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Original Article

Comparison of Accuracy and Reliability of Automated tracing Android appwith Conventional and Semiautomated Computer aided tracing software for Cephalometric Analysis – A cross-sectional study

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Abstract

Introduction
Cephalometry used as an adjuvant tool in orthodontic diagnosis has undergone significant changes from manual tracing to computer assisted digital tracing cephalometric analysis system. The smart phone apps running in android or other operating systems were introduced recently for doing cephalometric analysis. Hence this study was done comparing the accuracy and reliability of automated tracing (Webceph Android app) with gold standard manual tracing and semi-automatic tracing (NemoCeph).

Materials and Methods
The study was performed on 39 Pre-treatment lateral cephalograms. 10 angular and 11 linear skeletal, dental and soft tissue parameters were assessed by tracing the cephalograms manually, digitally using Nemoceph software and Webceph app. The mean and standard deviation were calculated, the overall intergroup comparisons were done using ANOVA test and individual intergroup comparisons were done by post-hoc analysis using Sidak Test. The overall interclass correlation coefficient (ICC) was calculated between the three groups.

Results
Angular measurements such as Occlusal plane to SN ($P< 0.05$) and Nasolabial angle ($P< 0.05$) showed significant difference between the different tracing methods and the linear parameters such as N perpendicular to Point A ($P< 0.05$) and Wits Appraisal ($P< 0.05$) showed significant difference between the different tracing methods. The overall reliability statistics showed good agreement ($P<0.05$) among all three groups.

Conclusion
Automated tracing (WebCeph) had more landmark identification errors when compared with manual or semi-automatic tracing (Nemoceph). Both WebCeph and Nemoceph were superior in their reliability when compared to manual tracing, with Nemoceph demonstrating greater efficacy compared to WebCeph.

Key Words - Cephalometrics, Automated tracing, Dental Landmarks

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Introduction

The advent of digital dentistry has broadened the scope and area of research activity particularly in the field of orthodontics. The recent advances in diagnosis and treatment planning using computer-assisted programs helps the clinician to view the problems in various dimensions and come to a definite diagnosis and treatment plan. Cephalometry introduced by Broadbent in 1931 was used as an adjuvant tool in orthodontic diagnosis. It has undergone significant changes from manual tracing to computer-assisted digital tracing.[1] The introduction of artificial intelligence in cephalometric tracing has made it even easier with the automatic identification of landmarks through Artificial neural network and deep learning.[2] The advantage of using computer-assisted digital cephalometric analysis over traditional manual tracing include: precision in measurement, decreased error, enhanced speed, decreased time and inventories, reduces physical storage space, decreased reproducibility errors. [2,3] The popularly used digital tracing Software's include Dolphin Imaging, Vistadent, Nemoceph, and Quick Ceph.[4] It was found that there are no significant differences between the manual and computer-assisted cephalometric analysis except in one or two parameters [4-7]

In recent years smartphone apps have taken up the role of computer software in performing cephalometric analysis. Smartphone applications are portable and available free of cost. [8,9] The advances in technology come with the question of accuracy, reliability, and reproducibility. The smart phone Apps running in Android or other operating systems introduced recently for cephalometric analysis can be either Automatic (Artificial intelligence powered) or Semi-Automatic (Requires manual identification of landmarks). The commonly available smart phone applications are CephNinja, SmartCeph Pro, OneCeph and WebCeph. There are very few literatures comparing the reliability of smartphone apps. The recently introduced WebCeph application (Assemble circle crop, Korea) in Android platform has gained popularity because of its Artificial intelligence technology for automatic detection of landmarks which are the features only available in computer tracing software's. This app has a user-friendly interface and available free of cost with optional paid membership for premium features. A recent study done by Yassir et al comparing WebCeph computer program with AutoCAD computer software and found errors in identification of landmark. [10] Another study done by Katyal et al found that WebCeph online program was found to be time saving and reliable. [11]

The literature evidence for the accuracy and reliability of this new smartphone app is still lacking. Hence this study was done comparing the accuracy and reliability of the automated tracing program (Webceph Android app) with standard manual tracing and semi-automated ceph tracing software (NemoCeph).

