DOI: 10.7860/JCDR/2025/76726.20713

Original Article

Dentistry Section

Reliability of Cephalometric Lines as Indicators for Dentoalveolar Stability in Forensic Identification: A Cross-sectional Study

GANDIKOTA KARTHEEK[1], MANYAM RAVIKANTH[2], VARMA D PRAVEEN KUMAR[3], PASUPULETI SWETHA[4], S SUPRAJA[5], BIRAJDAR SMITA[6]

ABSTRACT

Introduction: Cephalometric superimposition is an accepted method that has long been considered helpful for evaluating the growth and displacement of facial bones during orthodontic treatment. However, the use of these cephalometric records for individual identification has not been reported until recently. The present study emphasises the use of lateral cephalographs as a forensic tool for the identification of individuals.

Aim: To assess the alterations in the measurements of specific cephalometric lines observed in tracings obtained before and after orthodontic intervention.

Materials and Methods: A cross-sectional study was conducted in the Department of Oral Pathology, Vishnu Dental College, Bhimavaram, West Godavari District, Andhra Pradesh, India, from September 2024 to November 2024. Study involved 120 participants to assess the stability of cephalometric lines for forensic identification. Standardised lateral cephalometric radiographs, aligned with the Frankfort horizontal plane, were traced on acetate sheets by a single orthodontist to identify the chosen cephalometric lines: Pterygomaxillary fissure (Ptm)-nasion, basion-nasion, sella-nasion, Anterior Nasal Spine (ANS)-sella (anterior cranial base length), Frankfort Horizontal (FH), Posterior Nasal Spine (PNS)-nasion (posterior maxillary height), ANS-nasion (anterior maxillary height), ANS-PNS (maxillary length) and sella-articulare (posterior cranial base length). Pre and post-treatment cephalometric measurements were analysed using a paired t-test. Statistical analysis, performed using Statistical Package for the Social Sciences (SPSS) software version 26.0, deemed changes significant at p-value<0.05. To find significant differences, a paired t-test was used.

Results: Among the 120 samples analysed, the gender distribution was equal, with 50% females and 50% males. The results showed no significant change in the measurements of ANS-sella, FH plane, PNS-nasion, ANS-nasion, ANS-PNS and Sella-articulare, with a p-value >0.05, indicating that skeletal and alveolar stability remained unchanged before and after orthodontic correction.

Conclusion: The present study concludes that the ten reference lines taken can be used as reliable antemortem landmarks for personal identification. The present study is novel in the field of forensic dentistry and hence there is a need for further studies using a larger sample in order to establish a reliable forensic base.

Keywords: Cephalometric superimposition, Forensic identification, Post-treatment cephalograms

INTRODUCTION

For many years, radiographic analysis has been a crucial tool in various medical specialties for assessing internal structures and supporting diagnosis [1]. Cephalometric analysis, which measures the angles and separations between lines and reference points within the craniofacial skeleton, is one type of radiographic analysis [2]. It offers a quantitative method for analysing skeletal and dental relationships and is primarily used to determine the type and degree of malocclusion [3]. Although cephalometric analysis has been extensively employed in orthognathic surgery and orthodontics, little is known about its potential applications in forensic identification [1]. In the context of forensic identification, cephalometric analysis has been investigated, particularly in situations where more conventional techniques, like Deoxyribonucleic Acid (DNA) analysis or fingerprinting, are problematic or infeasible [4]. When soft tissues are severely damaged, as they often are in cases of fire, forensic identification frequently faces challenges [5]. Cranial skeletal structures can provide vital identifying characteristics in these situations [1]. Research has indicated that specific skeletal indicators, such as those observed in lateral cephalometric radiographs, may eventually be utilised in forensic settings for the purpose of identifying an individual [1].

Previous studies have not suggested a consistent or generally recognised technique for identifying people using lateral cephalometric radiographs of cranial skeletal features, despite the possibility of forensic applications [4,6-8]. The majority of forensic identification procedures rely on fingerprints, DNA, or dental data; however, these approaches are not always appropriate, especially when the body is severely decomposed or conventional identifying traits are missing [2]. The absence of studies on the durability of cephalometric reference lines prior to and during orthodontic treatment, as well as, their potential for forensic personal identification, represents a gap in the literature [1].

By investigating whether specific cephalometric lines remain stable and distinguishable following orthodontic procedures, the present study seeks to close this gap and provide an additional means of identification in situations where other approaches might not be practical [1]. The concept that certain cephalometric lines can be stable both before and after orthodontic treatment and could provide a trustworthy method of forensic identification is what makes this work novel [4]. This might be especially helpful in forensic situations where conventional identification techniques are jeopardised, like in the wake of trauma or decomposition [9]. These cephalometric lines will be assessed as a potential addition to the forensic identification toolbox, providing existing techniques with an extra degree of precision and dependability [1].

