interval	
		Lower Bound	Upper Bound
FMA	.838[c]	0.74	0.90
IMPA	.917[c]	0.87	0.95
FMIA	.931[c]	0.89	0.96
SNA	.929[c]	0.89	0.96
SNB	.928[c]	0.89	0.96
ANB	.840[c]	0.74	0.90
GOGNSN	.815[c]	0.70	0.88
N-A (mm)	.922[c]	0.88	0.95
N-A (angle)	.828[c]	0.72	0.89
N-B (mm)	.934[c]	0.90	0.96
N-B (angle)	.910[c]	0.86	0.94
1 to 1	.977[c]	0.96	0.99
occlusal to SN	.372[c]	0.00	0.61
s line to UL	.872[c]	0.80	0.92
s line to LL	.850[c]	0.76	0.91
Facial angle	.246[c]	-0.20	0.53
Angle of convexity	.660[c]	0.46	0.79
AB plane angle	-.736[c]	-1.78	-0.09
Mandibular plane angle	.897[c]	0.84	0.94
y -growth axis	-2.253[c]	-4.20	-1.03
cantt of occlusion	.529[c]	0.25	0.71
Interincisal angle	.921[c]	0.87	0.95
incisor occlusal plane angle	.641[c]	0.43	0.78
incisor mandibular plane angle	.123[c]	-0.40	0.45
1 to A-pog line	.926[c]	0.88	0.95

Table 2 correlation coefficient (ICC) between Manual & NemoCeph tracing method

Table 3 shows correlation between manual tracing method & tracing by Oneceph software. It was observed that values of eleven parameters showed high correlation between these two tracing methods. The parameters showing high correlation were FMIA, SNA, ANB, N-A angle, U1 to L1, S line to LL Mandibular plane angle, Y -Axis, interincisal Angle 1 to A- pog line (ICC >0.80). The values FMA, IMPA,Incisor occlusal plane angle showed moderate correlation. All other measured parameters that are, SNB, GOGN to SN, upper incisor to N-A (linear mm), lower incisor to N-B (linear mm), lower incisor to N-B (Angle), OCCL to SN, S line to upper lip , Facial angle, Angle of convexity, AB plane angle, , cant of occlusion & Incisor mandibular plane angle, showed poor correlation with ICC< 0.75 .

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Group	ICC	95% Confidence Interval	
		Lower Bound	Upper Bound
FMA	.615[c]	0.38	0.76
IMPA	.516[c]	0.23	0.70
FMIA	.933[c]	0.89	0.96
SNA	.865[c]	0.78	0.92
SNB	.342[c]	-0.05	0.59
ANB	.820[c]	0.71	0.89
GOGNSN	.600[c]	0.36	0.75
N-A (mm)	.448[c]	0.12	0.65
N-A (angle)	.961[c]	0.94	0.98
N-B (mm)	.676[c]	0.48	0.80
N-B (angle)	.212[c]	-0.26	0.51
1 to 1	.973[c]	0.96	0.98
occlusal to SN	.609[c]	0.38	0.76
s line to UL	.698[c]	0.52	0.81
s line to LL	.854[c]	0.77	0.91
Facial angle	-.009[c]	-0.61	0.37
Angle of convexity	.391[c]	0.03	0.62
AB plane angle	.417[c]	0.07	0.64
Mandibular plane angle	.876[c]	0.80	0.92
y -growth axis	.833[c]	0.73	0.90
cantt of occlusion	.712[c]	0.54	0.82
Interincisal angle	.917[c]	0.87	0.95
incisor occlusal plane angle	.619[c]	0.39	0.76
incisor mandibular plane angle	.032[c]	-0.55	0.39
1 to A-pog line	.918[c]	0.87	0.95

Table 3 correlation coefficient (ICC) between Manual & One ceph tracing method.

Discussion

Cephalometric radiography is an important diagnostic tool in clinical orthodontics. In the standardized radiographs, the orientation of various anatomical structures can be studied by means of angular and linear measurements. Serial cephalometric radiographs can be used to investigate growth and development of the facial skeleton that can assist in treatment planning and to assess changes between pre- and post-treatment measurements to evaluate the treatment results.[1]

Measurement of distances and angles between landmark locations were defined by the limitations of measurement devices (ruler and protractor) as well as the limitations of human visual performance in case of manual tracing as reported by Forsyth et al [9,10]. Human errors can occur both in recording of measurements or in the use of measurement devices. Time required for manual analysis is more and depends on how comprehensive the measurements are, and on the operator"s skill of identifying the landmarks[11,12]