Materials and methods

The study was conducted after getting approval from the Ethical committee at Rajas Dental College, Kavalkinaru. IRB approval number-RDCH/IRB/EC/09/22. The sample size was determined using nMaster 2.0 sample size software based on mean with equal allocation method using data obtained from a previous study.[11] The final sample size obtained with an effect size of 0.75 and power set at 80% was 39. The included cephalograms were analyzed with all the 3 methods of cephalometric tracing as three different groups (Group A- Manual tracing, Group B- Nemoceph, Group C- Webceph). The pre-treatment lateral cephalograms were obtained from the department of Oral medicine and Radiology, Rajas dental college and hospital, affiliated to Tamil Nadu Dr.MGR Medical University, the digital cephalogram image was imported directly from the SIDEXIS next Generation software instead of scanned images to avoid errors.[14] For manual tracing printed hard copy in 1:1 scale was used.

Selection Criteria

The lateral cephalograms of individuals who were indicated for orthodontic treatment with completely erupted permanent teeth, no gross craniofacial asymmetry or pathology, no previous history of orthodontic treatment and radiographs without any artifacts were selected.

All the lateral cephalograms were taken with Frankfort horizontal plane parallel to the floor and the midsagittal plane perpendicular to the X-ray beam with patient biting in centric occlusion and relaxed lips using ORTHOPHOS XG, Sirona dental system, Germany and printed using DRYPIX Lite (Fujifilm corporation) and calibrated hard copy of the radiograph was traced under an X-ray view box with 0.3mm hard black lead pencil on a 0.003mm Acetate tracing paper.

All landmarks were identified by a Final Year postgraduate student following the guidelines given by Hlongwa under the supervision of experienced orthodontist.[12] In case of superimposed bilateral anatomical structures and double images, the mid-point was chosen, not more than two cephalograms were traced in a single day to prevent examiner fatigue and the study was completed in a period of 3 months. 10 angular and 11 linear measurements containing skeletal, dental, and soft tissue parameters (Table 1) were recorded using scale and protractor.

For the digital tracing the images were directly exported from the SIDEXIS next Generation software in JPEG format (with a resolution of 1804×2148 pixels and 244 dpi and 24-bit depth). The images were imported into NemoCeph software in desktop and WebCeph Android application using a Samsung Galaxy J8 smartphone (Samsung C&T Corporation, Seoul, South Korea) (Figures 1 and 2). The images were calibrated and the same calibration was used for all to avoid errors in linear measurements.