Thus, the aim of the present study was to assess the reliability of cephalometric lines as indicators of dentoalveolar stability in forensic personal identification. The study aimed to assess dentoalveolar stability using cephalometric analysis before and after orthodontic treatment. The study involved a single orthodontist with a clear, standardised protocol for identifying anatomical landmarks and tracing cephalometric lines on the radiographs to minimise subjective variation. After measuring the cephalometric lines pre and post-treatment, the changes in the values were statistically analysed using a paired t-test to avoid random variation. If the lines remain consistent even after orthodontic interventions, they can be deemed reliable for use in forensic identification.

MATERIALS AND METHODS

The present cross-sectional study was conducted in the Department of Oral Pathology, Vishnu Dental College, Bhimavaram, West Godavari District, Andhra Pradesh, India, from September 2024 to November 2024. The study was approved by the Institutional Ethical Committee (IECVDC/24/F/OP/IVT/121).

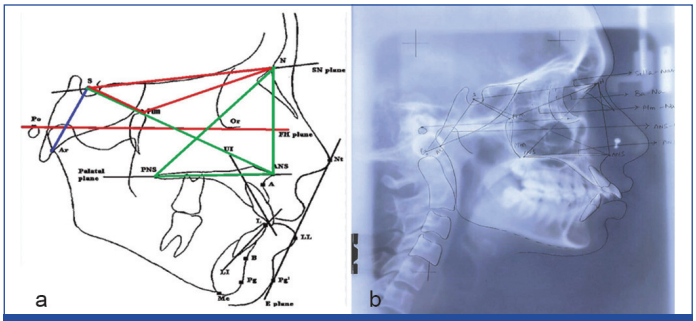
Inclusion criteria: Radiographs of male and female patients aged 16-27 years, without any pathology and with adequate density, contrast and clarity. Patients were selected who had completed their growth and their radiographs were of high quality.

Exclusion criteria: Radiographs that were blurred, had artifacts from metallic objects, did not cover the entire mandible, or presented associated pathologies that could interfere with cephalometric analysis.

Sample size calculation: Calculations were performed to determine the sample size for exploring the use of pre and post-treatment lateral cephalograms for forensic personal identification as the primary outcome, using G*Power software version 3.1.9.4. In the pilot study, which included five males and five females, the calculated effect size was 0.229, with an alpha level of 0.05 and a desired power of 80%. Based on these parameters, the estimated sample size required to achieve adequate statistical power was determined to be 120 participants.

Study Procedure

The study included 120 samples, consisting of 60 females and 60 males seeking orthodontic treatment, all aged between 16 years and 27 years (having completed their growth) at the start of treatment. Standardised lateral cephalometric radiographs were taken in a natural head position aligned with the FH plane using Orthoralyx™. These images were assessed at two stages: at the beginning of orthodontic treatment and after its completion. All pre and post-treatment cephalograms were manually traced on 0.003 lead acetate sheets. A single orthodontist identified the selected landmarks on cephalograms in a predetermined sequence to eliminate observer bias [Table/Fig-1a,b].



[Table/Fig-1]: Various cephalometric landmarks and lines selected in the present study. (a) Schematic representation; (b) Radiograph tracings.

The most commonly used cephalometric skeletal landmarks, such as Sella (S), Nasion (N), Articulare (Ar), Basion (B), Gonion (G), Menton (Me), Anterior Nasal Spine (ANS), Posterior Nasal Spine (PNS) and Pterygomaxillary fissure (Ptm), were used for the present study. The points taken into consideration representing the landmarks of the anterior skull base are S, N and Ptm. In the case of the maxilla, ANS and PNS were considered; for the mandible, articulare was preferred. All the landmarks were identified with the Frankfort plane (FH plane) parallel to the floor. The lines drawn between them typically represent key skeletal relationships that are well-defined and accessible through imaging techniques.

Lines were drawn between primary landmarks (Na, S, Or, Ar, ANS, PNS, Go and Me) and their values were measured [Table/Fig-1-3]. Pre and postoperative changes in the measurements were analysed to evaluate the stability of the selected landmarks as a reliable indicator for dentoalveolar stability in forensic personal identification.

