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Utilization of multi-point reloading as a radiographic superimposition method in 2D follow up cephalometric images of orthodontic cases (Retrospective study)

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ABSTRACT

Objective: *The current study aimed to accurately assess the digital wise superimposition of the lateral cephalometric images through the reloading of definite pre-treated images anatomical landmarks expressed points on the follow up ones.*

Methods: *Sixty-one pre and follow up orthodontic cases cephalometric images were superimposed using fiji software multi point tools. Linear and angular measurements between anatomical landmarks expressed points were obtained on the pre and follow up images to assess the accuracy of the superimposition used method by a radiologist and orthodontist.*

Results: *Intra and inter-observer reliability was more than 0.99. Pre and follow up linear and angular measurements showed no statistically significant difference ($p > 0.05$), except for C-D linear measurements that showed statistically significant difference ($p < 0.05$). Mann-Whitney test of the absolute measurement error (AME) difference between the linear and angular comparable measurements showed no significant difference ($p > 0.05$).*

Conclusion: *The current study concluded that reloading points that define specific landmarks from pre on follow up cephalometric radiographs can be considered as an accurate superimposition method for assessing the maxillofacial growth pattern and treatment changes follow up.*

KEYWORDS: *Digital superimposition; fiji software; landmarks; lateral cephalometric; reloading points.*

INTRODUCTION

Using the lateral cephalometric images as a diagnostic tool as well as an orthodontic treatment planning component in assessing maxillofacial and dental relationships through performing angular and linear measurements is persistence orthodontic need.**[1]** Severe skeletal malocclusions, performing orthognathic surgery and deciding the suitable orthodontic appliances could be a sequence of accurate lateral cephalometric analysis.**[1, 2]**

Orthodontic cephalometric analysis could be manually accomplished through hand tracing or digitally using varieties of. commercial software. Hand tracing on analog images is time consuming, skills dependent regarding the accurate and reproducible identification of the landmarks.**[2]** Digital assessment of dental- skeletal structures and growth foretelling using cephalometric programs is an efficient part of the orthodontic tasks nowadays.**[3]**

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Superimposition of standardized 2D lateral cephalometric radiographs taken at definite time point periods to assess the dentofacial complex treatment prognosis and judging the outcomes playing an important role in orthodontic field.**[4, 5]** Reference planes , variety of cephalometric landmarks and anatomical structures have been employed for cephalometric radiographs superimposition in different introduced superimposition methods .**[6, 7]** For being technique sensitive; cephalometric radiographs superimposition should be carefully executed in order to provide convincing evaluation of advance structural changes.**[8]**

Degree of anatomical landmarks stability in the superimposition of lateral cephalograms is essential more dependable orthodontic treatment outcomes prediction and assessment. Using stable landmarks such as cranial base, cranial points, lines or regional contours has been stablished as superimposition registration references.**[9]** In order to be precise and reproducible; superimpositions must be performed under optimum magnification conditions, patient head orientation, exposure parameters, and tracing of the superimpositions could be reproducible and accurately locate the relevant structures outlines, without any confusion.**[10]**

Since lateral cephalogram is routinely used for the assessment of maxillofacial skeletal pattern as well as for the assessment of pre-post treatment changes, In the current study we evaluate the value of reloading the cephalometric anatomical landmarks expressed as points of the pre-treatment images on the follow up ones as a superimposition method for assessing the orthodontic growth changes. Based on our knowledge no previous study has evaluated that.

METHODOLOGY

The current retrospective study was performed using 61 pre and follow up lateral cephalometric images of treated patients; (19 males and 42 females) of mean ages at pre and follow up images were 16 and 18 years respectively, collected from radiology department achieve, MTI University. The study approved by the research ethics committee, Faculty of dentistry, Cairo University. The study performed by a maxillofacial radiologist and an orthodontist, with more than 10 years of experience.

Eligibility criteria

Inclusion criteria

1. Serial digital cephalometric radiographs of the same patient.
2. Standardized lateral cephalometric radiographs obtained by the same machine.

Exclusion criteria

1. Blurred lateral cephalometric radiographs.
2. Patients undergone cranium surgery.
3. Any systemic conditions that could affect the cranium bony structures.

