Original Article

Comparison of Reliability and Validity of Posteroanterior Cephalometric Measurements Obtained from AutoCEPH© and Dolphin® Cephalometric Software Programs with Manual Tracing

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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 software programs, namely AutoCEPH© (version 2.1.1) and Dolphin® (version 11.9) as compared to manual tracings in posteroanterior (PA) cephalometry. **Materials and Methods:** Sixty pretreatment (PA) cephalograms were selected from the database of a postgraduate orthodontic clinic. The digital images of each cephalogram were imported directly into two softwares Dolphin® and AutoCEPH© for digitization. For manual tracings, digital images were printed using an X-ray printer (Drystar 5302, Agfa HealthCare NV, Mortsel, Belgium). After images were standardized and calibrated, 19 anatomical landmarks were plotted on each cephalogram. These landmarks were then utilized to evaluate 17 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 in the range of 0.813–0.998 were obtained for all parameters while comparing three methods, i.e., manual tracings versus AutoCEPH©; manual tracings versus Dolphin®; and AutoCEPH© versus Dolphin®. **Conclusion:** A high level of agreement (ICC >0.8) for cephalometric measurements was obtained from both the computerized softwares Dolphin® and AutoCEPH© in comparison with manual tracings.

Keywords: *AutoCEPH©, computerized cephalometric analysis softwares, Dolphin®, manual cephalometric tracings*

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Introduction

Since its introduction [1931] by Broadbent and Hofrath cephalometric radiography is an essential tool for studying growth and development of facial, skeleton structure, and diagnosis and treatment planning of various malocclusions. Furthermore, it is used for evaluating orthodontic treatment progress and surgical outcomes of dentofacial deformity treatment. Therefore, it is important to keep the method error to a minimum to see the valid small changes achieved by treatment.

Traditionally, cephalometric analysis has been performed manually by tracing radiographic landmarks on acetate overlays and measuring linear and angular variables. Despite its widespread use in orthodontics, the technique is time-consuming and has several drawbacks, including a high risk of error during hand tracing, landmark identification, and measurement.[1-3]

Recently, technological advances have made it possible to perform cephalometric tracing using computers. The use of computers is expected to reduce the errors due to operator fatigue and provide standardized, fast, and

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effective evaluation with high rate of reproducibility. The posteroanterior (PA) cephalogram offers effective tools in evaluating the craniofacial structure in transverse and vertical dimension. It allows us to look at the facial skeleton in relative view of the right-left face and upper lower face. In computerized cephalometric analysis, once the requested landmarks have been entered, the software automatically calculates distances and angles, thus eliminating errors that may occur in hand tracing when drawing lines with a ruler and measuring angles with a protractor.[4-6]

Materials and Methods

The study was started after obtaining institutional ethics approval. A total of sixty pretreatment PA 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; ×1.1). For manual tracing, hard copies of images were obtained on 8”×10” radiographic film using compatible X-ray printer (Drystar 5302, Agfa HealthCare NV, Mortsel, Belgium). The machine was operated in voltage of 74 kV and 6 mA current for adult patients.

Since PA cephalograms have no ruler to correct the magnification factor, it was a challenge to standardize the image. To address the issue, four human dry skulls were borrowed from Department of Orthodontics, Subharti Dental College, Swami Vivekanand Subharti University, Meerut, Uttar Pradesh. Then, lead bullets of 0.5 mm diameter were fixed in five different bilateral landmarks, namely zygomaticofrontal suture (ZR-ZL), zygomatic arch midpoint (ZAR-ZAL), concha (CR-CL), jugal point (JR-JL), and antegonial notch (AG-GA). Then, the PA of the same skull was taken and then film was printed in 8” × 10” film [Figure 1]. The reading was noted first manually in the dry human skull with the digital vernier caliper and then in radiograph on the spoted lead bullets [Figure 2]. On an average, 12.6% negative magnification was noted in the printed cephalograms, instead of 10% positive magnification. This was due to the film size we were using, which was 8” × 10”. Since the image formed was not being fit in it, the software automatically compressed the image formed to fit in the same film. This leads to negative magnification image. To solve it, the original soft copy of the image was imported in Adobe Photoshop CS version 8, and the distance between two bilateral lead bullets was measured [Figure 3]. It was then compared with direct measurement of the same bullets in the same human skull. The difference was then measured, and magnification factor was calculated with the formula (actual distance between lead bullets/distance