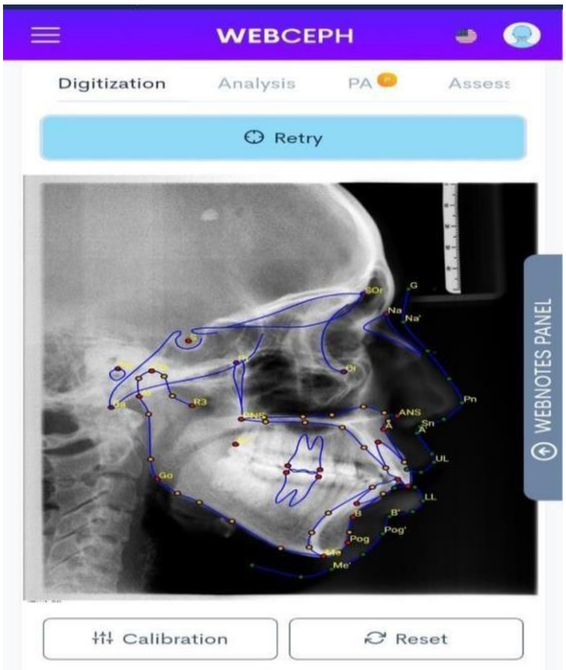

Figure 1 – Automatic tracing by Webceph App

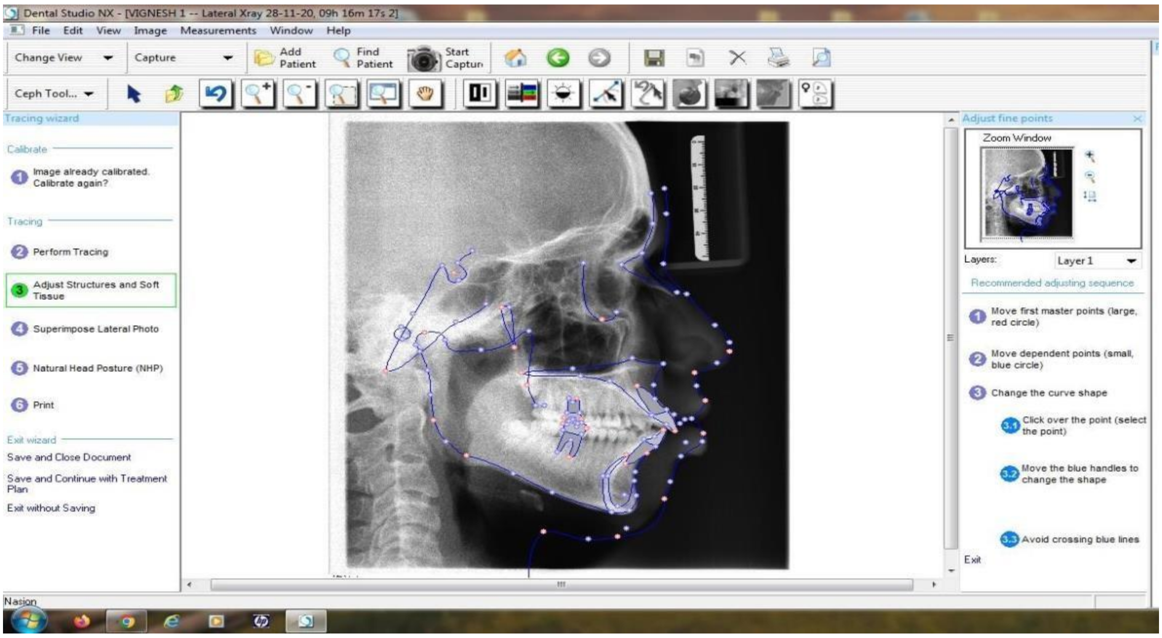

Figure 2 – Tracing using Nemoceph Software

Statistical analysis

Data regarding values of linear and angular measurements of different tracing groups were entered in Microsoft Excel and analyzed using SPSS Version 22 Software, IBM Statistics, USA. Normality test was accessed using Kolmogorov-Smirnov test, and the data obtained was found to be normally distributed. Mean and standard deviation were calculated, and overall intergroup comparison was done using ANOVA test [Table 2(a) and 2(b)] and individual intergroup comparison was done by post-hoc analysis using Sidak Test [Table 3(a) and 3(b)] and P value was set < 0.05 to be significant. The overall reliability statistics involving the interclass correlation coefficient (ICC) for inter-observer reliability were done (Table 4).

Results

This study was done comparing 10 angular measurements and 11 linear measurements between three different groups A, B, C (Manual tracing, Nemoceph, WebCeph) given in Table 1.

Table 1 – Parameters Measured :

Angular	**Linear**
SNA	U1 to NA mm
SNB	L1 to NB mm
ANB	N Perpendicular to A
GO GN to SN	N Perpendicular to POG
Occlusal Plane to SN	Effective Maxilla
U1 to NA Angular	Effective Mandible

L1 to NB Angular	LAFH
Inter Incisal Angle	U1 to Point A
Facial Axis Angle	L1 to APOG line
Naso Labial Angle	E Line to Lower Lip
	Wits Appraisal
U1- Upper Incisor POG- Pogonion L1 – Lower Incisor LAFH – Lower anterior facial height	

The overall intergroup comparison was done for angular and linear measurements which are given in the table 2(a) and 2(b) respectively. The angular measurements such as occlusal plane to SN (P< 0.05) and Nasolabial angle (P< 0.05) showed statistically significant difference between the different tracing methods and the linear parameters such as N perpendicular to Point A (P< 0.05) and Wits Appraisal (P< 0.05) showed statistically significant difference between the different tracing methods.