All pre and follow up standardized lateral cephalometric radiographs were superimposed

based on Björk structural superimposition method.**[11]**

Three stable cranium anatomical landmarks will be used as reference structures for the superimposition;

1. **The intersection of the anterior clinoid process lower contour and the anterior slope of sella, Walkers´s point. (Point a)**
2. **The intersection between the middle cranial fossa anterior contour and the orbital roof cranium interface. (Point b)**
3. **The intersection between the middle cranial fossa anterior contour and the bilateral fronto-ethmoidal crest contour. (Point c)**

The follow up lateral cephalometric radiographs have been reoriented (rotated) based on the cerebral orbital roof contour inclination to match that of the pre-treated ones if needed. The pre- and follow up lateral cephalometric radiographs will be superimposed by reloading the points defined by the multi point tool of NIH Fiji software (National Institutes of Health, Bethesda, MD) that represents the aforementioned anatomical landmarks of the pre ones which was saved on the ROI manager upon the follow up ones. After reloading the points, it has been dragged as a group and repositioned on its counterpart cranium anatomical landmarks using point a as a reference point.

All cephalometric images undergone calibrated, then for assessing the accuracy of the superimposition, additional landmark in the pre- and follow up radiographs was defined as point d (the intersection between the inner surface of the frontal bone and orbital roof cranium interface) without reloading it and four measurements has been taken; figure 1

- **Linear measurements between point b and point d, point c and point d.**
- **Angular measurements between the true horizontal line and the lines connected point b with point d, point c with point d.**

25% of the images were revaluated by the radiologist at one week interval and the inter and intra-observer reliability has been calculated.

Statistical analysis: The Statistical analysis done on excel 365 with real statistics resource pack v 7.1 as add in. data was tested for normality using Shapiro-Wilk test. Intra- and interclass correlation coefficients were calculated for each parameter to assess the reliability of measurements with the following scale; 0.50: poor, between 0.50 and 0.75: moderate, between 0.75 and 0.90: good, above 0.90: excellent. Paired T test and Wilcoxon signed rank tests were applied to test the parametric and non-parametric measured values respectively. with Alpha value 0.05, confidence interval 95% thus P value less than 0.05 is consider Significant. Absolute measurement error (AME) was calculated according to the following equation: Absolute measurement error (AME) = $\sqrt[2]{(pre - post)^2}$ and was presented as mean and standard deviation where the significance of the difference was tested by using Mann-Whitney Test, p value less than 0.05 is considered significant.