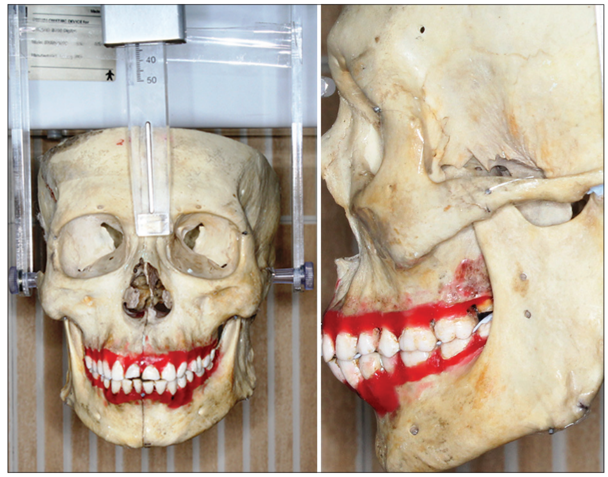

Figure 1: Human dry skull with 0.5 lead bullets

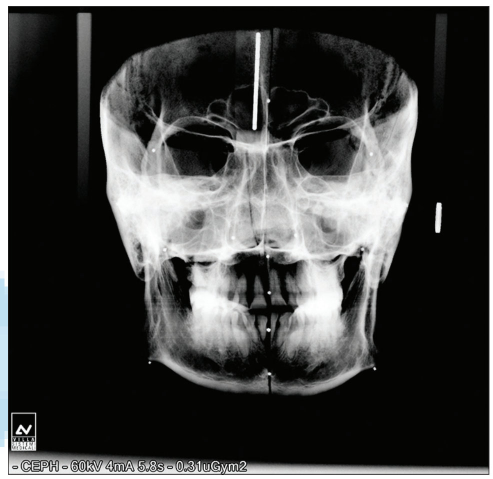

Figure 2: Radiograph obtained after exposure of the skull

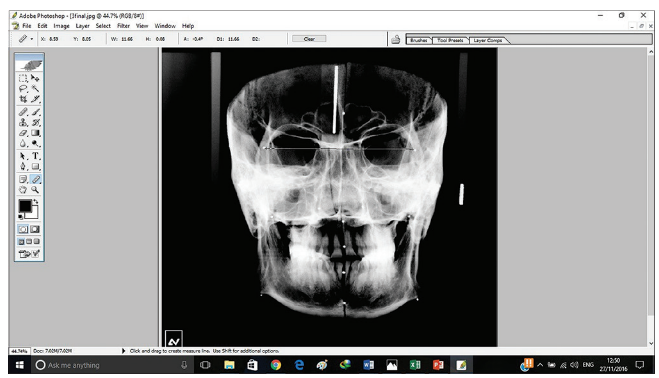

Figure 3: Distance measured between lead bullets

measured in Photoshop software). This gave the factor 0.694 now which was the magnification correction factor for all the radiographs. Now, each radiograph was imported to Adobe Photoshop, and the size of the image was seen. This dimensional value of the radiograph was multiplied by the known factor 0.694. The changed image was saved and transferred to new workplace of dimension 187 mm × 243 mm, which is the size of our printing film. During tracing the radiograph in software, the calibration was done in dots per inch (DPI).

Landmark identification is the major challenge in reducing the error. Minimizing the error is also related to operator experience. Since interexaminer error is considerably higher than intraexaminer, in this study, landmark identification tracing and measurements were executed by single examiner to reduce the error level.[7] Furthermore, to avoid the errors due to fatigue not more than 5 cephalograms was traced per day.

Manual tracings

For manual tracing, digitally, obtained images of all PA cephalograms were transferred to a computer loaded with software (Dental Studio, Villa Sistemi Medicali, Italy) and the hard copies were printed with the help of an X-ray printer (Drystar 5302, Agfa HealthCare NV, Mortsel, Belgium) on 8” × 10” radiographic film compatible with the same. Manual tracings were carried on a view box using transilluminated light in a dark room. Each cephalogram was firmly secured to the surface of view box, and a sheet of fine grade 0.003” × 8” × 10” matte acetate tracing paper was taped over the X-ray film. Linear and angular measurements were taken with the help of a millimeter ruler and protractor to the nearest 0.5 mm and 0.5°, respectively. All measurements were entered into an Excel spreadsheet.

