

# A comparison of cephalometric measurements obtained from two computerized cephalometric softwares with manual tracings

Ravi Kumar Mahto<sup>1</sup>, Om Prakash Kharbanda<sup>2</sup>, Ritu Duggal<sup>3</sup>, Harish Kumar Sardana<sup>4</sup>

## Abstract

**Objectives:** The objective of this study is to evaluate the reliability and accuracy of linear and angular cephalometric measurements obtained from two computerized cephalometric analysis softwares viz., AutoCEPH<sup>®</sup> (version 1.0) and Dolphin<sup>®</sup> (version 11.7) as compared to manual tracings. **Materials and Methods:** Fifty pretreatment lateral cephalograms were selected from the archives of a postgraduate orthodontic clinic. The digital images of each cephalogram were imported directly into two softwares Dolphin<sup>®</sup> and AutoCEPH<sup>®</sup> for onscreen digitization. While for manual tracings digital images were printed using a compatible X-ray printer. After images were standardized and calibrated 34 commonly used anatomical landmarks were plotted on each cephalogram. These landmarks were then utilized to evaluate 35 cephalometric parameters. Intraclass correlation coefficient (ICC) was used to determine both intrarater reliability for repeated measurements and agreement between linear and angular measurements obtained from the three methods. **Results:** High ICC values (>0.9) were obtained for all parameters while comparing three methods, i.e., manual tracings versus AutoCEPH<sup>®</sup>; manual tracings versus Dolphin<sup>®</sup> and AutoCEPH<sup>®</sup> versus Dolphin<sup>®</sup>. **Conclusion:** A high level of agreement (ICC >0.9) for cephalometric measurements was obtained from both the computerized softwares Dolphin<sup>®</sup> and AutoCEPH<sup>®</sup> in comparison with manual tracings.

**Key words:** AutoCEPH<sup>®</sup>, computerized cephalometric analysis softwares, Dolphin<sup>®</sup>, manual cephalometric tracings

## INTRODUCTION

Cephalometric radiography is an indispensable tool in orthodontics for studying growth and development of dentofacial skeleton, diagnosis, treatment planning, and evaluating treatment results.<sup>[1-4]</sup> Conventionally, manual

tracing is considered “Gold standard” in cephalometric analysis. However, it is cumbersome, time consuming and can be associated with various errors. These errors can occur due to improper tracing, inaccurate landmark identification, measurement and calculation errors in addition to errors occurring due to human fatigue.<sup>[3-8]</sup>

With recent technological advances and increasing use of computers in the field of orthodontics cephalometric analysis using computerized cephalometric analysis softwares have gained popularity. These softwares have eliminated various errors associated with manual tracings and are less time consuming. Another big advantage of using computerized cephalometry is that multiple analyses can be done in a very short period.<sup>[9-14]</sup>

Over the years, various softwares have been developed which claim to be as reliable and accurate if not more than manual tracings. Most of the studies which evaluated the reliability

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<sup>1</sup>Former Junior Resident, <sup>2</sup>Prof. and Head, <sup>3</sup>Professor, <sup>4</sup>Chief Scientist and Professor

<sup>1,2,3</sup>Division of Orthodontics and Dentofacial Deformities, Centre for Dental Education and Research, All India Institute of Medical Sciences, New Delhi, <sup>4</sup>Department of Computational Instrumentation, Academy of Scientific and Innovative Research, CSIR-Central Scientific Instruments Organization, Chandigarh, India

**Address for correspondence:** Prof. Om Prakash Kharbanda, Division of Orthodontics and Dentofacial Deformities, Centre for Dental Education and Research, All India Institute of Medical Sciences, New Delhi - 110 029, India.  
E-mail: dr.opk15@gmail.com

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and accuracy of different cephalometric measurements by cephalometric software programs have concluded that the differences between the measurements obtained from manual

tracing and that from computerized cephalometric softwares were statistically significant, but these differences were found to be clinically insignificant and acceptable [Table 1].

