IOSR Journal of Dental and Medical Sciences (IOSR-JDMS)
e-ISSN: 2279-0853, p-ISSN: 2279-0861.Volume 22, Issue 4 Ser.3 (April. 2023), PP 26-33
www.iosrjournals.org

To compare the reliability and accuracy of artificial intelligence (AI) based fully automated cephalometric tracing software with computer aided semi-automatic cephalometric software.

1. Dr. Nishal Khattri
PG Student, Department of Orthodontics,
Geetanjali Dental & Research Institute,
Udaipur, Rajasthan

2. Dr. Namit Nagar
Professor & Head, Department of Orthodontics,
Geetanjali Dental & Research Institute,
Udaipur, Rajasthan

3. Dr. Shreya Agarwal,
PG Student,
Department of Orthodontics,
Geetanjali Dental & Research Institute,
Udaipur, Rajasthan

4. Dr. Vibhuti Mehta
PG Student, Department of Orthodontics,
Geetanjali Dental & Research Institute,
Udaipur, Rajasthan

5. Dr. Niharika TK
PG Student, Department of Orthodontics,
Geetanjali Dental & Research Institute,
Udaipur, Rajasthan

6. Dr. Niharika Joshi
PG Student, Department of Orthodontics,
Geetanjali Dental & Research Institute,
Udaipur, Rajasthan

ABSTRACT
Introduction: Cephalometric study has been an instrumental in orthodontic diagnosis, treatment planning and craniofacial growth prediction. With the rapid evolution in field of Artificial Intelligence, Automatic cephalometric analysis has been a topic of interest during the past few years. This study is aimed to compare the reliability and accuracy of web-based fully automated AI driven cephalometric tracing software (WebCeph® 1.5) with Computer aided Digital manual cephalometric software (FACAD 3.10.1®).
Method: 100 Pre-treatment lateral cephalogram recorded in natural head position were collected. The digital images were calibrated by digitizing 3 points (30mm) on the ruler within the radiograph. 11 angular and 4 linear parameters were measured on all 100 radiographs using Fully Automated (WebCeph 1.5) cephalometric tracing software and computer Aided (FACAD 3.10.1) cephalometric software. Data obtained were statistically analyzed using Paired t-test. Intraclass correlation coefficient tests were used to evaluate the reliability between the two methods.
Result: The data of the measurement obtained with the Computer Aided cephalometric analysis method and AI based fully automated cephalometric tracing method showed Statistically significant difference (p<0.05) between two methods for the following measurements: SN-OP, SN-MP, U1-NA (Linear), U1-NA(Angular), AO-BO,

Articular Angle and Gonial Angle. Evaluation of the reliability between the two cephalometric method was analyzed using Intraclass correlation coefficient (ICC) and it was determined that the U1-NA(Angular), Saddle angle, Gonial angle and Bjork Sum parameters showed low values (ICC<0.50).

Conclusion: This study showed that there are significant differences between the AI based Fully automatic tracing method and computer aided Semi-automatic method in terms of measurement of parameters like SN-OP, SN-MP, U1-NA (Linear), U1-NA(Angular), AO-BO, Articular Angle and Gonial Angle. So, it is conclusive to say that within the present conditions, AI based fully Automatic cephalometric tracing algorithm is not developed enough to replace the reliable, tried and tested Computer Aided semi-automated method.

Date of Submission: 01-04-2023 Date of Acceptance: 11-04-2023

I. INTRODUCTION

Ever since the introduction of the cephalometric study by Broadbent in 1931, Cephalometry has been instrumental in orthodontic diagnosis, treatment planning, and craniofacial growth prediction. Manual tracing of lateral cephalograms on acetate paper has been a go-to method for many years. However, manual tracing comes with its drawbacks. It is prone to errors, is time-consuming, and has a risk of misreading values due to inaccurate landmark identification or poor-quality radiographs. With the rapid advancement in technology, the manual method is gradually being replaced by the digital cephalometric analysis software.