Digital tracing

For computerized cephalometric measurements, magnification-corrected digital images of same cephalograms were directly imported to the two computerized cephalometric softwares, namely AutoCEPH© Java version 2.1.1 and Dolphin® imaging software version 11.9, and DPI value was entered for calibration. Landmark identification was carried out manually on digital images using a mouse-driven cursor, and the image enhancement features of the software such as brightness, contrast adjustment, and magnification were used as needed to identify individual cephalometric landmarks as precisely as possible. The selected landmarks were traced, and once all the landmarks were marked, these landmarks were saved. After completion of landmark plotting, all the linear and angular measurements were automatically calculated by the software, and all measurements were entered into same Excel spreadsheet used for entering manual tracing values.

A total of 19 landmarks [Figure 4] were plotted on each cephalogram and 17 parameters were measured for all the three methods which were included in 2 different analyses, namely Ricketts analysis and Grummons analysis. Cephalometric parameters used in the Ricketts analysis were skeletal parameters – 3, dental to skeletal

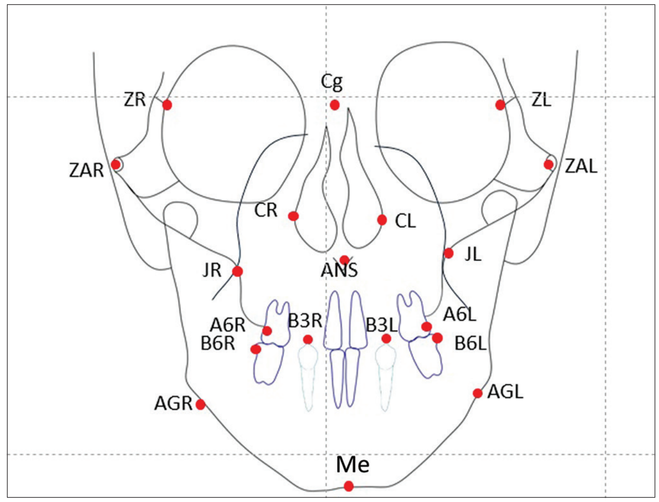

Figure 4: Various landmarks used in the study. Cg: Crista galli, ZR: Zygomatic suture right, ZL: Zygomatic suture left, ZAR: Zygomatic arch right, ZAL: Zygomatic arch left, CR: Conca right, CL: Conca left, JR: Jugal process right, JL: Jugal process left, ANS: Anterior nasal spine, A6R: Most prominent contour of upper right first molar, A6L: Most prominent contour of upper left first Molar, B6R: Most prominent contour of lower right first molar, B6L: Most prominent contour of lower left first molar, B3R: Tip of lower right canine, B3L: Tip of lower left canine, AGR: Antegonial right, AGL: Antegonial left, Me: Menton

parameters – 2, jaw to cranium parameter – 1, internal structures – 3, and dental parameters – 4 [Figure 5a-c]. Similarly, 4 parameters were taken from Grummons analysis [Figure 6].

Statistical analysis

A total of 3060 readings were recorded which included 51 readings from each patient (17 readings per method). The analysis was carried out using Statistical Package for Social Sciences version 20.0 (SPSS Inc., Chicago, IL, USA). ICC was used to determine 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

Intrarater reliability for hand tracing, AutoCEPH©, and Dolphin®

All ICC values exceeded 0.966 (0.966–0.998) indicative of a very high intrarater reliability [Table 1]. For manual tracing, ICC values lied in between 0.962 and 0.997, that for AutoCEPH© between 0.964 and 0.997, while for Dolphin®, it was between 0.976 and 0.998.