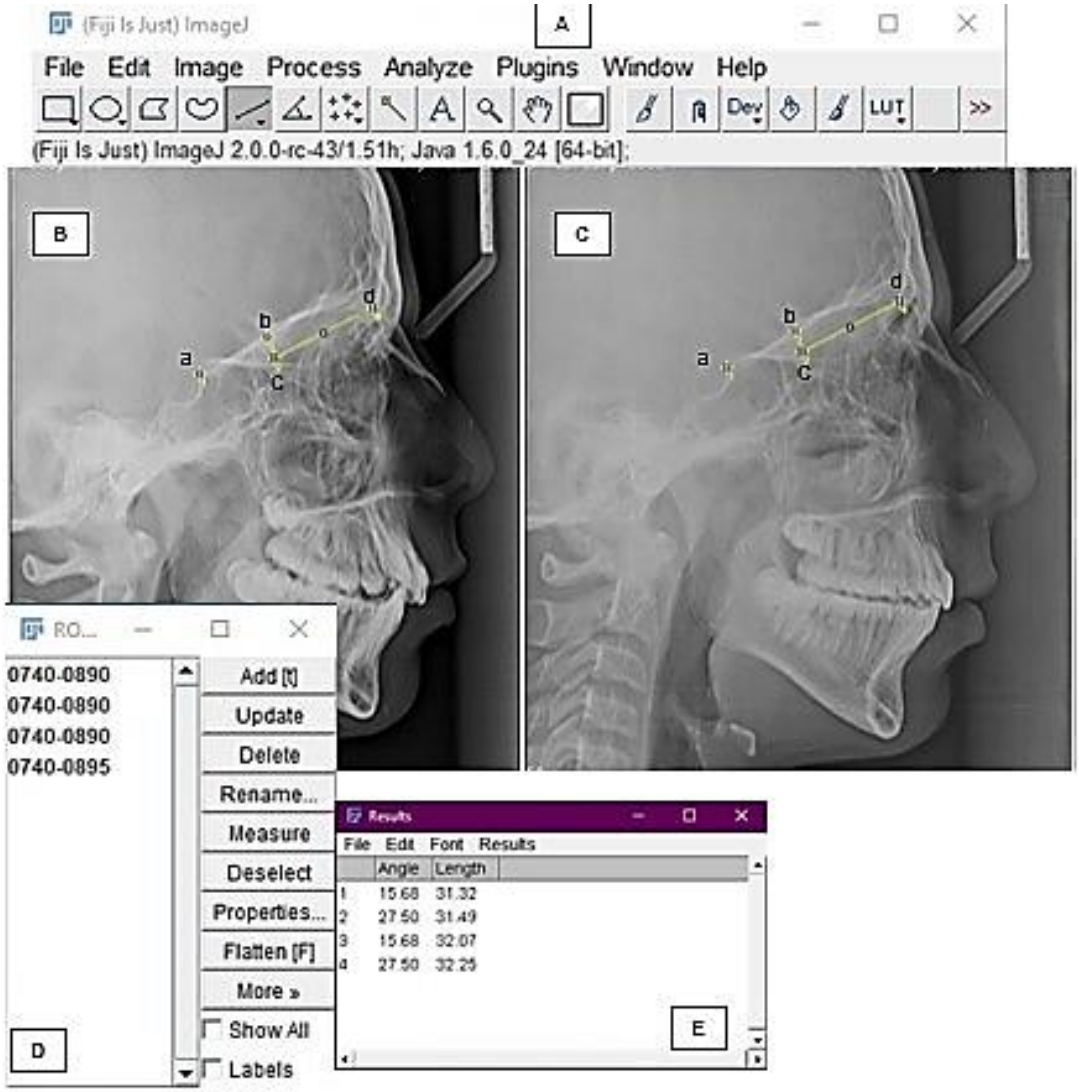

Fig. 1. Simple illustration of the study design; Fiji status bar illustrating straight line selection for linear measurements (A), pre cephalometric image illustrating the study used landmarks expressed as **a**, **b**, **c** and **d** points, and the **b-d** linear measurement (yellow line) (B), the follow up cephalometric image illustrating the study used landmarks expressed as **a**, **b**, **c** and **d** points, and the **b-d** linear measurement (yellow line) (C), ROI manager illustrating **a**, **b**, **c** and **d** points as x-y coordination (D), the results box showing the linear measurements and the angles formed with the horizontal line(E).

RESULTS

Sixty-one pre and follow up standardized lateral cephalometric radiographs were superimposed using reference digital point reloading of a stable anatomical landmark based on Björk structural superimposition method.

The intra and interclass correlation coefficient was used to estimate the reliability of measurements made by the same observer and between the two observers, and it showed strong correlation with ICC value 0.99.

Wilk test was used to check the data normal distribution. Paired T test was used for parametric data while Wilcoxon signed rank test was applied to test the non-parametric ones, with a significance level of 0.05 (α value) for all tested variables.

Pre and follow up cephalometric images **b-d** linear measurements, angular measurements between **bd-horizontal line** and **cd-horizontal line** **s**howed no statistically significant difference ($p > 0.05$), while **c-d** linear measurements **s**howed statistically significant difference ($p < 0.05$) as shown in **table 1**.

AME descriptive analysis of the linear and angular measured values was expressed as mean and standard deviation and shown in **table 2**

Mann-Whitney Test was used to test the AME significant difference between the linear and angular measurements, each one with its comparable and showed no significant difference with p= 0.81 for linear measurements and 0.75 for angular measurements respectively.

Table 1: Paired sampled p-value significance with confidence interval 95% of the tested values

	No.	*p-value**	*95% Confidence Interval*		*Sig*
			Lower	*Upper*	
D (b&d)**	**61**	**0.078**	**-0.374**	**0.020**	**No**
D (c&d)**	**61**	**0.047**	**-0.388**	**-0.002**	**Yes**
A* (bd-horizontal line)**	**61**	**0.504**	**-0.592**	**0.294**	**No**
A* (cd-horizontal line)**	**61**	**0.613**	**-0.531**	**0.316**	**No**

*** ≤ 0.05**

D for distance, A * for angle**

N.B. Wilcoxon Signed-Rank Test showed statistically no significant difference between the pre and post cephalometric images BD-horizontal line angular measurements (non-parametric data), p value > 0.05.