Lines selected on skull base (Marked in red)	Ptm-sella
	Ptm-nasion
	Basion-nasion
	Sella-nasion
	FH plane
Lines selected on maxilla (Marked in green)	PNS-nasion (Posterior maxillary height)
	ANS-nasion (Anterior maxillary height)
	ANS-sella
	ANS-PNS (Maxillary length)
Lines selected on mandible (Marked in blue)	Sella-articulare

[Table/Fig-2]: The selected cephalometric lines taken for consideration [6,7].

Landmark	Description
Nasion (N)	The anterior point where the nasal and frontal bones intersect.
Sella (S)	The midpoint of the pituitary fossa, also known as the sella turcica.
Orbitale (Or)	The lowest point on the inferior margin of the orbit.
ANS	Anterior Nasal Spine (ANS), the tip of the ANS (sometimes modified as the point on the upper or lower contour of the spine where it is 3 mm thick).
PNS	The Posterior Nasal Spine (PNS), defined as the tip of the palatine bone's posterior spine at the junction between the hard and soft palates.
Articulare (Ar)	The point where the contour of the posterior surface of the mandibular condyle intersects with the temporal bone.
Gonion (Go)	• The midpoint of the contour connecting the most inferior point of ramus (Go1) and the most posterior body of the mandible (Go2).
	• The midpoint in the mediolateral dimension on the most posterior border of the mandible.
Menton (Me)	The most inferior point on the chin.
Pterygomaxillary fissure (Ptm)	Most inferior point on average right and left outlines of pterygomaxillary fissure.

[Table/Fig-3]: The description of key landmarks in the lateral cephalograms [6,7].

STATISTICAL ANALYSIS

The collected data were entered into a Microsoft Excel spreadsheet and statistical analysis was conducted using SPSS software version 26.0 (IBM Corporation, USA). A paired t-test was applied to identify significant differences, with p-value<0.05 considered statistically significant. dentoalveolar stability was deemed statistically significant at a p-value of 0.05 or lower.

RESULTS

Among the 120 samples analysed, the gender distribution was equal, with 50% females and 50% males [Table/Fig-4]. The changes in the cephalometric parameters both pre and post-treatment have been illustrated in [Table/Fig-5].

Age group (years)	Males (n)	Females (n)
16-19	35	35
20-23	15	15
24-27	10	10

[Table/Fig-4]: Age and gender distribution of the study samples.

Reference line	Parameters	Males		Females		Overall sample	
		Pretreatment (Mean±SD)	Post-treatment (Mean±SD)	Pretreatment (Mean±SD)	Post-treatment (Mean±SD)	Pretreatment (Mean±SD)	Post-treatment (Mean±SD)
Lines on the skull base	Ptm-sella	20.78±13.25	21.78±13.38	32.86±13.15	32.4±14.09	31.04±15.26	30.54±16.26
	Ptm-nasion	61.5±15.5	66.33±10.1	62.86±9.68	62.8±8.46	62.25±11.87	64.125±9.08
	Basion-nasion	115.11±5.15	111.66±8.91	109±5.39	108.73±7.4	111.29±8.28	109.83±9.28
	Sella-nasion	77.88±3.1	78.44±4.21	72.66±3.37	73.53±3.68	74.62±4.16	75.37±4.50
	FH plane	84±6.9	85.77±9.27	80.06±5.71	80.46±8.58	81.54±6.37	82.45±9.03
Maxillary reference lines	PNS-nasion	65.33±18.6	69.66±16.08	65.8±12.98	64.4±12.93	65.62±6.58	66.37±7.58
	ANS-nasion	57.22±2.8	57.33±3.5	53.96±2.89	55.33±3.37	55.18±3.23	56.08±3.5
	ANS-sella	82±13.8	82.44±9.85	79.06±12.08	80.73±11.31	80.16±12.56	81.37±10.59
	ANS-PNS	56.33±6.96	57.66±7.90	53±4.92	55.86±5.40	54.25±5.86	56.54±6.35
Mandibular reference lines	Sella-Ar	32.77±11.06	33.55±12.62	34.13±7.51	33.53±9.49	33.62±8.79	32.29±10.5

[Table/Fig-5]: Descriptive data of study participants.
SD: Standard deviation

Upon comparison of pre and post-treatment tracings, the selected reference lines showed changes in their measurements. Lines such as Ptm-nasion, basion-nasion and PNS-nasion indicated a 3 mm increase in males compared to females. The slightest change was observed for the ANS-nasion line among males. Conversely, females exhibited larger differences in the ANS-nasion and ANS-PNS lines compared to males. However, the change in measurements was not statistically significant. For the entire sample, the greatest pre and post-treatment difference in measurement was observed for the ANS-PNS line, while the sella-articulare line showed the least change. The differences in reference lines across the sample ranged from 0.4 mm to 2.2 mm. However, no statistically significant difference in measurements was detected when pre and post-treatment radiographs were statistically analysed using a paired t-test (p-value>0.05) [Table/Fig-6].