Level of agreement between the cephalometric measurements obtained from manual tracings and Dolphin®

All the parameters showed high level of agreement between the measurements ICC >0.847 [Table 2]. Among all the parameters, ICC ranged from 0.847 to

Table 1: Intraclass correlation coefficient and 95% confidence interval of repeated cephalometric measurements for hand tracing, AutoCEPH®, and Dolphin®

Analysis	Measurements	Manual		AutoCEPH©		Dolphin®	
		ICC	95% CI	ICC	95% CI	ICC	95% CI
Molar relation left	A6-B6 left	0.973	0.900-0.993	0.965	0.854-0.989	0.982	0.9490.998
Molar relation right	A6-B6 right	0.980	0.931-0.990	0.960	0.871-0.975	0.976	0.902-0.903
Intermolar width	B6-B6	0.972	0.892-0.993	0.980	0.955-0.997	0.982	0.953-0.997
Intercanine width	B3-B3	0.966	0.864-0.992	0.981	0.925-0.995	0.992	0.967-0.998
Maxillomandibular midline	(ANS-Me) ⊥ (ZR-ZL)	0.967	0.869-0.992	0.995	0.981-0.999	0.993	0.974-0.998
Maxillary width	JR-JL	0.988	0.954-0.997	0.970	0.879-0.993	0.983	0.930-0.996
Mandibular width	AGR-AGL	0.969	0.875-0.992	0.984	0.936-0.996	0.994	0.977-0.999
Lower molar left to jaw left	B6L to AGL-JL plane	0.997	0.988-0.999	0.998	0.993-1.000	0.997	0.990-0.999
Lower molar right to jaw right	B6R to AGR-JR plane	0.992	0.969-0.998	0.996	0.985-0.999	0.993	0.974-0.998
Postural symmetry	(ZR-AGR-ZAR)-(ZL-AGL-ZAL)	0.996	0.983-0.999	0.998	0.991-0.999	0.997	0.988-0.999
Nasal width	CR-CL	0.996	0.982-0.999	0.998	0.993-1.000	0.998	0.991-0.999
Nasal height	ANS-(ZR-ZL)	0.997	0.990-0.999	0.980	0.920-0.995	0.989	0.957-0.997
Facial width	ZAR-ZAL	0.985	0.941-0.996	0.994	0.975-0.998	0.995	0.979-0.999
Jugal point right to midsagittal reference line	JR-MSR	0.962	0.846-0.991	0.992	0.966-0.998	0.998	0.991-0.999
Jugal point right to midsagittal reference line	JL-MSR	0.988	0.951-0.997	0.996	0.982-0.999	0.997	0.988-0.999
Antegonial right to midsagittal reference line	AGR-MSR	0.982	0.926-0.995	0.986	0.943-0.996	0.995	0.979-0.999
Antegonial left to midsagittal reference line	AGL-MSR	0.996	0.986-0.999	0.980	0.920-0.995	0.996	0.985-0.999

ICC: Intraclass correlation coefficient, CI: Confidence interval, ZR: Zygomatic Suture Right, ZL: Zygomatic Suture left, ZAR: Zygomatic arch right, ZAL: Zygomatic arch left, CR: Conca right, CL: Conca left, JR: Jugal process right, JL: Jugal process Left, ANS: Anterior nasal spine, AGR: Antegonial Right, AGL: Antegonial Left, Me: Menton, B6R: Most prominent contour of lower right first molar, B6L: Most prominent contour of lower left first, MSR: Midsagittal reference line

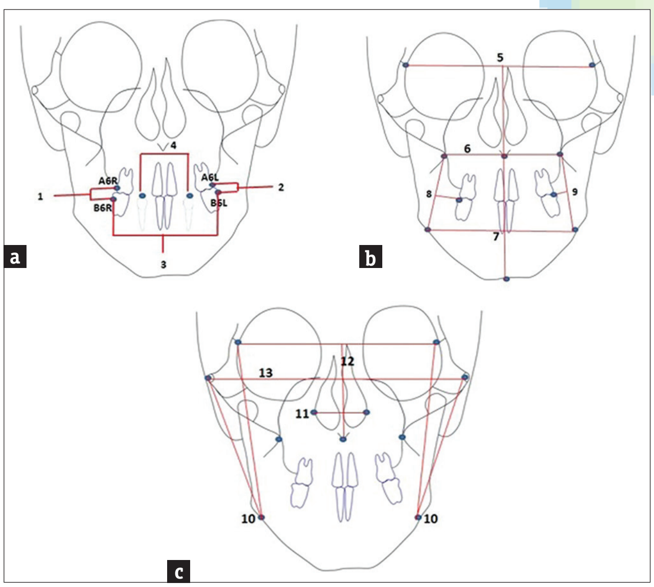

Figure 5: (a-c) Various parameters used in the Ricketts analysis. 1: Molar relation left, 2: Molar relation right, 3: Intermolar width, 4: Intercanine width, 5: Maxillomandibular midline, 6: Maxillary width, 7: Mandibular width, 8: Molar relation right to jaw right, 9: Molar relation left to jaw left, 10: Postural symmetry, 11: Nasal width, 12: Nasal height, 13: Facial width