Table 2(a): Overall Inter-Group Comparison for angular measurements

Angular Measurements		N	Mean	SD	p-value
SNA	Manual Tracing	39	83.07	3.38	0.204
	Nemo Ceph	39	84.25	4.59	
	Web Ceph	39	84.58	3.61	
SNB	Manual Tracing	39	79.30	3.04	0.904
	Nemo Ceph	39	79.66	4.29	
	Web Ceph	39	79.38	3.52	
ANB	Manual Tracing	39	3.76	2.80	0.059
	Nemo Ceph	39	4.59	2.59	
	Web Ceph	39	5.18	2.43	
GO GN to SN	Manual Tracing	39	30.92	5.99	0.123
	Nemo Ceph	39	31.79	6.66	
	Web Ceph	39	28.90	6.32	
Occlusal Plane to SN	Manual Tracing	39	16.76	5.16	< 0.001*
	Nemo Ceph	39	24.18	1.63	
	Web Ceph	39	12.84	4.91	
U1 to NA Angular	Manual Tracing	39	32.84	10.66	0.407

	Nemo Ceph	39	32.17	9.30	
	Web Ceph	39	30.01	9.09	
L1 to Nb Angular	**Manual Tracing**	39	33.41	10.83	0.963
	Nemo Ceph	39	33.01	9.45	
	Web Ceph	39	32.63	7.58	
Inter Incisal Angle	**Manual Tracing**	39	110.23	15.45	0.790
	Nemo Ceph	39	109.85	14.83	
	Web Ceph	39	111.90	11.50	
Facial Axis Angle	**Manual Tracing**	39	-0.28	4.34	0.866
	Nemo Ceph	39	0.16	3.82	
	Web Ceph	39	-0.27	4.46	
Naso Labial Angle	**Manual Tracing**	39	99.15	10.67	<0.001*
	Nemo Ceph	39	100.04	9.54	
	Web Ceph	39	84.42	14.13	
p-value based on Analysis of Variance (ANOVA) Test. * = Statistically Significant (p < 0.05).					

Table 2(b): Overall Inter-Group Comparison for Linear measurements

Linear measurements		**N**	**Mean**	**SD**	**p-value**
U1 to NA mm	**Manual Tracing**	39	7.84	3.39	0.265
	Nemo Ceph	39	7.11	3.26	
	Web Ceph	39	6.69	2.76	
L1 to Nb mm	**Manual Tracing**	39	7.23	3.49	0.663
	Nemo Ceph	39	7.51	3.35	
	Web Ceph	39	7.90	2.95	
N Perpendicular to A	**Manual Tracing**	39	-0.20	3.08	< 0.001*
	Nemo Ceph	39	-0.38	3.11	
	Web Ceph	39	2.05	2.58	
N Perpendicular to POG	**Manual Tracing**	39	-6.58	5.26	0.079
	Nemo Ceph	39	-7.29	6.18	
	Web Ceph	39	-4.54	5.07	

Effective Maxilla	**Manual Tracing**	39	82.10	5.29	0.122
	Nemo Ceph	39	78.41	13.80	
	Web Ceph	39	82.01	4.76	
Effective Mandible	**Manual Tracing**	39	102.17	7.11	0.160
	Nemo Ceph	39	101.15	9.49	
	Web Ceph	39	104.44	6.06	
LAFH	**Manual Tracing**	39	59.51	5.30	0.076
	Nemo Ceph	39	58.80	7.14	
	Web Ceph	39	61.70	4.74	
U1 to Point A	**Manual Tracing**	39	7.79	3.61	0.492
	Nemo Ceph	39	6.92	3.27	
	Web Ceph	39	7.59	3.16	
L1 to APOG	**Manual Tracing**	39	4.53	3.68	0.995
	Nemo Ceph	39	4.52	3.38	
	Web Ceph	39	4.59	3.28	
E Line to Lower Lip	**Manual Tracing**	39	2.56	2.96	0.302
	Nemo Ceph	39	2.36	3.16	
	Web Ceph	39	3.37	3.03	
Witts Appraisal	**Manual Tracing**	39	0.39	2.40	< 0.001*
	Nemo Ceph	39	-4.45	3.66	
	Web Ceph	39	3.27	3.67	
p-value based on Analysis of Variance (ANOVA) Test * = Statistically Significant (p < 0.05)					

The individual intergroup comparison was made for the angular and linear measurements given in Table 3(a) and 3(b). The individual intergroup comparison of angular and linear measurements showed statistically significant difference in Occlusal plane to SN and the wits appraisal when group A and group B, group B and group C, group A and group C were compared (P< 0.05). Nasolabial angle and N Perpendicular to point A showed statistically significant difference when group B and group C, group A and group C were compared (P< 0.05), but the comparison of group A and group B did not show statistically significant difference.