Reference lines	Parameters	Males		Females		Overall sample	
		Mean±SD Age: 19.77±3.41 years	p-value	Mean±SD Age: 19.06±2.98 years	p-value	Mean±SD Age: 19.08±2.54 years	p-value
Lines on the skull base	Ptm-sella	0.56±6.02	0.78	1.13± 10.76	0.92	0.92±9.12	0.79
	Ptm-nasion	4.78±9.32	0.23	0.2±5.25	0.93	1.67±7.28	0.30
	Basion-nasion	3.44±8.50	0.26	0.26±7.62	0.89	1.46±7.94	0.37
	Sella-nasion	0.77±1.92	0.43	0.46±3.2	0.29	0.58±2.75	0.18
	FH plane	1.77±6.75	0.53	0.4±4.93	0.75	0.91±5.58	0.42
Maxillary reference lines	PNS-nasion	4.33±6.28	0.12	1.4±8.39	0.52	0.75±8.04	0.97
	ANS-nasion	0.11±2.61	0.9	1.43±2.74	0.07	0.93±2.72	0.13
	ANS-sella	1.77±6.18	0.84	1.8±5.71	0.29	0.45±6.02	0.34
	ANS-PNS	1.33±7.98	0.62	2.86±5.12	0.048	2.29±6.22	0.80
Mandibular reference lines	Sella-Ar	0.77±3.15	0.48	0.73±3.91	0.52	0.16±3.65	0.90

[Table/Fig-6]: Mean±SD differences in pre and post-treatment cephalometric measurements for males, females and the overall sample.

DISCUSSION

The current study aimed to evaluate the reliability of specific cephalometric lines as indicators of dentoalveolar stability for forensic personal identification. The study analysed pre and post-treatment lateral cephalometric radiographs of 120 participants (60 males and 60 females, aged 16-27 years) using standardised protocols to minimise observer bias. Commonly utilised skeletal landmarks, including sella, nasion, ANS, PNS and Ptm, were identified and key cephalometric lines were measured to assess their changes in values pre and post-treatment.

The analysis revealed that among skull base lines, the Ptm-nasion and basion-nasion lines showed slight variation, but the changes were not statistically significant (p-value>0.05). Among maxillary reference lines, ANS-nasion and PNS-nasion demonstrated statistically insignificant variation. Females showed a significant difference in the ANS-PNS line (p-value=0.048). The mandibular line, sella-articulare, exhibited the least change across the sample. Despite the minimal variations in measures, none of the differences reached statistical significance (p-value>0.05) in the overall sample, demonstrating the stability of the selected cephalometric lines before and after orthodontic treatment.

The stability of these cephalometric lines enhances their reliability as markers for forensic personal identification. Cephalometric radiographs are increasingly being utilised in forensic settings for age estimation and identification. The unaltered dimensions of these lines after orthodontic intervention highlight their robustness as identifiers, even in individuals undergoing significant dental and orthodontic changes. This is particularly relevant in cases where forensic identification relies on pre-existing radiographic records. The study's findings reinforce the utility of cephalometric landmarks, such as the sella-nasion and ANS-PNS lines, as stable reference points in such scenarios.

This method, based on Two Dimensional (2D) cephalograms, provides a cost-effective and accessible alternative to traditional identification techniques. With the growing availability of radiographic databases in high-risk professions like firefighting, cephalometric records can be stored and retrieved for mass casualty events or individual identification. Additionally, the stability of cephalometric measurements post-orthodontic treatment underscores the importance of the long-term retention of diagnostic records in orthodontics. These records can serve as a reliable source of identification in mass disasters or situations where traditional methods, like dental or fingerprint identification, are unavailable. This is particularly relevant in forensic cases, where speed and accuracy are crucial, especially in large-scale incidents where traditional methods may be compromised.

The study conducted by Santana LG et al., showed that cephalometric landmarks Na, S, Ba and Pogonion (Po) exhibited positional changes relative to the anterior cranial fossa during the growth period from

8-17 years, with statistically significant differences (p-value=0.001). In contrast, Orbitale remained stable in both vertical and sagittal dimensions, making it a reliable reference point for 2D cephalometric superposition. Additionally, their study indicated that the S-Na, Na-Ba and FHP lines exhibited significant angular changes between the ages of 8 years and 10 years but remained stable and reliable for facial growth analysis in the age group of 11-17 years. Another study conducted by Kravitz ND and Miller S also showed positional changes of sella and nasion [8,10]. Variations in measurements may arise from factors such as landmark tracing reproducibility, radiographic magnification (0.6-2%), interobserve differences, geographic and environmental variations and differences in growth and skeletal maturity between genders [9,11].