**Table 1: Studies comparing different computerized cephalometric analysis softwares with manual tracings**

Author(s) and year	N	Software(s)	Parameters	Results
Nimkarn and Miles (1995) <sup>[15]</sup>	40	Quick Ceph	40	High agreement
Ongkosuwito <i>et al.</i> (2002) <sup>[16]</sup>	20	AOCeph™	24 (14 A and 10 L)	High agreement
Gregston <i>et al.</i> (2004) <sup>[17]</sup>	10	Dolphin® and Vistadent™	15 (10 A and 5 L)	High agreement except SN-GoMe, FH-GoMe, SNA, SNB, NBa-PTGn, U1-NA (mm), L1-NB (°) and L1-NB (mm)
Power <i>et al.</i> (2005) <sup>[18]</sup>	60	Dolphin®	8 (7 A and 1R)	Statistically significant difference for most of the parameters
Gossett <i>et al.</i> (2005) <sup>[19]</sup>	31	Dolphin®	16 (8 A and 8 L)	High agreement except interincisal angle, U1-NA, L1-NB
Santoro <i>et al.</i> (2006) <sup>[20]</sup>	50	Dolphin®	13 (9 A, 2 L and 2 R)	High agreement except S-Go/N-Me, U1-L1 (°)
Bruntz <i>et al.</i> (2006) <sup>[21]</sup>	30	Dolphin®	23 (20 A and 3 L)	High agreement except facial plane, Y axis, occlusal plane, FMA, FH/NA, U1-FH
Sayinsu <i>et al.</i> (2007) <sup>[10]</sup>	30	Dolphin®	35 (18 A, 13 L and 4 R)	High agreement
Roden <i>et al.</i> (2008) <sup>[22]</sup>	30	Quick Ceph	-	High agreement
Dvortsin <i>et al.</i> (2008) <sup>[23]</sup>	20	Viewbox®	17 (11 L and 6 A)	Statistically significant difference for most of the parameters but difference was clinically insignificant
Celik <i>et al.</i> (2009) <sup>[9]</sup>	125	JOE and Vistadent™	28	High agreement except Nperp-Pog, Go-Me, APFH, ANS-Me (mm), U1-NA (mm), Nasolabial angle
Polat-Ozsoy <i>et al.</i> (2009) <sup>[24]</sup>	30	Vistadent™	26	High agreement except SNB, Wits, Cd-A, Cd-Gn, FMA, SN-PP, U1-NA (mm), U1-FH, L1-NB (mm) and Li-E plane
Naoumova and Lindman (2009) <sup>[25]</sup>	30	FACAD®	-	High agreement
Uysal <i>et al.</i> (2009) <sup>[26]</sup>	100	Dolphin®	17 (11 A and 6 L)	High agreement except Na perpendicular A, Na perpendicular Pog, and U1-NA distance
Tsorovas and Karsten (2010) <sup>[11]</sup>	30	Viewbox®, OnyxCeph®, OrisCeph®, Facad® and Winceph®	23 (14 A and 9 L)	High agreement except AB on FOP and Li-NB (mm)
Krishnaraj R <i>et al.</i> (2010) <sup>[27]</sup>	10	Dolphin®	18 (11 A and 7 L)	High agreement except U1-NA (°), U1-NA (mm), L1-NB (mm), L1-APg (°), N-A, Co-A
Paixão MB <i>et al.</i> (2010) <sup>[28]</sup>	50	Dolphin®	14 (8 A and 6 L)	High agreement
Guedes PA <i>et al.</i> (2010) <sup>[29]</sup>	50	Cef-X 2001	7 (2 L and 5 A)	High agreement except 1-NA, 1-NB
Erkan <i>et al.</i> (2012) <sup>[13]</sup>	30	Dolphin®, Vistadent™, Nemoceph NX and Quick Ceph	15 (5 L and 10 A)	High agreement
Albarakati <i>et al.</i> (2012) <sup>[14]</sup>	30	Dolphin®	16 (10 A and 6 L)	Statistically significant difference for most of the parameters but difference was clinically insignificant
Tikku T <i>et al.</i> (2014) <sup>[30]</sup>	40	Nemoceph NX	26 (13 L and 13 A)	High agreement except AFH, PFH, ULL, LLL, ACBL, PCBL, MxL, MdL, L1-NB line, LLP and occlusal plane angle
Prabhakar R <i>et al.</i> (2014) <sup>[31]</sup>	30	Dolphin® and Nemoceph NX	21 (12 A and 9 L)	High agreement except Co-A and Co-Gn
Kumar D <i>et al.</i> (2014) <sup>[32]</sup>	60	Nemoceph NX	Burrstone analysis; 36 (20 hard tissue and 16 soft tissue)	High agreement except AO-BO, Ar-Ptm, Ar-GoN, B-Pg, PNS-N, Ptm-N, Inter labial gap, lower face throat angle, nasolabial angle, lip embrasure to occlusal plane, lip protrusion, upper lip length
Segura <i>et al.</i> (2014) <sup>[33]</sup>	20	Nemoceph NX	12 (6 L and 6 A)	High agreement
Goracci and Ferrari (2014) <sup>[34]</sup>	20	Smile Ceph and Nemoceph NX	11 (6 A and 5 L)	High agreement except for Wits, A to N-perp and Pog to N-perp

N: Number of samples, L: Linear, A: Angular, R: Ratio. Quick Ceph (Quick Ceph Systems, San Diego, California, USA), AOCeph™ (American Orthodontics, Sheboygan, USA), Dolphin® (Dolphin Imaging, Chatsworth, California, USA), Vistadent™ (GAC International, Bohemia, New York, USA), Viewbox® (dHAL Software, Kifissia, Greece), JOE (Rocky Mountain Orthodontics, Denver, CO, USA), Facad® (Ilexis AB, Linköping, Sweden), OnyxCeph® (Image Instruments GmbH, Frankfurt, Germany), OrisCeph® (Elite ComputerItalia, Vimodrone, Italy), Winceph® (Rise CorpoRn, Sendai, Japan), Cef-X 2001 software (CDT, Cuiabá, Brazil), NemocephNX (Nemotec, Madrid, Spain), Smile Ceph (GlanceSoftware, Imola, Italy), SN-GoMe (Sella Nasion -Gonion Menton angle), FH-GoMe (Frankfort Horizontal - Gonion Menton angle), SNA (Sella-Nasion-point A angle), SNB (Sella-Nasion-point B angle), NBa-PTGn (Nasion Basion-Pt Point Gnathion angle), UI-NA (Upper incisor to NA), LI-NB (Lower incisor to NB), S-Go/N-Me (Sella Gonion/Nasion Menton ratio), U1-L1 (upper incisor-lower incisor angle), FMA (Frankfort mandibular plane angle), FH/NA (Frankfort horizontal plane to Nasion point A plane), U1-FH (Upper incisor to Frankfort horizontal plane), Nperp-Pog (Pogonion to nasion perpendicular), Go-Me (Gonion -Menton), APFH (ratio between post. and ant. Facial height), ANS-Me (Anterior nasal spine to Menton), Cd-A/Co-A (Condylion to point A), Cd-Gn/Co-Gn (Condylion toGnathion), SN-PP (Sella Nasion to Palatal plane angle), LI-NB ( Lower incisor to NB), Li E-plane (lower incisor to E-plane), L1APg (Lower incisor to A-Pogonion), 1-NA (angle between incisor and NA line), 1-NB (angle between incisor and NB line), AFH (Anterior facial height), PFH (Posterior facial height), ULL (Upper lip length), LLL (Lower lip length), ACBL (Anterior cranial base length), PCBL (Posterior cranial base length), MxL (Maxillary length), MdL (Mandibular length), LLP (Lower lip protrusion), AOBO (Distance between point A and point B projected on occlusal plane) Ar-Ptm (Articulare to Ptm point ), Ar-GoN (Articulare Gonion Nasion), B-Pg (point B to Pogonion), PNS-N (Posterior nasal spine-Nasion), Ptm-N (Ptm point-Nasion)

Recently, an indigenous two-dimensional (2D) computerized cephalometric analysis software named “AutoCEPH”<sup>®</sup> has been designed and developed in the context of Indian orthodontic clinical practices by CSIR-Central Scientific Instruments Organization (CSIO), Chandigarh in collaboration with Department of Orthodontics and Dentofacial Deformities, CDER, All India Institute of Medical Sciences, New Delhi after extensive research and field trial. An indigenous version must be cost-effective, reliable, user-friendly, and it must be equipped with population-based normative data for chosen ethnic group. Keeping in mind about the needs, we have designed “AutoCEPH”.<sup>®</sup> This software output allows comparison with means of the original studies and with that of respective means on Indian ethnic groups.