To overcome the shortcomings of the conventional tracing technique, computerized cephalometric systems were introduced into clinical orthodontics. This technique is being used extensively for diagnosis, treatment evaluation and simulation of treatment outcomes. The process requires 10% of time of a normal manual registration because it is only necessary to digitize the radiographic points directly on the

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cephalogram and the calculations are done within no time.[13]

There are also several drawbacks present in digital cephalometrics, here it represents the two dimensional representation of a three dimensional structure, so there will be difficulty in identifying the landmarks. There will be superimposition of the bilateral structures, the resolution of the image will be affected as the image is compressed. This computerized cephalometric analysis also requires digital cephalometric radiographic machine as well as its software which is expensive. [14]

This study compared manual & three different computerized cephalometric programs AUTOCEPH, NEMOCEPH AND ONECEPH. Comparisons were made between these computerized technique and hand tracing in terms of accuracy of individual measurements.

A study done by **Mahito et al**[7] found no significant difference in the parameters of Tweeds analysis (FMA**)** that is similar to our study as the present study also reported no statistically significant difference between the mean values obtained from four different tracing methods that were evaluated for **Tweed's** analysis **.**In contrast to present study**, Kabeer et al** [15] showed significant difference between Autoceph and manual tracing method for FMA value of Tweed's analysis.

Three parameters of Steiner's analysis showed statistical significant difference ($p<0.005$) when compared between Autoceph and manual tracing method in present study. These were OCCL to SN, S line to UL, S line to LL (Table 1).

Kabeer et al reported significant difference in SNA value between Autoceph and manual tracing method but in contrast to this, our study showed no significant difference for SNA value (Table 1). They reported no significant difference for SNB, ANB, GOGNSN, similar to their study we also found no significant difference for these parameters. **Chen et al**[16] studied the effects of differences in landmark plotting on the values of cephalometric measurements, and found out differences between all cephalometric measurements between manual and digital tracing but their differences are clinically acceptable.

Present study reported significant difference for facial angle, angle of convexity, mandibular plane angle, Y Axis and cant of occlusion plane, incisor occlusal plane angle and incisor mandibular plane angle (p value 0.01) and A-B plane angle when compared their values obtained from Autoceph and manual tracing method. Similarly **Singh et al**[17] found significant difference for the Angle of convexity among manual & Autoceph tracing method.

Mahito et al [5] reported the reliability and accuracy of linear and angular cephalometric measurements obtained from two computerized cephalometric analysis softwares viz., **AutoCEPH©** (version 1.0) and Dolphin® (version 11.7) as compared to manual tracings and their findings suggested that the cephalometric measurement values obtained from AutoCEPH© showed **good correlation** for parameters such as SNA,SNB,ANB,U1-NA(angular), U1-NA (linear), L1 -NB (angular),L1 -NB (linear) except UI-E line (ICC 0.574 [0.249–0.758]) and LI-E line (ICC −2.579 [−5.367 to −1.031]). Similar to this, our study also showed **good correlation** for these parameters (Table 1) among Autoceph and manual tracing measurements. But our study observed poor correlation for some parameters which were Occl to SN (ICC 0.750), S line to UL (ICC 0.571), S line to LL (ICC 0.713), facial angle (ICC 0.533), Angle of convexity (ICC 0.638), A-B plane angle (ICC 0.404), Y axis (ICC 0.788), Cantt of Occlusion (ICC 0.74), Incisor occlusion plane angle (ICC = -1.592) & Incisor mandibular plane angle (ICC= - 0.50).

Kabeer S et al [15] also compared reliability and accuracy of cephalometric landmark plotting and analyses between **Manual tracing** and **AutoCeph** (1.1.2 version). In their study a total of 14 measurements were recorded (10 skeletal parameters and 4 dental parameters) which comes under Steiner's, Downs and Tweed's analysis. Most of the parameters showed excellent correlation among the groups **except for SNA and FMA.** They concluded, that which of the digital cephalometric tracing software is highly reliable in case of landmark plotting and analysis and can replace classical cephalometric tracing method in the coming years. It also provides several advantages such as saving time, reducing use of paper in the office, easier storage and retrieval. As **AutoCeph** is inexpensive and readily available online. So it is better than manual tracing method.