Digital cephalometric analysis has numerous advantages such as facilitated image acquisition, faster measurements, archiving, faster treatment planning and reduced chemically associated hazards. Many computer programs have been developed for cephalometric analysis, such as Dolphin Imaging, Dentofacial Planner, Quick Ceph, and FACAD™ over the years. The aspect that these digital tracing systems have in common, regardless of whether they are used on a tablet, smartphone, or computer, is that the anatomical points need to be marked individually by the orthodontist during the tracing, making the cephalometric program only semi-automated.[1]

With the rapid development of Artificial intelligence (AI) and Machine Learning past few years. The use of AI has become prevalent in numerous aspects of daily life, and AI-based algorithms are now widely used in technology. Recently, automated methods using convolutional neural networks (CNNs) have been developed.[2] Deep learning is one of the most evolving areas in artificial intelligence. Generally, Deep learning (DL)-based methods require high-specification hardware. For this reason, the development of web application for DL-based methods was essential.[3] AI driven cephalometric analysis has gathered an interest during the past few years. However, the software algorithms developed did not seem accurate enough in identifying the landmarks. Since accurate identification of landmarks is of utmost importance in cephalometric analysis and also the main source of error, it is important to assess the reliability of recently developed computer automated programs.

Recently various Web-based Fully Automatic AI cephalometric software such as CephX, WeDoCeph, AudaxCeph, DentaliQOrtho has become commercially available in market. WebCeph® is such web-based AI driven algorithm that performs automatic, immediate cephalometric analyses and is highly accessible. The aim of this study is to compare AI based fully automatic cephalometric analysis with Computer Aided Semi-automatic cephalometric analysis (FACAD™) in orthodontics and to evaluate the reliability of AI in various Angular and Linear measurements.

II. MATERIAL AND METHODS

To conduct this study, 100 Pre-treatment lateral Cephalogram recorded in natural head position were collected. Radiographs were scanned using EPSON scanner with resolution of 600 dpi and were saved in JPEG format to render the compatibility issues with the software and allotted an ID to maintain the uniformity. Digital images were uploaded to the respective software and calibrated by digitizing 3 points (30mm) on the ruler within the cephalograms. 15 parameters (12 angular and 3 linear) were used in this study are presented in Table 1

Table 1: Description of Angular and Linear measurements

ANGULAR MEASUREMENTS:

SNA: Angle determined by the points Sella, Nasion and A

SNB: Angle determined by the points Sella, Nasion and B

ANB: Angle determine by the points A, Nasion and B

SN-OP: Angle formed by the intersection of SN plane and Occlusal Plane

SN-MP: Angle formed by the intersection of SN plane and Mandibular plane

U1-NA: Angle formed by the intersection of upper incisor axis and the NA line (Nasion-A point)

L1-NB: Angle formed by the intersection of the lower incisor axis and NB line (Nasion -B point)

U1-L1: Angle formed by the intersection of the long axis of upper and lower incisor

SADDLE ANGLE: Angle determined by points S, N and Ar (Articulare)

ARTICULAR ANGLE: Angle determine d by the points N, Ar and Go (Gonion)

GONIAL ANGLE: Angle determine by the points Ar, Go and Me (Menton)

BJORK SUM: Sum of Saddle angle, Articular angle and Gonial angle

LINEAR MEASUREMENTS:

U1-NA: Linear distance between the most anterior point of maxillary central incisor (U1) and NA line

L1-NB: Linear distance between the most anterior point of mandibular incisor (L1) and NB line

AO-BO: Linear distance between the point AO (Perpendicular drawn from point A unto occlusal plane) and point BO (Perpendicular drawn from point B unto occlusal plane)