0.998. The least value of ICC was for postural symmetry (degree) (ICC = 0.847) and highest value was for facial width (ICC = 0.998).

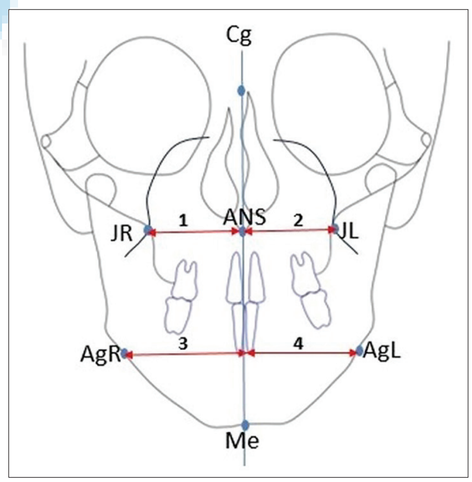

Figure 6: Various parameters used in the Grummons analysis. 1: Jugal point right to midsagittal reference line, 2: Jugal point left to midsagittal reference line, 3: Antegonial right to midsagittal reference line, 4: Antegonial left to midsagittal reference line

Level of agreement between the cephalometric measurements obtained from manual tracings and AutoCEPH©

All the parameters showed high level of agreement between the measurements ICC >0.892 [Table 3]. Among all the parameters, ICC ranged from 0.892 to 0.997. The least value of ICC was for maxillary

Table 2: Intraclass correlation coefficient and 95% confidence interval of cephalometric measurements between hand tracing and Dolphin®

Analysis	Parameters	Manual versus Dolphin®	
		ICC	95% CI
Molar relation left	A6-B6 left	0.962	0.937-0.977
Molar relation right	A6-B6 right	0.932	0.886-0.959
Intermolar width	B6-B6	0.995	0.991-0.997
Intercanine width	B3-B3	0.986	0.977-0.992
Maxillomandibular midline (degree)	(ANS-Me) ⊥ (ZR-ZL)	0.976	0.960-0.986
Maxillary width	JR-JL	0.906	0.842-0.944
Mandibular width	AGR-AGL	0.991	0.985-0.995
Lower molar left to jaw left	B6L to AGL-JL Plane	0.942	0.903-0.965
Lower molar right to jaw right	B6R to AGR-JR Plane	0.928	0.880-0.957
Postural symmetry (degree)	(ZR-AGR-ZAR)-(ZL-AGL-ZAL)	0.847	0.744-0.908
Nasal width	CR-CL	0.985	0.993-0.987
Nasal height	ANS-(ZR-ZL)	0.992	0.986-0.995
Facial width	ZAR-ZAL	0.998	0.996-0.999
Jugal point right to midsagittal reference line	JR-MSR	0.990	0.984-0.994
Jugal point left to midsagittal reference line	JL-MSR	0.979	0.965-0.988
Antegonial right to midsagittal reference line	AGR-MSR	0.990	0.984-0.994
Antegonial left to midsagittal reference line	AGL-MSR	0.965	0.942-0.979

ICC: Intraclass correlation coefficient, CI: Confidence interval, ZR: Zygomatic Suture Right, ZL: Zygomatic Suture left, ZAR: Zygomatic arch right, ZAL: Zygomatic arch left, CR: Conca right, CL: Conca left, JR: Jugal process right, JL: Jugal process Left, ANS: Anterior nasal spine, AGR: Antegonial Right, AGL: Antegonial Left, Me: Menton, B6R: Most prominent contour of lower right first molar, B6L: Most prominent contour of lower left first, MSR: Midsagittal reference line

width (ICC = 0.892) and highest value was for facial width (ICC = 0.997).