However, no study has been done so far to evaluate the reliability and accuracy of cephalometric measurements obtained from it. Hence, this study was done with the aim to evaluate the reliability and accuracy of linear and angular cephalometric measurements obtained from two computerized cephalometric analysis softwares viz., AutoCEPH<sup>®</sup> (version 1.0) and Dolphin<sup>®</sup> (version 11.7) (Dolphin Imaging, Chatsworth, California, USA) as compared to manual tracings.

## MATERIALS AND METHODS

A total of fifty pretreatment lateral cephalogram of patients were obtained from the cephalometric database of a postgraduate orthodontic clinic. All the cephalograms acquired were taken from the same digital cephalometer (STRATO 2000 Digital Version, Villa Sistemi Medicali, Italy; magnification  $\times 1.1$ ) and had the calibration ruler for determination of magnification. For manual tracing, hard copies of images were obtained on 8”X10” radiographic film using compatible X-ray printer (Drystar 5302, Agfa HealthCare NV, Mortsel, Belgium).

Calibration of the actual size of each image in millimeters was done based on measurement of the known distance (e.g., 10 mm) between the two fixed points of the ruler present on the analog as well as digital cephalogram displayed onscreen.

### Manual tracings

Manual tracing was done using standard protocols. Using a millimeter ruler and protractor all linear and angular measurements were taken with the help of to the nearest 0.5 mm and 0.5° respectively [Figure 1]. After adding magnification factor to the obtained linear measurements, final values were recorded. All measurements were entered into an Excel spreadsheet.

### Digital tracing

For computerized cephalometric measurements, digital images of same cephalograms were directly imported to the computerized cephalometric softwares viz., AutoCEPH<sup>®</sup> version 1.0 [Figure 2] and Dolphin<sup>®</sup> imaging software version 11.7 [Figure 3]. These direct digital images were standardized and calibrated in millimeters using ruler present

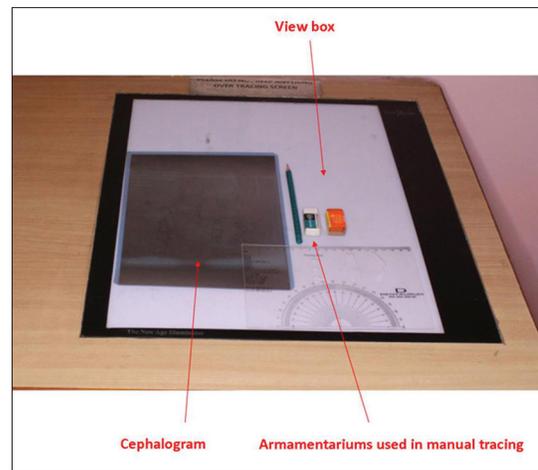


Figure 1: Manual tracing

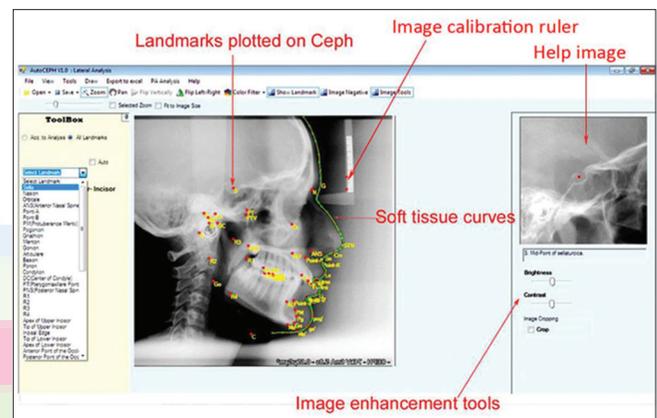


Figure 2: On-screen digitization using AutoCEPH<sup>®</sup> (version 1.0)

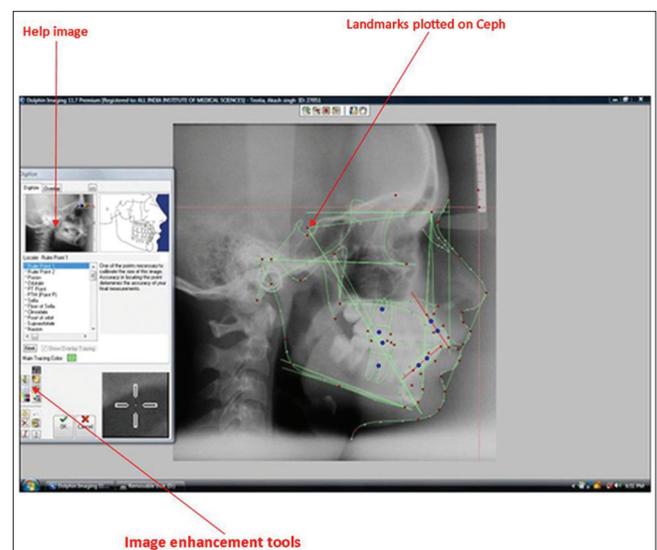


Figure 3: On-screen digitization using Dolphin<sup>®</sup> (version 11.7)

on cephalogram. Using on-screen digitization landmarks were plotted and the image enhancement features of the software such as zooming, brightness and contrast adjustment, color

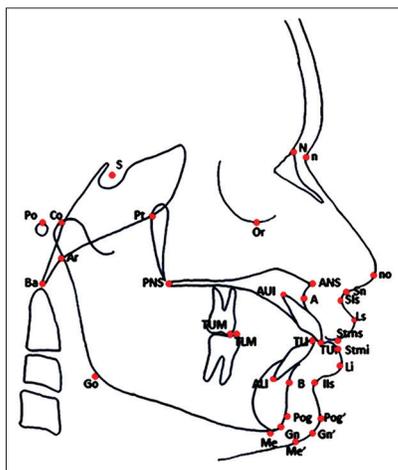
filters were used as needed to identify individual cephalometric landmarks as precisely as possible. The selected landmarks were traced with bilateral structures averaged to make a single structure or landmark.