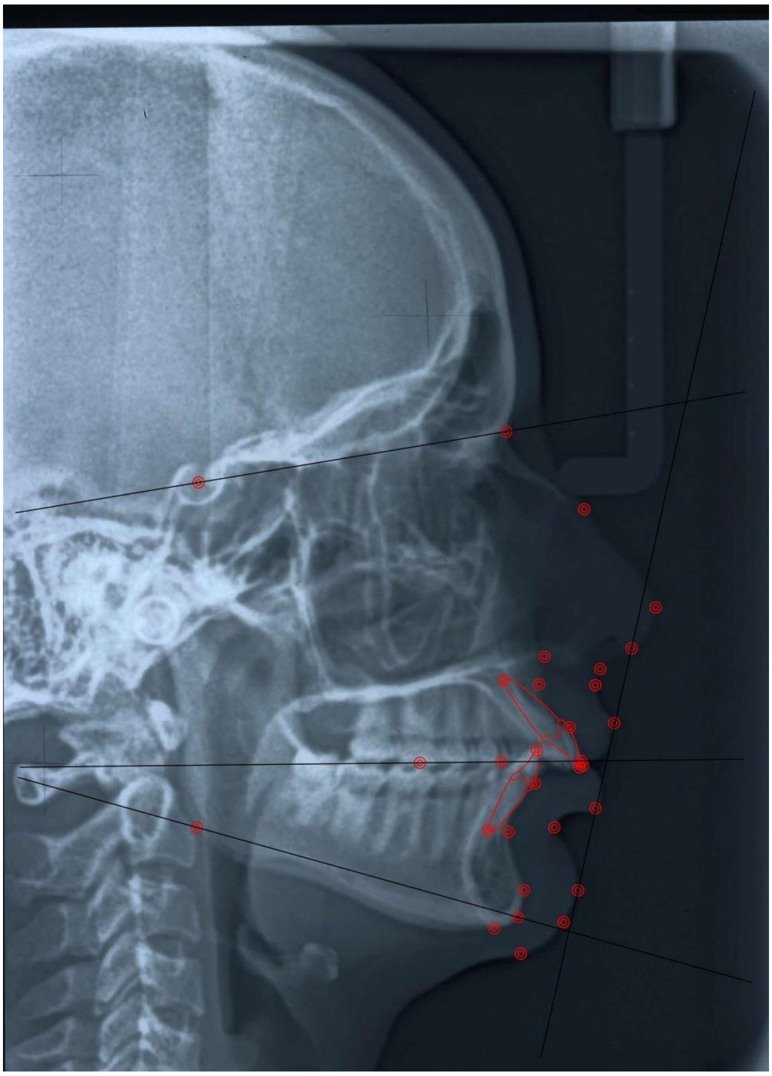


Fig 1. Landmarks and Analysis – FACAD™

Web Based AI driven Fully Automated Tracing

For the fully automated tracing WebCeph® Version 1.5.0 (Artificial Intelligence Orthodontic and Orthognathic Cloud Platform, South Korea, 2020) was used. Digital Images of the same radiographs with allotted ID in JPEG format were uploaded to the WebCeph® server. Using AI Digitization algorithm landmarks were traced automatically onto the digital images. Digital images of cephalogram were calibrated using Image size calibration (30mm) feature of the software. (Fig. 2)