Table 2: Mean and standard deviation of Absolute Measurement Error (AME)

	Mean	***SD***
D (b&d)**	**0.578**	**0.535**
D (c&d)**	**0.567**	**0.527**
A* (bd-horizontal line)**	**1.317**	**1.119**
A* (cd-horizontal line))**	**1.266**	**1.058**

D for distance, A*** for angle**

DISCUSSION

Cephalometric radiographic images have considered substantial tool regarding maxillofacial orthodontic problems diagnosis, treatment planning and growth pattern changes since it was first discovered by **Hofrath and Broadbent in 1931.[12]** Although being subjective, time-consuming and accuracy is experience dependent; hand tracing of the craniofacial anatomic structural contours recorded on cephalograms on acetate paper used to be the default cephalometric analysis method.**[7, 13-18]** To gain accuracy and time saving; computerized cephalometric analysis was defined as an adequate replacement for the traditional hand tracing method.**[19-23]**

Lateral Cephalometric radiographic images superimposition is a determining orthodontic-orthopaedic tool in the era of evaluating treatment response and orthognathic surgery outcomes.**[24]** Structural based superimposition method fastens on the tracing of structural specifics, which is independent of landmarks and is still not credible by all the current available software.**[25]** Digital structural superimposition on stable regions instead of reference planes has been established as the most accurate superimposition method.**[12]**

Björk structural superimposition-based method to evaluate the craniofacial growth in growing patient has been widely recognized as the gold standard superimposition method,**[26]** this method is entrenched on the stability of specific anatomical bone structures.**[27, 28]**

As digital superimposition of serial cephalometric radiographs to track the maxillofacial orthodontic changes with free available software, easy applied method and as accurate as the commercial used superimposition software is a persistent need, the current study main target was to fulfill all the aforementioned requirements.

As the reliability and accuracy levels of a superimposition are affected by the specific superimposition method used;**[29]** in the current study we employed Björk structural superimposition-based method to digitally superimpose different time point cephalometric radiographs through the reloading of definite anatomical landmarks expressed points of the base line radiograph on the follow up one. Our

results showed that our used method has high reliability and accuracy and comparable with the Björk's based three used digital techniques conducted by **Al-Taai N, et al., 2021** especially the subtraction one,**[30]** however that study evaluate different linear and angular measurements.

The accuracy of the superimposition method used also based on the degree of stability of the structure used, so in the current study we used T point (our **Point a**) as a reference point for registration of serial cephalometric radiographs beside the reorientation of the follow up images according to the inclination angle of cerebral orbital roof contour. **Mirzen Z, et al., 2010** mentioned that T point is the most stable cranial base landmark in both horizontal and vertical directions and through all stages.**[8]**

In the current study the only variant that showed significant difference between the pre and follow up images was **c-d** linear measurements, that can be explained as that by slight magnification of one of the serial images the angular measurements remain unchanged because of the proportioned magnification of all structures, while linear measures could be affected.**[31]** furthermore as **c-d** linear measurements in our study are greater than **b-d** linear measurements so greater error could be assumed.

Although the **c-d** linear measurements between the pre and the follow up images showed significant difference in the current study, it assumed to has no clinical significance according to the study conducted by **Durão AR, et al., 2014[32]** as the mean difference regarding all measured **c-d** linear measurements is 0.57± 0.53 mm which is generally within one standard deviation of "base images" values. Furthermore, mean difference between comparable variants (**b-d** and **c-d** linear measurements), (**bd**-horizontal line and **cd**-horizontal line angular measurements) showed no significance difference which mean the sustainability of accuracy within the different directions.

CONCLUSION

The current superimposition method can be considered accurate for assessing the maxillofacial growth and orthodontic treatment planning and follow up. This method offers an easy, reproducible and cost free available alternative superimposition method competing with the manual and licensed commercially available software.