All the tracings (manual as well as digital) were done by a same investigator. Only five cephalograms were analyzed daily to avoid the human fatigue errors. To evaluate intraobserver reliability and reproducibility for manual and digital methods, ten radiographs were randomly selected. The same radiographs were then retraced manually and digitally with each cephalometric tracing program, with a 10 days gap between evaluations. To evaluate the intra-observer reliability and reproducibility for all the three methods of cephalometric measurement, intraclass correlation coefficient (ICC) was calculated. We found that all ICC values were more than 0.9 for all the three methods. It shows a very high intrarater agreement for all the three methods.

A total of 34 commonly used anatomical landmarks were plotted on each cephalogram [Figure 4]. These landmarks were then utilized to evaluate 35 cephalometric parameters which include 19 linear, 15 angular, and 1 ratio [Figures 5-8]. Of these parameters, there were 22 skeletal, 9 dental, and 4 soft tissue related variables [Table 2].

### Statistical analysis

A total of 5250 readings were recorded which included 105 readings from each patient (35 readings per method). The analysis was carried out using Statistical Package for Social Sciences version 16.0 (SPSS Inc., Chicago, IL, USA). Average values of cephalometric measurements were calculated and presented as mean ± standard deviation. Differences in the



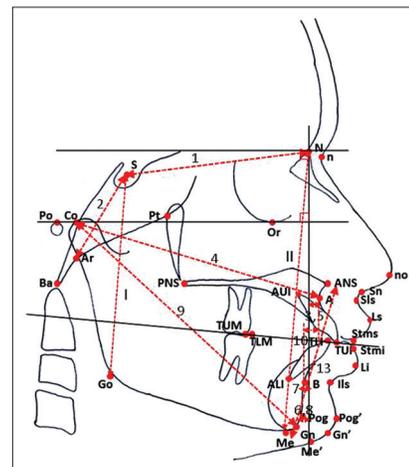
**Figure 4:** Landmarks used in the study (S: Sella, N: Nasion, Po: Porion, Or: orbitale, Pt: Pt Point, Co: Condylion, Ar: Articulare, Ba: Basion, Go: Gonion, PNS: Posterior Nasal Spine, ANS: Anterior Nasal Spine, A: Pt A, B: Pt B, Pog: Pogonion, Me: Menton, Gn: Gnathion, TUI: Tip of U1, ALI: Apex of L1, TUM: Cusp tip of U6, TLM: Cusp tip of L6, n: Soft tissue nasion, no: Tip of nose, Sn: Subnasale, Sls: Superior labial sulcus, Ls: Labrale superius, Stms: Stomion superius, Stmi: Stomion inferius, Li: Labrale inferius, IIs: Inferior labial sulcus, Pog': Soft tissue pogonion, Gn': Soft tissue gnathion, Me': Soft tissue menton)

mean were analyzed using analysis of variances. The level of significance was set at  $P < 0.05$ . ICC was used to determine

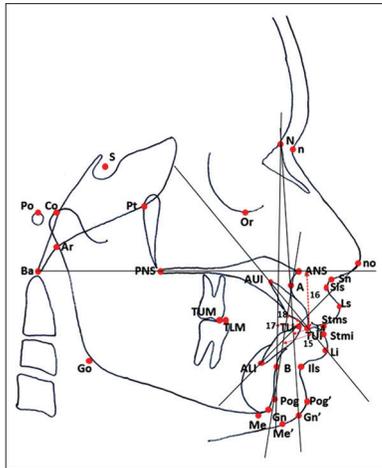
**Table 2: Cephalometric parameters used in the study**

Skeletal parameters	Dental parameters
ACBL (S-N)	UINA (°)
PCBL (S-Ar)	UINA (mm)
SA (N-S-Ar)	U1APog (mm)
SNA	U1SN (°)
Pt. A -N per	U1NF (mm)
Co -Pt. A	LINB (°)
N-A (II HP)	LINB (mm)
SNB	LIMP (°)
Pog-N Perp	L1A-Pog (mm)
N-B (II HP)	Soft tissue
N-Pg (II HP)	NA
Co-Gn	UI E line
ANB	L1 E line
WITS	HA
MMD	
FMA	
Ar-Go-Me	
S-N X Go-Gn	
YAA (S-Gn X Po-Or)	
FAA (Ba-N X	
Ptm-Gn)	
JR (S-Go/N-Me)	
LAFH (ANS – Me)	

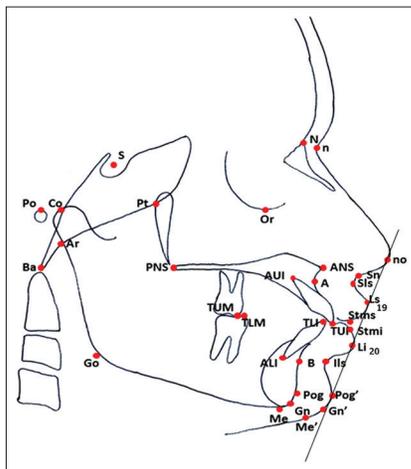
ACBL: Anterior cranial base length, PCBL: Posterior cranial base length, SA: Saddle Angle, SNA: Sella-Nasion- point A, Pt. A N per: Point A to Nasion perpendicular, Co Pt. A: Condylion to point A, N-A (II HP): Nasion to point A (parallel to horizontal plane), SNB: Sella-Nasion-point B, Pog N perp: Pogonion to nasion perpendicular, N-B (II HP): Nasion to point B (parallel to horizontal plane), N Pog II HP: Nasion to pogonion parallel horizontal plane, CoGn: Condylion to Gnathion, MMD: Maxillary/mandibular difference, FMA: Frankfort mandibular plane angle, GA: Gonial angle, YAA: Y-axis angle, FAA: Facial-axis angle, JR: Jarabaks ratio, LAFH: Lower anterior facial height, UINA: Upper incisor to NA, UIAPog: Upper incisor to A-Pog, UI SN: Upper incisor to S-N, U1 NF: Upper incisor to nasal floor, LINB: Lower incisor to NB, LIMP: Lower incisor to Mandibular Plane, L1APog: Lower incisor to A-Pogonion, NA: Nasolabial angle, UI E line: Upper lip to E line, LI E line: Lower lip to E line, HA: Holdaway angle