Level of agreement between the cephalometric measurements obtained from Dolphin® tracings and AutoCEPH© [Table 4]

All the parameters showed high level of agreement between the measurements ICC >0.813 [Table 4]. Among all the parameters, ICC ranged from 0.813 to 0.997. The least value of ICC was for lower molar right to jaw right and postural symmetry (degree) (ICC 0.813) and highest value was for facial width (ICC = 0.997).

Discussion

Cephalometric analysis has been used widely as an important aid in orthodontic diagnosis and treatment planning as well as for assessment of craniofacial growth. It also helps in analyzing anchorage requirements for individual cases and evaluating treatment changes and relapse following orthodontic treatment. Hence, it has made the need of accuracy and reproducibility in data obtained from cephalometric analysis of different stages for evaluating exact change. With the advancement in technology, number of commercially available computerized cephalometric analysis softwares is now available in the market. However, the reliability and reproducibility of newly launched software cannot be accepted unless it is validated against the previously available and internationally accepted software and against the hand tracing which is a considered as a gold standard till the date. The objectives of this study were to compare the cephalometric measurements of manual tracing with computerized cephalometric analysis software programs, to compare the cephalometric measurements obtained from manual tracing with that from indigenous computerized cephalometric software AutoCEPH©, and to compare the cephalometric measurements obtained with indigenous computerized cephalometric software AutoCEPH© with established computerized cephalometric analysis software[8] Dolphin® (Dolphin Imaging, Chatsworth, California, USA).

An indigenous computerized cephalometric analysis software named AutoCEPH© has been designed and developed by Central Scientific Instruments Organisation in collaboration with Department of Orthodontics and Dentofacial Deformities, CDER, All India Institute of Medical Sciences, New Delhi. This user-friendly cephalometric analysis system offers on-screen digitization capabilities with automated analyses and comparison with chosen ethnic group. It has been developed to perform 16 standard lateral and 3 PA analysis.

Till date, numerous studies have been conducted to assess the accuracy of cephalometric measurements by various available cephalometric software programs such as QuickCeph (Quick Ceph Systems, San Diego, California, USA),[4-6] AOCeph™ (American Orthodontics,

Table 3: Intraclass correlation coefficient and 95% confidence interval of cephalometric measurements between hand tracing and AutoCEPH©

Analysis	Parameters	Manual versus AutoCEPH©	
		ICC	95% CI
Molar relation left	A6-B6 left	0.962	0.937-0.977
Molar relation right	A6-B6 right	0.932	0.886-0.959
Intermolar width	B6-B6	0.972	0.953-0.983
Intercanine width	B3-B3	0.970	0.950-0.982
Maxillomandibular midline (degree)	(ANS-Me) ⊥ (ZR-ZL)	0.960	0.933-0.976
Maxillary width	JR-JL	0.892	0.820-0.936
Mandibular width	AGR-AGL	0.992	0.992-0.987
Lower molar left to jaw left	B6L to AGL-JL plane	0.953	0.922-0.972
Lower molar right to jaw right	B6R to AGR-JR plane	0.909	0.848-0.946
Postural symmetry (degree)	(ZR-AGR-ZAR)-(ZL-AGL-ZAL)	0.917	0.861-950
Nasal width	CR-CL	0.985	0.976-0.991
Nasal height	ANS-(ZR-ZL)	0.984	0.974-0.991
Facial width	ZAR-ZAL	0.997	0.995-0.998
Jugal point right to midsagittal reference line	JR-MSR	0.954	0.924-0.973
Jugal point left to midsagittal reference line	JL-MSR	0.967	0.944-0.980
Antegonial right to midsagittal reference line	AGR-MSR	0.971	0.952-0.983
Antegonial left to midsagittal reference line	AGL-MSR	0.965	0.942-0.979

ICC: Intraclass correlation coefficient, CI: Confidence interval, ZR: Zygomatic Suture Right, ZL: Zygomatic Suture left, ZAR: Zygomatic arch right, ZAL: Zygomatic arch left, CR: Conca right, CL: Conca left, JR: Jugal process right, JL: Jugal process Left, ANS: Anterior nasal spine, AGR: Antegonial Right, AGL: Antegonial Left, Me: Menton, B6R: Most prominent contour of lower right first molar, B6L: Most prominent contour of lower left first, MSR: Midsagittal reference line