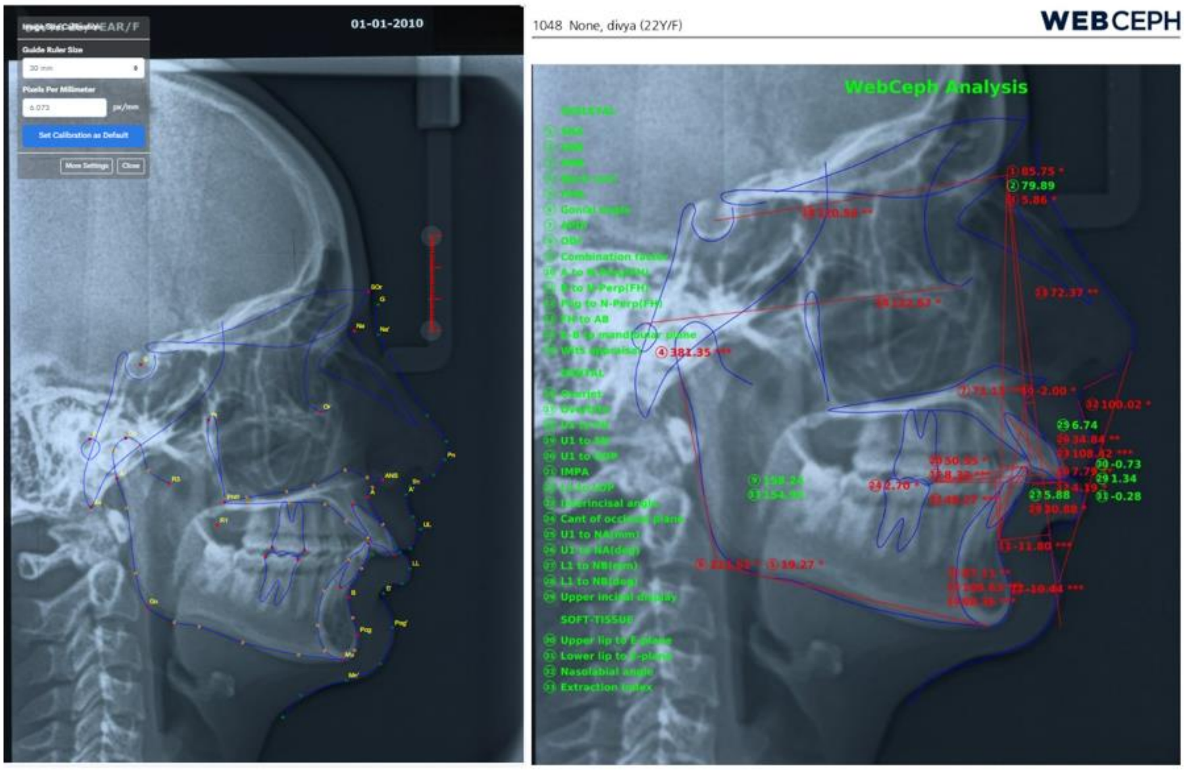


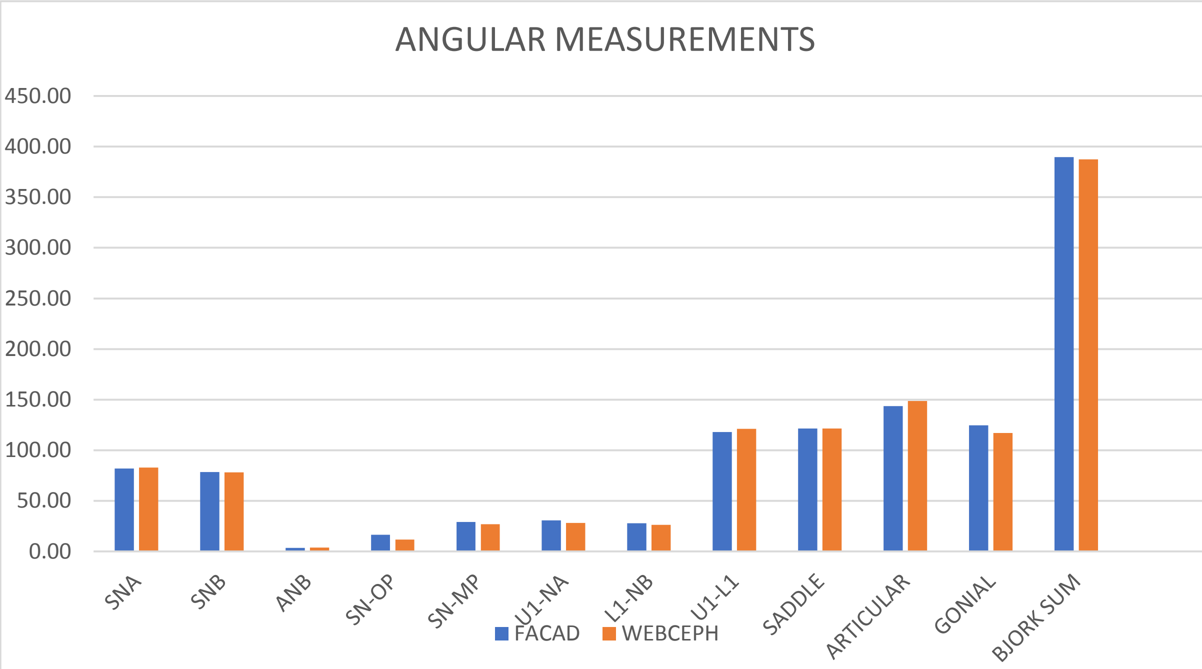
Fig. 2: Landmarks (left) and Analysis(right)-WebCeph®