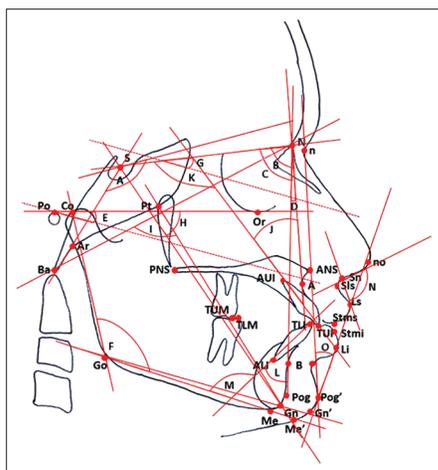
**Figure 5:** Skeletal linear parameters used in the study (1: ACBL, 2: PCBL, 3: Pt. A-N per, 4: Co-Pt. A, 5: N-A [II HP], 6: Pog-N Perp, 7: N-B [II HP], 8: N-Pg [II HP], 9: Co-Gn, 10: WITS, 11: MMD[9-4], 12: JR [S-Go(N)/N-Me(II)], 13: LAFH)



**Figure 6:** Dental linear parameters used in the study (14: U1NA [mm], 15: U1APog [mm], 16: U1NF [mm], 17: L1NB [mm], 18: L1A-Pog [mm])



**Figure 7:** Soft-tissue linear parameters used in the study (19: U1 E line, 20: L1 E line)



**Figure 8:** Angular parameters used in the study (A: SA [N-S-Ar], B: SNA, C: SNB, D: ANB, E: FMA, F: GA [Ar-Go-Me], G: S-N X Go-Gn, H: YAA [S-Gn X Po-Or], I: FAA [Ba-N X Ptm-Gn], J: U1NA [°], K: U1SN [°], L: L1NB [°], M: L1MP [°], N: NA, O: HA)

intrarater reliability for each tracing technique as well as to evaluate reproducibility for each cephalometric parameter. ICC value of 0.75 is indicative of low agreement whereas ICC value of >0.75 is indicative of a good agreement.

## RESULTS

The average values of cephalometric measurements used in the 3 methods are shown in Table 3. There were no significant differences for most of the parameters by three methods except UI-E line and LI-E line ( $P < 0.05$ ).

The ICC values of cephalometric measurements obtained with the three tracing techniques are reported in Tables 4-6. Of 35 parameters analyzed ICC values for 33 parameters exceeded 0.9 indicative of very high level of agreement.

### Manual tracings versus AutoCEPH®

All the 33 parameters showed high level of correlation between the measurements (ICC >0.943) except UI-E line (ICC 0.574 [0.249-0.758]) and LI-E line (ICC -2.579 [-5.367 to -1.031]).

Among the skeletal parameters, ICC value was between 0.943 and 0.995, for dental parameters, it was between 0.973 and 0.994 while for soft tissue it was between -2.579 and 0.990. The highest value was for MMD (ICC 0.995).

### Manual tracings versus Dolphin®

All the parameters showed high level of agreement between the measurements (ICC >0.915). Among the skeletal parameters ICC value was between 0.916 and 0.995, for dental parameters, it was between 0.939 and 0.993 while for soft tissue it was between 0.915 and 0.990. The highest value was for ANB (ICC 0.995).

### AutoCEPH® versus Dolphin®

All the 33 parameters showed high level of correlation between the measurements (ICC >0.906) except UI-E line (ICC 0.593 [0.283-0.769]) and LI-E line (ICC -2.454 [-5.0286 to -0.960]).

Among the skeletal parameters ICC ranged from 0.906 to 0.998, for dental parameters it was between 0.935 and 0.997 while for soft tissue it ranged between -2.454 and 0.994. The highest value was for ANB (ICC 0.998).

## DISCUSSION

Cephalometric analysis has been considered as an important aid both in day to day clinical practice as well as research necessitating the accuracy in data obtained from cephalometric analysis. With the technological advancement, a number of commercially available computerized cephalometric analysis softwares have been developed which claim to be accurate and user-friendly.

AutoCEPH® is an indigenous 2D computerized cephalometric analysis software designed and developed by keeping in mind about the need of India and Indian subcontinent. However,

**Table 3: Average values of cephalometric measurements used in the 3 methods (hand tracing, AutoCEPH® and Dolphin®) (n=50)**