Table 3(a): Individual Intergroup Comparison for angular measurements

Angular measurements	Groups	Groups	p-value
SNA	Manual Tracing	NEMO CEPH	0.550
		WEB CEPH	0.272
	Nemo Ceph	WEB CEPH	1.000
SNB	Manual Tracing	NEMO CEPH	1.000
		WEB CEPH	1.000
	Nemo Ceph	WEB CEPH	1.000
ANB	Manual Tracing	NEMO CEPH	0.502
		WEB CEPH	0.055
	Nemo Ceph	WEB CEPH	0.950
GO GN to SN	Manual Tracing	NEMO CEPH	1.000
		WEB CEPH	0.487
	Nemo Ceph	WEB CEPH	0.138
Occlusal Plane to SN	Manual Tracing	NEMO CEPH	< 0.001*
		WEB CEPH	< 0.001*
	Nemo Ceph	WEB CEPH	< 0.001*
U1 to NA Angular	Manual Tracing	NEMO CEPH	1.000
		WEB CEPH	0.601
	Nemo Ceph	WEB CEPH	0.985
L1 to Nb Angular	Manual Tracing	NEMO CEPH	1.000
		WEB CEPH	1.000
	Nemo Ceph	WEB CEPH	1.000
Inter Incisal Angle	Manual Tracing	NEMO CEPH	1.000
		WEB CEPH	1.000
	Nemo Ceph	WEB CEPH	1.000
Facial Axis Angle	Manual Tracing	NEMO CEPH	1.000
		WEB CEPH	1.000
	Nemo Ceph	WEB CEPH	1.000
Naso Labial Angle	Manual Tracing	NEMO CEPH	1.000

		WEB CEPH	< 0.001*
	NEMO CEPH	**WEB CEPH**	< 0.001*

p-value based on Post-hoc analysis using Sidak Test after adjusted for multiple comparisons.
* = Statistically Significant (p < 0.05).

Table 3(b): Individual Intergroup Comparison for Linear measurement

Linear measurements	Groups	Groups	p-value
U1 to NA mm	**Manual Tracing**	**NEMO CEPH**	0.915
		WEB CEPH	0.325
	Nemo Ceph	**WEB CEPH**	1.000
L1 to Nb mm	**Manual Tracing**	**NEMO CEPH**	1.000
		WEB CEPH	1.000
	Nemo Ceph	**WEB CEPH**	1.000
N Perpendicular to A	**Manual Tracing**	**NEMO CEPH**	1.000
		WEB CEPH	0.003*
	Nemo Ceph	**WEB CEPH**	0.001*
N Perpendicular to POG	**Manual Tracing**	**NEMO CEPH**	1.000
		WEB CEPH	0.315
	Nemo Ceph	**WEB CEPH**	0.091
Effective Maxilla	**Manual Tracing**	**NEMO CEPH**	0.216
		WEB CEPH	1.000
	Nemo Ceph	**WEB CEPH**	0.238
Effective Mandible	**Manual Tracing**	**NEMO CEPH**	1.000
		WEB CEPH	0.589
	Nemo Ceph	**WEB CEPH**	0.186
LAFH	**Manual Tracing**	**NEMO CEPH**	1.000
		WEB CEPH	0.298
	Nemo Ceph	**WEB CEPH**	0.089
U1 to Point A	**Manual Tracing**	**NEMO CEPH**	0.770
		WEB CEPH	1.000

	Nemo Ceph	**WEB CEPH**	1.000
L1 to APOG	**Manual Tracing**	**NEMO CEPH**	1.000
		WEB CEPH	1.000
	Nemo Ceph	**WEB CEPH**	1.000
E Line to Lower Lip	**Manual Tracing**	**NEMO CEPH**	1.000
		WEB CEPH	0.725
	Nemo Ceph	**WEB CEPH**	0.433
Witts Appraisal	**Manual Tracing**	**NEMO CEPH**	< 0.001*
		WEB CEPH	0.001*
	Nemo Ceph	**WEB CEPH**	< 0.001*

p-value based on Post-hoc analysis using Sidak Test after adjusted for multiple comparisons.
* = Statistically Significant (p < 0.05).