Table 4: Intraclass correlation coefficient and 95% confidence interval of cephalometric measurements between Dolphin® and AutoCEPH©

Analysis	Parameters	Dolphin® versus AutoCEPH©	
		ICC	95% CI
Molar relation left	A6-B6 left	0.958	0.930-0.975
Molar relation right	A6-B6 right	0.850	0.749-0.910
Intermolar width	B6-B6	0.976	0.960-0.986
Intercanine width	B3-B3	0.981	0.968-0.989
Maxillomandibular midline	(ANS-Me)⊥(ZR-ZL)	0.945	0.907-0.967
Maxillary width	JR-JL	0.987	0.978-0.992
Mandibular width	AGR-AGL	0.994	0.989-0.996
Lower molar left to jaw left	B6L to AGL-JL Plane	0.953	0.922-0.972
Lower molar right to jaw right	B6R to AGR-JR Plane	0.813	0.887-0.960
Postural symmetry	(ZR-AGR-ZAR)-(ZL-AGL-ZAL)	0.813	0.687-0.888
Nasal width	CR-CL	0.986	0.977-0.992
Nasal height	ANS-(ZR-ZL)	0.976	0.960-0.986
Facial width	ZAR-ZAL	0.997	0.995-0.998
Jugal point right to midsagittal reference line	JR-MSR	0.951	0.918-0.971
Jugal point left to midsagittal reference line	JL-MSR	0.979	0.965-0.988
Antegonial right to midsagittal reference line	AGR-MSR	0.971	0.952-0.983
Antegonial left to midsagittal reference line	AGL-MSR	0.937	0.895-0.962

ICC: Intraclass correlation coefficient, CI: Confidence interval, ZR: Zygomatic Suture Right, ZL: Zygomatic Suture left, ZAR: Zygomatic arch right, ZAL: Zygomatic arch left, CR: Conca right, CL: Conca left, JR: Jugal process right, JL: Jugal process Left, ANS: Anterior nasal spine, AGR: Antegonial Right, AGL: Antegonial Left, Me: Menton, B6R: Most prominent contour of lower right first molar, B6L: Most prominent contour of lower left first, MSR: Midsagittal reference line

Sheboygan, USA),[9] Dolphin® (Dolphin Imaging, Chatsworth, California, USA),[5,7,8,10-13] Vistadent™ (GAC International, Bohemia, New York, USA),[5,11,14,15] Viewbox® (dHAL Software, Kifisia, Greece),[16,17] JOE (Rocky Mountain Orthodontics, Denver, Co),[14] Facad® (Ilexis AB, Linköping, Sweden),[16,18] OnyxCeph® (Image Instruments GmbH, Frankfurt, Germany),[16] OrisCeph® (Elite Computer Italia, Vimodrone, Italy),[16] Winceph® (Rise Corporation, Sendai, Japan),[16] Cef-X2001 (CDT, Cuiabá, Brazil),[18] Nemoceph NX (Nemotec, Madrid, Spain),[4,19-22] and Smile Ceph[10] (Glace Software, Imola, Italy). No study has been done so far to evaluate the reliability of posteroanterior cephalometric measurements obtained from AutoCEPH©. However, a study has been conducted to check the reliability of AutoCEPH© in lateral ceph analysis against Dolphin® software and hand tracing. A high level of agreement (ICC >0.9) for cephalometric measurements was obtained from both the computerized softwares Dolphin® and AutoCEPH© in comparison with manual tracings.[23]

The present study was conducted with an aim of comparing the digital and conventional tracing methods of PA cephalogram in terms of the reliability (agreement between two measurements of the same object) as well as reproducibility (agreement between two measurements of two methods). Furthermore, accuracy and reproducibility of linear and angular cephalometric measurements obtained from indigenously developed computerized cephalometric software "AutoCEPH©" version 2.1.1 was compared with manual and Dolphin® imaging software version 11.9 (Dolphin Imaging, Chatsworth, California, USA), respectively.