Parameters	Average cephalometric values			P
	Manual	AutoCEPH®	Dolphin®	
ACBL (mm)	65.65±3.55	64.87±3.89	65.58±3.70	0.50
PCBL (mm)	31.75±3.10	31.92±3.43	32.16±3.35	0.82
SA (°)	123.90±5.11	124.15±5.32	124.42±5.32	0.88
SNA (°)	81.48±3.72	81.31±4.00	81.20±3.76	0.93
Pt. A N per (mm)	-0.37±3.19	-0.46±3.29	-0.35±3.25	0.98
Co Pt. A (mm)	81.98±5.88	81.32±6.13	82.21±6.23	0.75
N-A (II HP) (mm)	-1.62±3.37	-1.57±3.63	-1.7±3.56	0.97
SNB (°)	78.97±5.02	78.70±5.05	78.52±4.96	0.90
Pog N perp (mm)	-3.99±7.12	-3.96±7.09	-3.80±6.91	0.98
NB II HP (mm)	-6.61±7.73	-6.48±7.48	-6.84±7.56	0.97
N Pog II HP (mm)	-6.11±8.29	-5.91±8.11	-6.30±8.15	0.97
CoGn (mm)	104.59±7.31	103.79±7.72	104.79±7.45	0.77
ANB (°)	2.51±4.14	2.61±4.08	2.66±4.15	0.98
Wits (mm)	-0.23±5.42	-0.28±5.44	-0.06±5.71	0.94
MMD (mm)	22.57±5.67	22.46±5.83	22.55±5.89	0.99
FMA (°)	24.90±6.27	25.17±6.28	27.75±6.28	0.94
GA (°)	126.90±6.94	127.67±6.76	125.54±8.11	0.33
SnGoGN (°)	29.97±6.46	30.23±6.39	29.94±6.48	0.97
YA (°)	57.92±4.09	58.10±4.08	58.55±4.05	0.72
FAA (°)	1.33±4.26	1.05±4.20	0.288±4.24	0.44
JR	64.89±5.57	64.76±5.64	64.51±5.44	0.94
LAFH (mm)	58.83±5.69	58.66±5.78	58.98±5.36	0.96
U1NA (°)	28.59±7.28	29.02±7.10	28.63±7.00	0.94
U1NA (mm)	5.00±2.71	4.93±2.69	4.95±2.69	0.99
U1APog (mm)	6.34±3.76	6.27±3.51	6.37±3.57	0.99
U1 SN (°)	109.82±8.34	110.28±8.18	109.81±7.93	0.94
U1 NF (mm)	24.27±2.85	24.67±2.77	24.55±2.61	0.75
L1NB (°)	28.35±8.12	28.53±7.92	28.36±7.95	0.99
L1NB (mm)	5.36±3.39	5.58±3.17	5.62±3.20	0.91
L1MP (°)	96.41±9.56	96.46±9.33	96.62±9.26	0.99
L1APog (mm)	3.49±3.43	3.52±3.45	3.50±3.51	0.99
NA (°)	101.01±9.60	101.69±10.04	101.22±8.46	0.93
UI E line (mm)	-1.21±3.09	-2.56±1.98	-0.29±2.95	0.02*
LI E line (mm)	1.11±3.56	-2.58±2.66	1.44±3.42	0.00**
HA (°)	19.60±6.42	19.58±6.39	19.67±6.38	0.99

\*P<0.05, \*\*P<0.01. ACBL: Anterior cranial base length, PCBL: Posterior cranial base length, SA: Saddle Angle, SNA: Sella-Nasion- point A, Pt. A N per: Point A to Nasion perpendicular, Co Pt. A: Condylion to point A, N-A (II HP): Nasion to point A (parallel to horizontal plane), SNB: Sella-Nasion- point B, Pog N perp: Pogonion to nasion perpendicular, N-B (II HP): Nasion to point B (parallel to horizontal plane), N Pog II HP: Nasion to pogonion parallel horizontal plane, CoGn: Condylion to Gnathion, MMD: Maxillary/mandibular difference, FMA: Frankfort mandibular plane angle, GA: Gonial angle, YAA: Y-axis angle, FAA: Facial-axis angle, JR: Jarabaks ratio, LAFH: Lower anterior facial height, U1NA: Upper incisor to NA, UIAPog: Upper incisor to A-Pog, UI SN: Upper incisor to S-N, UI NF: Upper incisor to nasal floor, LINB: Lower incisor to NB, L1MP: Lower incisor to Mandibular Plane, L1APog: Lower incisor to A-Pogonion, NA: Nasolabial angle, UI E line: Upper lip to E line, LI E line: Lower lip to E line, HA: Holdaway angle

no study has been done so far to evaluate the reliability and accuracy of cephalometric measurements obtained from AutoCEPH®.

Hence, this study was conducted with an aim of comparing the digital and conventional tracing methods. Furthermore,

**Table 4: Intraclass correlation coefficient and 95% confidence interval of cephalometric measurements between hand tracing and AutoCEPH®- skeletal, dental and soft tissue parameters**

Parameters	Manual versus Autoceph®	
	ICC	95% CI
ACBL	0.943	0.899-0.967
PCBL	0.976	0.958-0.986
SA	0.961	0.931-0.978
SNA	0.986	0.975-0.992
Point A N perpendicular	0.982	0.967-0.990
Co Pt. A	0.966	0.940-0.981
NA II HP	0.978	0.962-0.988
SNB	0.993	0.988-0.996
Pog N perpendicular	0.991	0.983-0.995
NB II HP	0.991	0.984-0.995
N Pog II HP	0.990	0.982-0.994
CoGn	0.975	0.956-0.986
ANB	0.994	0.990-0.997
Wits	0.994	0.989-0.996
MMD	0.995	0.991-0.997
FMA	0.993	0.987-0.996
GA	0.979	0.964-0.988
SnGoGN	0.992	0.985-0.995
YA	0.985	0.974-0.992
FAA	0.988	0.978-0.993
JR	0.987	0.977-0.993
LAFH	0.983	0.970-0.990
U1NA (°)	0.975	0.957-0.986
U1NA (mm)	0.981	0.966-0.989
U1APog (mm)	0.994	0.990-0.997
U1 SN (°)	0.985	0.973-0.991
U1 NF (mm)	0.973	0.953-0.985
L1NB (°)	0.986	0.976-0.992
L1NB (mm)	0.992	0.986-0.995
L1MP (°)	0.990	0.983-0.994
L1APog	0.993	0.987-0.996
NA	0.950	0.912-0.972
UI E line	0.574	0.249-0.758
LI E line	-2.579	-5.367--1.031
HA	0.990	0.982-0.994

ACBL: Anterior cranial base length, PCBL: Posterior cranial base length, SA: Saddle Angle, SNA: Sella-Nasion- point A, Pt. A N per: Point A to Nasion perpendicular, Co Pt. A: Condylion to point A, N-A (II HP): Nasion to point A (parallel to horizontal plane), SNB: Sella-Nasion-point B, Pog N perp: Pogonion to nasion perpendicular, N-B (II HP): Nasion to point B (parallel to horizontal plane), N Pog II HP: Nasion to pogonion parallel horizontal plane, CoGn: Condylion to Gnathion, MMD: Maxillary/mandibular difference, FMA: Frankfort mandibular plane angle, GA: Gonial angle, YAA: Y-axis angle, FAA: Facial-axis angle, JR: Jarabaks ratio, LAFH: Lower anterior facial height, U1NA: Upper incisor to NA, UIAPog: Upper incisor to A-Pog, UI SN: Upper incisor to S-N, UI NF: Upper incisor to nasal floor, LINB: Lower incisor to NB, L1MP: Lower incisor to Mandibular Plane, L1APog: Lower incisor to A-Pogonion, NA: Nasolabial angle, UI E line: Upper lip to E line, LI E line: Lower lip to E line, HA: Holdaway angle

reliability and accuracy of linear and angular cephalometric measurements obtained from indigenously developed computerized cephalometric software “AutoCEPH®” version 1.0 was compared with manual and Dolphin®