But in contrast to this, present study showed high correlation for these two parameters between **manual and Autoceph** tracing method. Inspite of this there were some other parameters which showed **good correlation** were IMPA, FMIA, SNB, ANB, upper incisor to N-A (linear mm) , upper incisor to N-A (angle), lower incisor N-B (linear mm), lower incisor to

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N-B (angle), interincisal angle, 1 to A -pog but **poor correlation** was seen for some parameters which were Occl to SN ,S line to UL ,S line to LL ,facial angle, Angle of convexity ,A-B plane angle ,Y axis ,Cantt of Occlusion, Incisor occlusion plane angle & Incisor mandibular plane angle. (Table 1).

When **manual** and **Nemoceph** tracing methods were compared, parameters of Tweed analysis showed no difference between the two methods. Most of parameters of Steiner's analysuis showed no difference between **Nemoceph and manual tracing methods except for** OCCL to SN, Facial angle, Angle of convexity, y-growth axis. Cant of occlusion, Incisor occlusal plane angle, Incisor mandibular plane angle. **Tikku et al**[6] also found significantly higher values for parameters i.e occlusal plane & S line to LL while comparing manual and Nemoceph tracing methods. Another study done by **Aggrawal et al** [18] **also** found significant difference in value of Occl to SN among nemoceph and manual tracing**.**Thus their studies are in favour of present study**.**

Similarly The mean values of A-B Plane angle, mandibular plane angle values (26.4º, 23.2 º), Y Axis and cant of occlusion plane were also significantly different among these 2 tracing methods.Similarly the study conducted by **Tikku et al**[6] also showed statistically significant differences for Facial angle (FA) and and Mandibular plane angle (MP). **kumar et al**[19] **also found significant difference for y axis as measured by manual and nempceph tracing method. So both these studies were** supporting the findings of present study and Statistically significant differences were observed in values of incisor occlusal plane angle and incisor mandibular plane angle (p value 0.01). The mean values of incisor occlusal plane angle were 31.47º and 21.22º as measured from manual tracing method and Nemoceph respectively. Values of incisor mandibular plane angle were 21.25º and 100.87º.

Kabeer S et al[15] evaluated reliability and accuracy of cephalometric landmark plotting and analyses between **Manual tracing** and Computerized cephalometric tracing software, namely, **NemoCeph NX 2006**. Most of the parameters showed excellent correlation among the groups except for **FMA that showed poor correlation results (p 0.004)**. But in our study the **FMA showed high level of correlation** while comparing between manual and Nemoceph (Table 2). Similar to present study, **Mitra et al**[65] also reported **high level of correlation** of **FMA** & other parameters between manual and Nemoceph tracing method. Nemoceph also provides several advantages such as saving time, reducing use of paper in the office, easier storage and retrieval. So **NemoCeph** can be used instead of manual tracing but is rather expensive.

Mitra et al [20] compared the accuracy of cephalometric tracing by the manual, semi-digital, and fully digital **(NEMOCEPH)** cephalometric tracing methods in orthodontics

They also found **good correlation** among all variables except two linear variables i.e., effective length maxilla ("EL-Max") ($P < 0.000$) and effective length mandible ("EL-Mand'')($P < 0.02$) which were traced more accurately in semi-digital method. They observed that semi-digital method was relatively better in linear measurement than the other two methods. Similarly in our study we found **good correlation for the parameters** between manual and Nemoceph tracing measurements except for some parameters which were Occl to SN, S line to UL , S line to LL , facial angle, Angle of convexity ,A-B plane angle, Y axis ,Cantt of Occlusion ,Incisor occlusion plane angle & Incisor mandibular plane angle which showed poor **correlation**.

Tikku T et al [6] compared the cephalometric measurements obtained from computerized tracing of direct digital radiographs using **Nemoceph** and hand tracing of their digital radiographic printouts. Total 26 measurements were obtained. The measurements of angular parameters like SNA, SNB, ANB U1 TO NA, L1- NB, Facial angl, Interincisal angle were showed good correlation. They observed that Similar results were found in this present study for these parameters and reported as **good correlation**. But **only occlusal plane angle** showed statistically significant difference between the two techniques that was not clinically acceptable. In our study also showed significant difference for the value of occlusal plane angle as measured from Nemoceph & Manual tracing.

Segura et al [21] used **Nemoceph Nx**, with the tracing done manually.. Once the captured image was transferred directly to the same computer program (Nemoceph Nx) it was also printed for the tracing of 12 measures in which some parameters are SNA, SNB and ANB and they found no statistically significant differences ($p > 0.05$) between the two groups, the present study also showed no significant difference

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results for similar parameters and showed **good Correlation**. They concluded that Nemoceph program is excellently reliable for cephalometric tracing done for diagnosis using digital radiography.