III. RESULTS

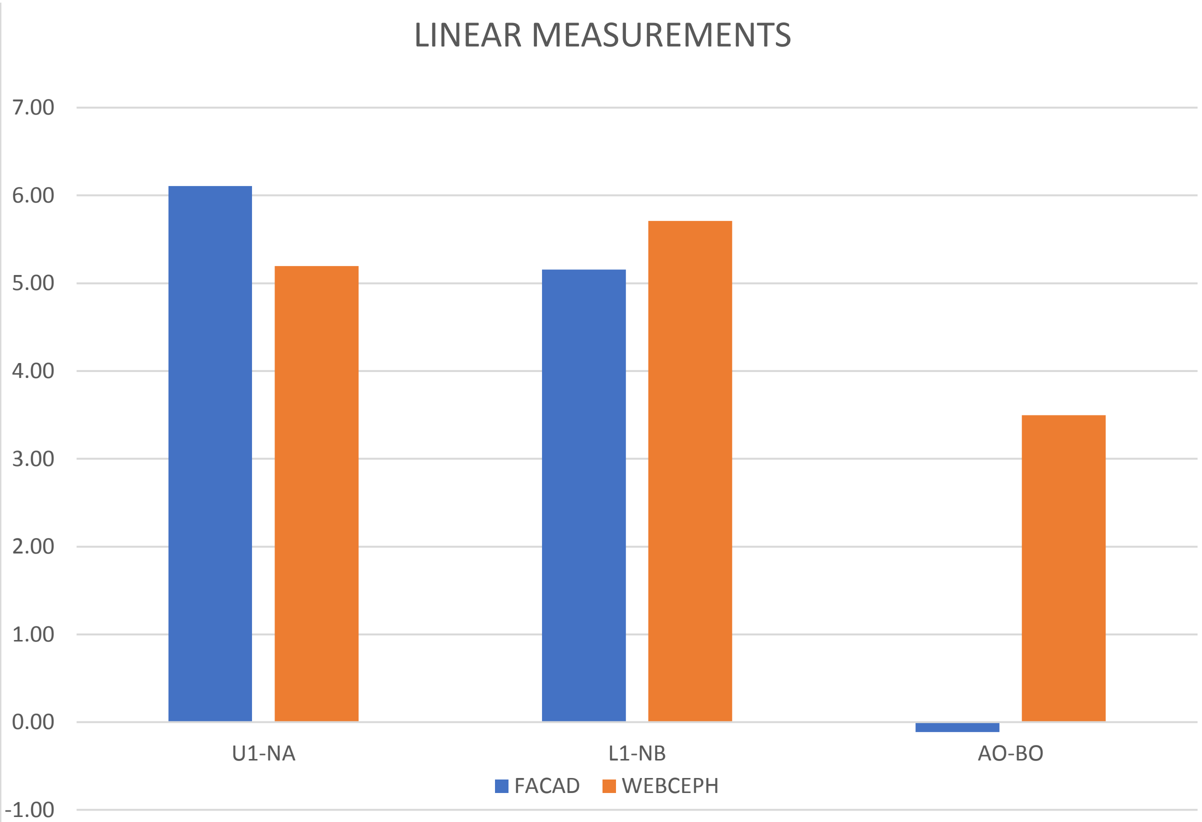
Values obtained were tabulated on MS Excel (Microsoft Office 2019, Redmond, Washington). Paired *t*-test was used to evaluate the measurements obtained by Digital Manual FACAD™ and Fully Automated AI algorithm WebCeph®. The statistical significance value was defined as $p<0.05$ as significant, $p<0.001$ as highly significant and $p>0.05$ as non-significant. Intraclass correlation coefficient test was used to evaluate the reliability between the two methods. The representation of data of the measurement obtained with the Computer Aided cephalometric analysis method and AI based fully automated cephalometric tracing method for angular and linear parameters is presented in the Table 2 and Graph 1 & 2.

	FACAD		**WEBCEPH**				
	MEAN	**SD**	**MEAN**	**SD**	**P-VALUE**	**ICC**	**P-VALUE**
SNA	81.86	4.20	82.93	5.46	0.12	0.57	<0.001
SNB	78.47	4.25	78.14	8.84	0.74	0.60	<0.001
ANB	3.38	3.06	3.70	6.66	0.66	0.53	<0.001
SN-OP	16.44	5.08	11.73	5.32	<0.001	0.62	<0.001
SN-MP	29.01	6.49	26.89	6.48	0.02	0.89	<0.001
U1-NA°	30.70	8.17	28.08	9.74	0.04	0.47	<0.001
L1-NB°	27.81	8.40	26.19	7.66	0.16	0.84	<0.001
U1-L1	118.02	13.27	121.23	16.02	0.12	0.71	<0.001
SADDLE	121.44	12.79	121.60	4.99	0.91	0.31	<0.001
ARTICULAR	143.47	6.11	148.67	5.00	<0.001	0.68	<0.001
GONIAL	124.68	12.77	116.95	6.42	<0.001	0.23	>0.05
BJORK SUM	389.49	26.42	387.46	7.03	0.46	-0.03	>0.05
AO-BO	6.11	2.00	5.19	2.47	<0.001	0.66	<0.001
U1-NA (MM)	5.16	2.26	5.71	2.26	0.40	0.66	<0.001
L1-NB (MM)	-0.11	3.63	3.50	3.64	<0.001	0.54	<0.001