REFERENCES

1. American Association of Orthodontists. Clinical Practice Guidelines for Orthodontics and Dentofacial Orthopedics. Pretreatmet Considerations: Diagnostic Records. 2017 [Available from: https://www.scribd.com/document/367418780/Clinical-Practice-Guidelines-2017.

2. Thurzo A, Javorka V, Stanko P, Lysy J, Suchancova B, Lehotska V, et al. Digital and manual cephalometric analysis. Bratislavske lekarske listy. 2010;111(2):97-100.

3. Segura FJ, Valverde AS, Ocampo AM, Angelares PR. Comparative study between digital and manual cephalometry with digital radiographs. Revista Mexicana de Ortodoncia. 2014;2(2):95-98.

4. Jacobson A, Sadowsky PL. Superimposition of cephalometric radiographs. In Alexander J, eds. A. Radiographic cephalometry: from basics to videoimaging. Chicago: Quintessence. 1995:165-173.

5. Weissheimer A, Menezes LM, Koerich L, Pham J, Cevidanes LH. Fast three-dimensional superimposition of cone beam computed tomography for orthopaedics and orthognathic surgery evaluation. Int J Oral Maxillofac Surg. 2015;44(9):1188-1196. doi: 10.1016/j.ijom.2015.04.001.

6. Ghafari J, Engel FE, Laster LL. Cephalometric superimposition on the cranial base: a review and a comparison of four methods. Am J Orthod Dentofacial Orthop. 1987;91(5):403-413. doi: 10.1016/0889-5406(87)90393-3

7. Baumrind S, Miller D, Molthen R. The reliability of head film measurements: 3. Tracing superimposition. Am J Orthod. 1976;70(6):617-644. doi: 10.1016/0002-9416(76)90224-4.

8. Arat ZM, Türkkahraman H, English JD, Gallerano RL, Boley JC. Longitudinal growth changes of the cranial base from puberty to adulthood: a comparison of different superimposition methods. Angle Orthod. 2010;80(4):537-544. doi: 10.2319/080709-447.1.

9. Lenza MA, Carvalho AA, Lenza EB, Lenza MG, Torres HM, Souza JB. Radiographic evaluation of orthodontic treatment by means of four different cephalometric superimposition methods. Dental Press J Orthod. 2015;20:29-36. doi: 10.1590/2176-9451.20.3.029-036.oar.

10. Graber LW, Vanarsdall RL, Vig KW, Huang GJ. Orthodontics-Inkling Enhanced E-Book: Current Principles and Techniques. Elsevier Health Sciences; 2016 Jul 15.

11. Lo Giudice A, Ronsivalle V, Zappalà G, Leonardi R, Campagna P, Isola G, et al. The Evolution of the Cephalometric Superimposition Techniques from the Beginning to the Digital Era: A Brief Descriptive Review. Int J Dent. 2021. doi: 10.1155/2021/6677133. eCollection 2021.

12. Björk A. Guide to Superimposition of Profile Radiographs by “The Structural Method”. Allen Press: Lawrence, KS, USA; 2010.

13. Broadbent BH. A new x-ray technique and its application to orthodontia. Angle Orthod. 1931;1(2):45-66.

14. Huja SS, Grubaugh EL, Rummel AM, Fields HW, Beck FM. Comparison of hand-traced and computer-based cephalometric superimpositions. Angle Orthod. 2009;79(3):428-435. doi: 10.2319/052708-283.1.

15. Xia JJ, Gliddon MJ, Gateno J, Teichgraeber JF, Wong HT, Liebschner MA. The accuracy of cephalometric tracing superimposition. J Oral Maxillofac Surg. 2006;64(2):194-202. doi: 10.1016/j.joms.2005.10.028.

16. Roden-Johnson D, English J, Gallerano R Comparison of hand-traced and computerized cephalograms: landmark

identification, measurement, and superimposition accuracy. Am J Orthod Dentofacial Orthop. 2008;133(4):556-64. doi: 10.1016/j.ajodo.2006.03.041.

17. Cook PA, Gravely JF. Tracing error with Björk's mandibular structures. Angle Orthod.1988;58(2):169-178.doi:10.1043/0003-3219(1988)058<0169:TEWBMS>2.0.CO;2.