**Table 5: Intraclass correlation coefficient and 95% confidence interval of cephalometric measurements between hand tracing and Dolphin®-skeletal, dental and soft tissue parameters**

Parameters	Manual versus Dolphin®	
	ICC	95% CI
ACBL	0.916	0.852-0.952
PCBL	0.970	0.948-0.983
SA	0.978	0.961-0.987
SNA	0.983	0.970-0.990
Pt. A Nper	0.976	0.958-0.987
Co Pt. A	0.972	0.950-0.984
NA II HP	0.977	0.960-0.987
SNB	0.991	0.985-0.995
Pog N perp	0.990	0.982-0.994
NB II HP	0.990	0.982-0.994
N Pog II HP	0.990	0.983-0.995
CoGn	0.971	0.949-0.983
ANB	0.995	0.992-0.997
Wits	0.992	0.986-0.996
MMD	0.992	0.987-0.996
FMA	0.990	0.983-0.994
GA	0.964	0.937-0.980
SnGoGN	0.991	0.984-0.995
YA	0.982	0.968-0.990
FAA	0.990	0.982-0.994
JR	0.983	0.971-0.991
LAFH	0.982	0.968-0.990
UINA (°)	0.977	0.960-0.987
UINA (mm)	0.982	0.969-0.990
UIAPog (mm)	0.993	0.988-0.996
UI SN (°)	0.983	0.971-0.991
UI NF (mm)	0.939	0.892-0.965
LINB (°)	0.984	0.972-0.991
LINB (mm)	0.992	0.986-0.996
LIMP (°)	0.989	0.980-0.994
L1APog	0.990	0.982-0.994
NA	0.915	0.851-0.952
UI Eline	0.990	0.982-0.994
LI Eline	0.988	0.980-0.993
HA	0.985	0.974-0.992

ACBL: Anterior cranial base length, PCBL: Posterior cranial base length, SA: Saddle Angle, SNA: Sella-Nasion-point A, Pt. A N per: Point A to Nasion perpendicular, Co Pt. A: Condylion to point A, N-A (II HP): Nasion to point A (parallel to horizontal plane), SNB: Sella-Nasion- point B, Pog N perp: Pogonion to nasion perpendicular, N-B (II HP): Nasion to point B (parallel to horizontal plane), N Pog II HP: Nasion to pogonion parallel horizontal plane, CoGn: Condylion to Gnathion, MMD: Maxillary/mandibular difference, FMA: Frankfort mandibular plane angle, GA: Gonial angle, YAA: Y-axis angle, FAA: Facial-axis angle, JR: Jarabaks ratio, LAFH: Lower anterior facial height, UINA: Upper incisor to NA, UIAPog: Upper incisor to A-Pog, UI SN: Upper incisor to S-N, UI NF: Upper incisor to nasal floor, LINB: Lower incisor to NB, LIMP: Lower incisor to Mandibular Plane, L1APog: Lower incisor to A-Pogonion, NA: Nasolabial angle, UI E line: Upper lip to E line, LI E line: Lower lip to E line, HA: Holdaway angle

imaging software version 11.7 (Dolphin Imaging, Chatsworth, California, USA) respectively.

To determine the reliability and accuracy of computerized cephalometric softwares, cephalometric measurements

**Table 6: Intraclass correlation coefficient and 95% confidence interval of cephalometric measurements between AutoCEPH® and Dolphin®-skeletal, dental and soft tissue parameters**

Parameters	AutoCEPH® versus Dolphin®	
	ICC	95% CI
ACBL	0.906	0.834-0.947
PCBL	0.968	0.943-0.982
SA	0.978	0.962-0.988
SNA	0.991	0.984-0.995
Pt. A Nper	0.990	0.982-0.994
Co Pt. A	0.960	0.930-0.977
NA II HP	0.988	0.979-0.993
SNB	0.994	0.989-0.997
Pog N perp	0.994	0.990-0.997
NB II HP	0.992	0.987-0.996
N Pog II HP	0.993	0.988-0.996
CoGn	0.963	0.934-0.979
ANB	0.998	0.996-0.999
Wits	0.991	0.984-0.995
MMD	0.996	0.992-0.997
FMA	0.994	0.989-0.996
GA	0.975	0.956-0.986
SnGoGN	0.994	0.989-0.996
YA	0.992	0.986-0.996
FAA	0.990	0.983-0.994
JR	0.986	0.975-0.992
LAFH	0.967	0.942-0.981
UINA (°)	0.987	0.976-0.992
UINA (mm)	0.992	0.986-0.995
UIAPog (mm)	0.997	0.995-0.998
UI SN (°)	0.988	0.980-0.993
UI NF (mm)	0.935	0.885-0.963
LINB (°)	0.990	0.982-0.994
LINB (mm)	0.995	0.991-0.997
LIMP (°)	0.990	0.982-0.994
L1APog	0.996	0.993-0.998
NA	0.919	0.858-0.954
UI E line	0.593	0.283-0.769
LI E line	-2.454	-5.0286--0.960
HA	0.994	0.989-0.997

ICC: Intraclass correlation coefficient, CI: Confidence interval, ACBL: Anterior cranial base length, PCBL: Posterior cranial base length, SA: Saddle Angle, SNA: Sella-Nasion-point A, Pt. A N per: Point A to Nasion perpendicular, Co Pt. A: Condylion to point A, N-A (II HP): Nasion to point A (parallel to horizontal plane), SNB: Sella-Nasion- point B, Pog N perp: Pogonion to nasion perpendicular, N-B (II HP): Nasion to point B (parallel to horizontal plane), N Pog II HP: Nasion to pogonion parallel horizontal plane, CoGn: Condylion to Gnathion, MMD: Maxillary/mandibular difference, FMA: Frankfort mandibular plane angle, GA: Gonial angle, YAA: Y-axis angle, FAA: Facial-axis angle, JR: Jarabaks ratio, LAFH: Lower anterior facial height, UINA: Upper incisor to NA, UIAPog: Upper incisor to A-Pog, UI SN: Upper incisor to S-N, UI NF: Upper incisor to nasal floor, LINB: Lower incisor to NB, LIMP: Lower incisor to Mandibular Plane, L1APog: Lower incisor to A-Pogonion, NA: Nasolabial angle, UI E line: Upper lip to E line, LI E line: Lower lip to E line, HA: Holdaway angle

obtained were used in place of landmark identification in this study because cephalometric measurements are the result of cephalometric tracing process and provide data for diagnosis and treatment planning. Also because of differences

in landmark position used in combination to obtain the measurements might cancel each other out or increase the discrepancy.<sup>[16,20]</sup>