When the measurements of manual tracing & Oneceph were compared, parameters of Tweeds analysis showed no significant difference between **manual** and **Oneceph. Khader et al.**[8] They assessd the reliability of the android smartphone based digital tracing software Oneceph with the manual tracing using Tweed analysis**.** Values obtained by android based OneCeph and manual methods were compared. There was no statistically significant difference between the values of parameters of Tweed analysis obtained from android based tracing and manual cephalometric tracing. This android based OneCeph app has programs for the most commonly used analyses in cephalometrics such as Downs, Holdway, Jarabak, McNamara, Ricketts, Steiners, Schwarz, Tweed, Wits Appraisal, Beta angle, and Yen angle.

But when the parameters of Steiners and Downs were compared, some parameters showed **significant differences between Oneceph & Manual tracing method, these parameters are** Occl to SN, S line to UL & S line to LL, facial angle, angle of convexity, A-B plane angle & mandibular plane angle, Y Axis and cant of occlusion plane. Statistically significant differences were also observed in values of incisor occlusal plane angle and incisor mandibular plane angle (p value 0.01) in manual and Oneceph tracing methods). **Maruf et al** [22] also found significant difference for the values of **Angle of convexity,** when compared between Oneceph & Manual tracings. But they also found significant difference for ANB angle & U1 to N-A.(angular) which contradict the present study as no difference was seen for ANB & U1 to NA values in our study.

It was observed that values of 11 parameters **showed high correlation** between these two tracing methods. The parameters showing high correlation were FMIA, SNA, ANB, N-A angle 1 to 1, S line to LL Mandibular plane angle, Y -Axis, interincisal Angle 1 to A- pog line (ICC >0.80) (Table 3). similar studies has been done by **Maruf H et al**[22] evaluated the accuracy and reliability of Mobile Application-Based Software for chair side cephalometric analysis. Pretreatment lateral cephalograms of 20 patients (10 males and 10 females) were selected randomly and were traced manually and also using Application-based software (**One Ceph**). 20 angular and three linear parameters (Tweeds, Steiners & Downs) were measured both manually and with the software .They found no significant difference between two methods for most of the measurements except for (Angle of convexity (N-A; A-Pog); ANB angle; Upper Incisor to NA (Angular) which showed statistically significant difference. Similarly in present study most of the parameters of tweeds, steiners & Downs analysis showed similar results were found **good correlation except** FMA, IMPA, SNB, GOGN to SN, upper incisor to N-A (linear mm), lower incisor to N-B (linear mm), lower incisor to N-B (Angle), OCCL to SN, S line to upper lip , Facial angle, Angle of convexity, AB plane angle, , cant of occlusion, Incisor occlusal plane angle & Incisor mandibular plane angle **showed poor correlation.**

CONCLUSION

The aim of the study was to evaluate and compare the accuracy and reliability of three different computerized cephalometric analytic program namely, Autoceph, Nemoceph & Oneceph. The parameters used in this study consisted of linear and angular measurements of Steiners, Downs & Tweeds analysis.

Data obtained were entered in Microsoft Excel 2020, subjected to statistical analysis by a blinded statistician, and analyzed using the IBM Corp. Released 2012, IBM SPSS® Statistics for Windows, Version 21.0. Armonk, NY: IBM Corp.

The descriptive statistics were presented as mean ± standard deviation for continuous variables and as frequencies with percentages for categorical variables. The normality of the data was assessed prior to analysis using the Shapiro-Wilk's test/Kolmogorov-Smirnov test. Data were found to be normally distributed. Thus, parametric test was chosen. Descriptive statistics were used to calculate frequencies, percentages, and mean values. MANOVA followed by Tukey's post hoc test was carried out to determine the difference between the groups. All statistical tests were performed at a significance level of 5% ($p \leq .05$).

The study concluded

1.The mean values of FMA, IMPA, FMIA, SNA, SNB, ANB, upper incisor to N-A (linear mm), upper incisor to N-A (angle), lower incisor N-B (linear mm), lower incisor to N-B (angle), interincisal angle, 1 to A -pog showed high correlation between two different tracing methods with ICC value > 0.80.

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2. The values FMA, IMPA & Incisor occlusal plane angle showed moderate correlation while comparing the manual and Oneceph tracing methods.

3. AUTOCEPH gave the most accurate and reliable result, which was followed by NemoCeph and Oneceph respectively among three digital softwares.

4. It was concluded that Autoceph, Nemoceph and Oneceph provided cephalometric measurements as accurate as the manual method in most of the parameters.

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