18. Tsorovas G, Linder-Aronson Karsten A. A comparison of hand-tracing and cephalometric analysis computer programs with and without advanced features--accuracy and time demands. European journal of orthodontics. Eur J Orthod. 2010;32(6):721-728. doi: 10.1093/ejo/cjq009.

19. Yue W, Yin D, Li C, Wang G, Xu T. Automated 2-D cephalometric analysis on X-ray images by a model-based approach. IEEE Trans Biomed Eng. 2006;53(8):1615-1623. doi: 10.1109/TBME.2006.876638.

20. Chen YJ, Chen SK, Chung-Chen Yao J, Chang HF. The effects of differences in landmark identification on the cephalometric measurements in traditional versus digitized cephalometry. Angle Orthod. 2004;74(2):155-161. doi: 10.1043/0003-3219(2004)074<0155:TEODIL>2.0.CO;2.

21. Ongkosuwito EM, Katsaros C, Van't Hof MA, Bodegom JC, Kuijpers-Jagtman AM. The reproducibility of cephalometric measurements: a comparison of analogue and digital methods. Eur J Orthod. 2002;24(6):655-665. doi: 10.1093/ejo/24.6.655.

22. Baumrind S, Miller DM. Computer-aided head film analysis: The University of California San Francisco method. Am J Orthod. 1980;78(1):41-65. doi: 10.1016/0002-9416(80)90039-1.

23. Polat-Ozsoy O, Gokcelik A, Toygar Memikoglu TU. Differences in cephalometric measurements: a comparison of digital versus hand-tracing methods. Eur J Orthod. 2009;31(3):254-259. doi: 10.1093/ejo/cjn121.

24. Heinz J, Stewart K, Ghoneima A. Evaluation of two-dimensional lateral cephalogram and three-dimensional cone beam computed tomography superimpositions: a comparative study. Int J Oral Maxillofac Surg. 2019;48(4):519-525. doi: 10.1016/j.ijom.2018.10.002.

25. Jiang Y, Song G, Yu X, Dou Y, Li Q, Liu S, et al. The application and accuracy of feature matching on automated cephalometric superimposition. BMC Med Imaging. 2020;20(1):1-7. doi: 10.1186/s12880-020-00432-z.

26. Kim MG, Moon JH, Hwang HW, Cho SJ, Donatelli RE, Lee SJ. Evaluation of an automated superimposition method based on multiple landmarks for growing patients. Angle Orthod. 2022;92(2):226-232. doi: 10.2319/010121-1.1.

27. Bjo A, Skieller V. Facial development and tooth eruption: an implant study at the age of puberty. Am J Orthod. 1972;62(4):339-383. doi: 10.1016/s0002-9416(72)90277-1.

28. Björk A, Skieller V. Normal and abnormal growth of the mandible. A synthesis of longitudinal cephalometric implant studies

over a period of 25 years. Eur J Orthod. 1983;5(1):1-46. doi: 10.1093/ejo/5.1.1.

29. Houston WJ, Lee RT. Accuracy of different methods of radiographic superimposition on cranial base structures. Eur J Orthod. 1985;7(2):127-135. doi: 10.1093/ejo/7.2.127.

30. Al-Taai N, Levring Jäghagen E, Persson M, Ransjö M, Westerlund A. A superimposition-based cephalometric method to quantitate craniofacial changes. Int J Environ Res Public Health. 2021;18(10):5260. doi: 10.3390/ijerph18105260.

31. Rino Neto J, Paiva JB, Queiroz GV, Attizzani MF, Miasiro Junior H.. Evaluation of radiographic magnification in lateral cephalograms obtained with different X-ray devices: experimental study in human dry skull. Dental Press J Orthod. 2013;18:17e1-e7. doi: 10.1590/s2176-94512013000200005.

32. Durão AR, Bolstad N, Pittayapat P, Lambrichts I, Ferreira AP, Jacobs R. Accuracy and reliability of 2D cephalometric analysis in orthodontics. Revista Portuguesa de Estomatologia, Medicina Dentária e Cirurgia Maxilofacial. 2014;55(3):135-141. https://doi.org/10.1016/j.rpemd.2014.05.003.