According to Yu *et al*.,[24] landmark identification from digital images can be affected by several factors such as spatial and contrast resolution of the display device, background luminance level and luminance range of the display system, brightness uniformity, extraneous light in the reading room, displayed field size, viewing distance magnification functions, and user interface. Furthermore, linear measurements may be affected by the inclination of the reference line, and angular measurements cannot indicate correctly the jaw relationship in the case of extreme facial divergence as stated by Williams *et al*.[25] Therefore, it is reasonable to evaluate a set of structural relationships by multiple cephalometric parameters rather than by a single parameter. Hence, as many as possible common parameters on both the softwares were included.

The intraclass correlation coefficient (ICC) was calculated to determine intrarater reliability for each tracing technique. Furthermore, to evaluate reproducibility for each cephalometric parameter, the agreement between the value derived from AutoCEPH©, that given by Dolphin®, and that measured manually was assessed with the ICC agreement which was rated as low for an ICC ≤0.75. Conversely, an ICC >0.75 was considered indicative of good agreement.[26]

Level of agreement between the cephalometric measurements obtained from manual tracings and Dolphin®

All the parameters of Ricketts analysis and Grummons analysis showed from good to high level of agreement between the measurements with ICC ranging from 0.847 to 0.998. In Ricketts analysis, among the dental parameters, ICC was least for molar relation right with value 0.932 and highest for intermolar width ICC 0.995. In skeletal parameters, ICC was least with value 0.847 for postural symmetry and highest for facial width with ICC value of 0.998. For internal structures, the ICC value showed high level of agreement with minimum of 0.985 for nasal width and maximum of 0.998 for facial width. For dental to skeletal relation also, there was high level of agreement with ICC value of 0.942 for lower molar left to jaw left and 0.928 for lower molar right to jaw right. For Grummons analysis, the ICC value showed high level of agreement with minimum ICC of 0.965 for antegonial left (AGL) to midsagittal reference (MSR) line and highest of 0.990 for JR to MSR.

Level of agreement between the cephalometric measurements obtained from manual tracings and AutoCEPH©

All the parameters in Ricketts analysis and Grummons analysis showed from good to high level of agreement between the measurements with ICC ranging from 0.892 to 0.997. In Ricketts analysis, among the dental parameters, ICC was least for molar relation right with value 0.932 and highest for intermolar width ICC 0.972. In skeletal parameters, ICC was least with value 0.892 for maxillary width and highest for mandibular width with ICC value of 0.992. For internal structures, the ICC value showed high level of agreement with minimum of 0.984 for nasal height and maximum of 0.997 for facial width. For dental to skeletal relation also, there was high level of agreement with ICC value of 0.909 for lower molar right to jaw right and 0.953 for lower molar left to jaw left. For Grummons analysis, high level of agreement was seen with ICC ranging from 0.954 for JR to MSR and 0.971 for AGR to MSR.

Level of agreement between the cephalometric measurements obtained from AutoCEPH© and Dolphin®

All the parameter in Ricketts analysis and Grummons analysis showed from good to high level of agreement between the measurements with ICC ranging from 0.813 to 0.997. In Ricketts analysis, among the dental parameters, ICC was least for molar relation right with value 0.850 and highest for intercanine width with ICC of 0.981. In skeletal parameters, ICC was least with value of 0.945 for maxillomandibular midline relation and highest for mandibular width with ICC value of 0.994. For internal structures, the ICC value showed high level of agreement with minimum of 0.986 for nasal width and maximum of 0.997 for facial width. For dental to skeletal relation also, there was high level of agreement with ICC value of 0.813 for lower molar right to jaw right and 0.953 for lower molar left to jaw left. For Grummons analysis, high level of agreement was seen with ICC ranging from 0.937 for AGL to MSR and 0.979 for JL to MSR.

Conclusion

The reliability and reproducibility of measurements obtained from two computerized cephalometric analysis softwares, namely AutoCEPH© and Dolphin® imaging software were high with each other and to gold standard hand tracing. A high level of agreement for cephalometric measurements obtained from the AutoCEPH© version 2.1.1 with both manual as well as for Dolphin® version 11.9 in most of the parameters gives a clear evidence that AutoCEPH© software can be used widely with good accuracy in carrying out routine PA cephalometric analysis. The user-friendly and time-saving characteristics of computerized cephalometric measurements using direct digital images make it a preferred option against the conventional manual method.

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Conflicts of interest

There are no conflicts of interest.

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