Graph 1. Graphical representation of comparison of angular measurements by 2 different cephalometric analysis methods



Graph 2. Graphical representation of comparison of linear measurements by 2 different cephalometric analysis methods



For the very long duration cephalometric study has been an indispensable tool in the arsenal of Orthodontics for diagnosis, treatment planning and a research work. Manual Tracing of cephalogram was considered “gold standard” for many years regardless of its flaws. It was time consuming, susceptible to errors and misreading values and inconsistent within and among observers as pointed by **Linder C[2]**. This has largely been overcome by the evolution of technology. With the development in the field of computer science, various computer software for cephalometric study has become commercialized. It is fast, reliable and convenient, but the need to identify individual landmarks manually makes it semi-automated at best as suggested by **Kim H et al[3].**

With the rapid development in the field of AI and machine learning it has become possible to make the cephalometric tracing fully automatic. Hence, this study was conducted to validate the reliability of AI based fully automated cephalometric tracing.

In order to conduct this study 100 Pre-treatment Lateral Cephalograms recorded in natural head position were collected. Cephalometric Radiographs were scanned using EPSON scanner with resolution of 600 dpi and was saved in JPEG format to render the compatibility issues with the software and allotted an ID to maintain the uniformity. 15 parameters (12 Angular and 3 Linear) were selected due to their clinical significance and commonality between the two software to be used.

Digital images of the scanned radiographs were uploaded to the respective software and calibrated by digitizing 3 points (30mm) on the ruler within the cephalograms. Said parameters were evaluated using Computer Aided semi-automatic cephalometric tracing FACAD™ software and Fully Automatic AI driven cephalometric tracing WebCeph® algorithm separately.

Amongst the parameters considered **SNA, SNB, ANB, L1-NB(Angular), L1-NB (Linear), U1-L1, Saddle Angle** showed no significant difference and parameters like **SN-OP, SN-MP, U1-NA (Linear), U1-NA(Angular), AO-BO, Articular Angle and Gonial Angle** showed statistically significant values.

Chen YJ et al [5] has indicated that the difference of less than 2 degree or 2mm in mean value amongst two different methods are clinically insignificant. In concordance with above study, the present study showed that the difference in mean value between two methods for the parameters **SN-OP, SN-MP, U1-NA (Linear), U1-NA(Angular), AO-BO, Articular Angle and Gonial Angle** were more than 2 Degree or 2mm, hence, the difference could be considered clinically significant. Similarly, the study conducted by **Meric P and Naumova J [6]** and **Katyal D and Balakrishnan N[7]** showed no statistically significant difference in values for parameters such as SNA, SNB, ANB, U1-L1, SN-OP and had significantly higher values for SN-MP, U1-NA (Angular) and U1-NA(Linear).

But the lack of consistency with other studies cannot be ignored such as in case with the finding of **Coban G et al[8]** with the statistically significant difference in parameters such as SNA, SNB, SN-MP, U1-NA (Angular), U1-NA (linear), L1-NB (Angular) and L1-NB (linear). These findings reinforce those of **Alqahtani H [4]** and **Mahto RK et al. [9]**

Differences in the values obtained from 2 different method during cephalometric analysis may come from systemic and random errors as pointed by **Leonardi R et al. [10]**

As observed by **Anuwongnukroh N et al [11]** Systematic errors can occur when obtaining cephalograms if the geometry of the system varies and no compensation is made. Random errors involve tracing, landmark identification, and measurement errors. Since both of the method does not involve tracing and measurements, difference in values can be attributed to the faulty landmark identification.

This study showed multiple differences in the values obtained from the AI based WebCeph® and Computer Aided FACAD™. Difference was observed in 7 out of 15 i.e., 47% of the parameters which is significant. These differences were most likely a result of inaccurate landmark identification by the software. The inaccurately identified landmarks by the fully automatic software were mostly bilateral landmark such as **Gonion** and **Articulare** and overlapping structures such as **Tooth and Nasion** which is consistent with the finding of this study which showed the statistically significant difference in values of Gonial Angle, Articular Angle, SN-MP, SN-OP, U1-NA(Angular), U1-NA(Linear), AO-BO between two methods.