We did this study on larger sample size as compared to most of the previous studies to obtain a quantitative and objective evaluation of the accuracy of cephalometric measurements obtained from computerized cephalometric softwares.

Most studies evaluating the accuracy of on-screen computer tracing software have transferred conventional cephalometric film to a digital format using indirect acquisition which may result in image distortion. Bruntz *et al.*<sup>[21]</sup> found both vertical and horizontal distortion when analog film was converted to digital format using a scanner. Hence, the direct acquisition was used in our study to obtain digital image.

Landmark identification, a major source of error in cephalometric analysis is greatly affected by operator experience. Since the interexaminer error, in general, is greater than intraexaminer error, in this study all the landmark identification, tracing, and measurements were carried out by one investigator to minimize error.<sup>[10]</sup> Furthermore, to avoid the errors due to fatigue, not more than 5 cephalograms were traced per day.

Further, the skeletal, dental, and soft tissue parameters used in this study were commonly used cephalometric variables for orthodontic diagnosis, treatment planning, and evaluation of treatment results [Table 2]. In addition, the parameters used included all the areas of the cephalogram for a more meaningful and reliable comparison between digital and manual tracing techniques.

Comparing level of agreement between the cephalometric measurements obtained from manual tracings and Dolphin<sup>®</sup> all the parameters showed high level of agreement between the measurements (ICC >0.915)

While comparing level of agreement between the cephalometric measurements obtained from manual tracings and AutoCEPH<sup>®</sup> out of 35 parameters 33 parameters showed high level of correlation between the measurements (ICC >0.943) except UI-E line (ICC 0.574 [0.249–0.758]) indicative of poor correlation whereas for LI-E line there was negative correlation (ICC –2.579 [–5.367 to –1.031]) with values outside theoretically possible range. Various studies comparing different commercially available computerized cephalometric softwares with conventional hand tracing have shown similar high agreement for most of the parameters.<sup>[10,11,26,34]</sup>

Similarly, while comparing level of agreement between the cephalometric measurements obtained from AutoCEPH<sup>®</sup> and Dolphin<sup>®</sup> out of 35 parameters 33 parameters showed high level of correlation between the measurements (ICC >0.906) except UI-E line (ICC 0.593 [0.283–0.769]) indicative of poor correlation whereas for LI-E line there was negative correlation (ICC –2.454 [–5.0286 to –0.960]) with values outside theoretically possible range.

All these findings suggest that the cephalometric measurement values obtained from AutoCEPH<sup>®</sup> showed good agreement with that obtained from both manual as well as Dolphin<sup>®</sup>. However, due to a programming error in the AutoCEPH<sup>®</sup> a constant negative sign appeared along with measured values in Rickett’s soft tissue analysis.<sup>[35]</sup> Although the measured values were closer in magnitude but because of constant negative sign in place of original sign convention used while calculating Rickett’s soft tissue analysis the values differed by a huge margin. This resulted in these aberrant values while comparing soft tissue parameters (UI-E line and LI-E line) in case of manual versus AutoCEPH<sup>®</sup> and AutoCEPH<sup>®</sup> versus Dolphin<sup>®</sup>. After analyzing the results, these findings were discussed with the software development engineers and necessary modifications were done in the newer version of the software, i.e., AutoCEPH<sup>®</sup> (V2.0). We evaluated the accuracy of these two parameters in newer version. Average values for these two cephalometric parameters did not show significant differences ( $P < 0.05$ ) [Table 7] and ICC values were above 0.9 [Table 8], suggestive of very high correlation for all the 35 parameters.

## CONCLUSION

A high level of agreement for cephalometric measurements obtained from the AutoCEPH<sup>®</sup> version 1.0 with both manual as well as for Dolphin<sup>®</sup> version 11.7 in all the parameters gives clear evidence that AutoCEPH<sup>®</sup> software can be used widely with good accuracy in carrying out routine cephalometric analysis. AutoCEPH<sup>®</sup> is an indigenous 2D cephalometric analysis software which has been developed keeping in view current trends in cephalometric software. Hence, it can serve as a cost-effective and user-friendly tool fulfilling the needs of the contemporary clinical practices as well as clinical research prevalent in India and the neighboring countries.

**Table 7: Average cephalometric values of soft tissue parameters in newer version of AutoCEPH<sup>®</sup> compared with Hand tracing and Dolphin<sup>®</sup> software**

Parameters	Average cephalometric values			P
	Manual	AutoCEPH <sup>®</sup>	Dolphin <sup>®</sup>	
UI E line (mm)	0.33±2.65	0.10±2.50	0.07±2.49	0.97
LI E line (mm)	3.71±3.77	3.75±3.67	3.98±3.55	0.98

**Table 8: Intraclass correlation coefficient (ICC) and 95% confidence interval (CI) of cephalometric measurements in newer version between hand tracing, AutoCEPH<sup>®</sup> and Dolphin<sup>®</sup>- Soft tissue parameters**

Parameters	Manual VsAutoceph		Manual Vs Dolphin		AutocephVs Dolphin	
	ICC	95% CI	ICC	95% CI	ICC	95% CI
UI E line	0.985	0.939-0.996	0.991	0.965-0.998	0.990	0.959-0.997
LI E line	0.989	0.956-0.997	0.990	0.959-0.997	0.998	0.991-0.999

ICC: Intraclass correlation coefficient, CI: Confidence interval

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## Conflicts of interest

There are no conflicts of interest.

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