The overall reliability statistics showed good agreement (P<0.05) with interclass correlation coefficient of 0.811(Manual tracing and Nemoceph), 0.859 (Manual tracing Versus Webceph) 0.861 (Nemoceph versus Web ceph) as shown in Table 4.

Table 4 : **Reliability Statistics**

Group	**Group**	**Inter-Class Correlation (ICC) Value**	**p-value**
Manual Tracing	**NEMO CEPH**	0.861	< 0.001*
Manual Tracing	**WEB CEPH**	0.859	< 0.001*
NEMO CEPH	**WEB CEPH**	0.811	< 0.001*

p-value based on Reliability Statistics
* = Statistically Significant (p < 0.05)

ICC	**Interpretation**
< 0.5	Poor agreement
0.5 to < 0.75	Moderate agreement
0.75 to < 0.9	Good agreement
0.9 – 1.0	Excellent agreement

Discussion

The machine learning algorithm has revolutionized the field of diagnosis and treatment planning in all the fields of dentistry and even in orthodontics, its contribution is rising in recent years.[2] The automated android Webceph Application introduced recently is one milestone making cephalometric analysis easily affordable. Many studies have reported the enhanced speed and accuracy of measurement by computer-aided cephalometric analysis software.[3] This study was done to evaluate the accuracy and reliability of automated ceph tracing (Webceph android app) with conventional (manual tracing) and semi-automatic tracing (Nemoceph) programs. 10 angular and 11 linear measurements were chosen from commonly used cephalometric analysis. The comparison of mean values of all the measurements was done using ANOVA test and individual intergroup comparison was done by post-hoc analysis using Sidak Test.

Among the analyzed 10 Angular and 11 Linear measurements, occlusal plane to SN and Wits appraisal measurements varied in Nemoceph and Webceph when compared with the manual tracing ($P < 0.05$). This was consistent with the results of the study done by Tikku et al, where Occlusal plane to SN showed significant variation with Nemoceph when compared to manual tracing.[13] Regarding the parameters Nasolabial angle and N perpendicular to point A, the variation was more with WebCeph when compared to the Semi-automatic tracing (Nemoceph) and manual tracing. The significant difference in the Nasolabial angle in Automatic tracing (WebCeph) may be due to proportionally larger measurement errors as the Nasolabial angle is determined using landmarks positioned on a curve with wide radii. [14,15]

The other parameter N perpendicular to point A also showed more variation with Automatic tracing (WebCeph) when compared to the Semi-automatic tracing (Nemoceph) and manual tracing. The reason behind this may be linked to inaccuracies in identifying landmarks like porion with Webceph and this landmark identification difficulty was reported even with other semiautomated software's in the past by Chen et al.[15]

In terms of reliability the overall ICC indicates both Nemoceph and WebCeph were reliable with Nemoceph being close to manual tracing. Recently a study done by Tsolakis et al compared the reliability and accuracy of automated tracing (CS imaging V8 software) and Semi-automated (Dolphin 3D Imaging program) and found to be accurate and reliable.[16] Similar results were seen in studies by Goracci and Ferrari,[17] Polat-Ozsoy et al.[18]

The android applications like OneCeph, and CephNinja were also used for cephalometric analysis and studies show that the accuracy and reliability were comparable with manual tracing or Nemoceph.[6,9] The limitation of this study was the inter-observer error with two or more observers for manual and semi-automatic tracing were not done. Another limitation was relatively smaller sample size, although sample size was calculated, since the study involves the comparison of measurements and applicability to the entire population, a bigger sample size would have enhanced the precision.

Conclusion

The smartphone-assisted automated tracing application (WebCeph) had more landmark identification errors (occlusal plane to SN, Nasolabial angle, N perpendicular to point A and Wits appraisal) when compared to manual tracing. Semi-automatic tracing software (Nemoceph) also was inherent with some landmark identification errors (occlusal plane to SN, and Wit's appraisal). On comparing the reliability, both Nemoceph and WebCeph were found to be equally reliable, and keeping in mind the user-friendly interface and free-of-cost availability Webceph can be viewed as an alternative to semi-automated and manual cephalometric tracing.

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Conflict of Interest

The authors have no conflict of interests to declare.

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