IV. CONCLUSION

With the development of the AI based fully automated cephalometric tracing software recently, cephalometric study has become faster and operator friendly and it is undeniable but the reliability of such algorithm is still questionable. This study showed that there are significant differences between the AI based Fully automatic tracing method and computer aided Semi-automatic method in terms of measurement of parameters like **SN-OP, SN-MP, U1-NA (Linear), U1-NA(Angular), AO-BO, Articular Angle and Gonial Angle**. Among them **SN-OP, U1-NA (Linear), AO-BO, Articular and Gonial angle** had higher significant difference **(p<0.001).** So, it is conclusive to say that within the present conditions, AI based fully Automatic cephalometric tracing algorithm is not developed enough to replace the reliable, tried and tested Computer Aided semi-automated method. But the beauty of AI and machine learning is that it is constantly evolving in most literal sense so it can't be far-fetched to say that AI has the potential to replace and surpass existing methods in the near future.

REFERENCES

[1]. Livas C et al. Concurrent validity and reliability of cephalometric analysis using smartphone apps and computer software. Angle Orthod. 2019; 89(6):889-896.

[2]. Lindner C et al. Fully Automatic System for Accurate Localisation and Analysis of Cephalometric Landmarks in Lateral Cephalograms. Sci. Rep. 2016; 6:1-10.

[3]. Kim H, Shim E, Park J, Kim YJ, Lee U, Kim Y. Web-based fully automated cephalometric analysis by deep learning. Comput Methods Programs Biomed. 2020; 194:1-7.

[4]. Alqahtani H. Evaluation of an online website-based platform for cephalometric analysis. J Stomatol Oral Maxillofac Surg. 2020;121(1):53-57.

[5]. Chen YJ et al. The effects of differences in landmark identification on the cephalometric measurements in traditional versus digitized cephalometry. Angle Orthod 2004; 74(2):155-61.

[6]. Meric P, Naoumova J. Web-based Fully Automated Cephalometric Analysis: Comparisons between App-aided, Computerized, and Manual Tracings. Turk J Orthod 2020; 33(3): 142-9.

[7]. Katyal D, Balakrishnan N. Evaluation of the accuracy and reliability of WebCeph – An artificial intelligence-based online software. APOS Trends Orthod. 2022

[8]. Coban G, Ozturk T, Hashimli N, Yagci A. Comparison between cephalometric measurements using 2 digital manual and web-based artificial intelligence cephalometric tracing software. Dental Press J Orthod. 2022; 27(4):1-26.

[9]. Mahto RK, Kafle D, Giri A, Luintel S, Karki A. Evaluation of fully automated cephalometric measurements obtained from web‑ based artificial intelligence driven platform. BMC Oral Health. 2022; 22:132.

[10]. R Leonardi, D Giordano, F Maiorana, C Apampinato. Automatic cephalometric analysis: A systematic review. Angle Orthod. 2008; 78:145-151.

[11]. Anuwongnukroh N et al. Assessment of the Reliability of Automatic Cephalometric Analysis Software. Int. J. Mech. Eng. Robot. Res. 2018; 7(1):61-65.

[12]. YA et al., The accuracy and reliability of WebCeph for cephalometric analysis. J Taibah Univ Med Sci. 2022;17(1):57-66

[13]. Rahimi HM et al. Machine learning and orthodontics, current trends and the future opportunities: A scoping review. Am J Orthod Dentofacial Orthop. 2021; 160(2):170-192.

[14]. Bichu YM, Hansa I, Bichu AY, Premjani P, Mir CF, Vaid NR. Applications of artificial intelligence and machine learning in orthodontics: a scoping review. Prog Orthod. 2021; 22:18

[15]. Ristau B, coreil M, Chapple A, Armbruster P, Ballard R. Comparison of AudaxCeph®'s fully automated cephalometric tracing technology to a semi-automated approach by human examiners. Int Orthod. 2022

[16]. Bulatova G et al. Assessment of automatic cephalometric landmark identification using artificial intelligence. Orthod Craniofac Res. 2021; 2:37-42.

[17]. Kim J et al. Accuracy of automated identification of lateral cephalometric landmarks using cascade convolutional neural networks on lateral cephalograms from nationwide multi-centres. Orthod Craniofac Res. 2021; 2:59-67.

Dr. Nishal Khattri. "To compare the reliability and accuracy of artificial intelligence (AI) based fully automated cephalometric tracing software with computer aided semi-automatic cephalometric software." *IOSR Journal of Dental and Medical Sciences (IOSR-JDMS),* 22(4), 2023, pp. 26-33.