The role of orthodontists in maintaining diagnostic records is pivotal, not only for treatment planning but also for forensic purposes. As noted, orthodontists have a professional responsibility to ensure the storage and protection of cephalometric records, which can be crucial in situations requiring forensic identification. The ethical and legal implications of this responsibility are profound, as dental and cephalometric records can assist legal authorities in identifying individuals involved in legal cases or accidents. Given the increasing prevalence of natural disasters and mass casualties, cephalometric databases could become a valuable resource for identifying victims when conventional methods, such as fingerprints or visual identification, are not feasible.

Limitation(s)

As the present study method is metric-based, it may lead to similarities in measurements among different individuals. However, combining various geometric features can enhance individual identification. Limitations include reduced accuracy when skeletal fractures or displacements affect the jaw. Utilising advanced Artificial Intelligence (AI) techniques for the virtual reconstruction of lateral cephalograms could be beneficial. Additionally, the lack of ante mortem cephalograms during disaster victim identification poses a challenge. Variations in measurements might have occurred from factors such as landmark tracing reproducibility, radiographic magnification, interobserver differences, etc.

CONCLUSION(S)

In summary, the 10 reference lines examined in the present study demonstrated stability both pre and post-treatment, with significant accuracy, confirming stable dentoalveolar integrity before and after orthodontic correction. This indicates their potential as a reliable tool for personal identification during disasters, natural calamities and legal investigations. Despite promising outcomes, challenges remain, such as managing severe trauma cases and variability in manual landmark selection. Future studies with a longer follow-up period and a prospective design could provide more comprehensive insights into the long-term stability of these cephalometric markers. Results of the present study provide valuable data on ten reference lines for forensic identification pre and postoperatively. This novel approach in forensic dentistry calls for further research with larger sample sizes and different age groups to establish a reliable forensic database. Incorporating AI techniques, such as key point detection, can improve landmark selection accuracy and automate cephalometric data analysis. Advanced machine learning models, like Convolutional Neural Networks (CNNs), trained on extensive datasets of cephalometric images and could enhance precision.

Authors' contribution: GK: Conceptualisation, investigation, methodology, resources, supervision, validation, writing review and editing; RM: Investigation, methodology, project administration, software, supervision, writing original draft, review and editing; SS: Methodology, writing original draft; SP: Project administration, writing original draft. All authors have read and agreed to the published version of the manuscript.

Acknowledgement

The authors thank, Vishnu Dental College, Bhimavaram, Andhra Pradesh, India, Dental College for providing the required data and supporting the study.

REFERENCES

[1] Kavousinejad S, Yazdanian M, Kanafi MM, Tahmasebi E. A novel algorithm for forensic identification using geometric cranial patterns in digital lateral cephalometric radiographs in forensic dentistry. Diagnostics (Basel). 2024;14(17):1840. Doi: 10.3390/diagnostics14171840. PMID: 39272625; PMCID: PMC11393991.
[2] You QL, Hägg U. A comparison of three superimposition methods. Eur J Orthod. 1999;21(6):717-25. Doi: 10.1093/ejo/21.6.717. PMID: 10665202.
[3] Bhat M, Sudha P, Tandon S. Cephalometric norms for Bunt and Brahmin children of Dakshina Kannada based on McNamara's analysis. J Indian Soc Pedod Prev Dent. 2001;19(2):41-51. PMID: 11692821.
[4] Jain P, Bajaj K, Mehta S. Orthodontics pertaining to forensic odontology- Narrative literature review. International Journal of Innovative Research in Technology. IJIRT. 2024;11(5):82-88.
[5] Pope EJ, Smith OC. Identification of traumatic injury in burned cranial bone: An experimental approach. J Forensic Sci. 2004;49(3):431-40. PMID: 15171155.
[6] Agrawal N, Gupta S, Gupta S, Nazmeen S, Bhuyan D, Singh GB. Cephalometric superimposition in orthodontics-A review. IP Indian J Orthod Dentofacial Res. 2022;8(1):01-06.
[7] Juneja M, Garg P, Kaur R, Manocha P, Prateek, Batra S, et al. A review on cephalometric landmark detection techniques. Biomedical Signal Processing and Control. 2021;66:102486.
[8] Santana LG, Cheib PL, de Pársia HG, Franchi L, Moro A, Souki BQ. Stability of fiducial cephalometric landmarks of growing Class II malocclusion patients: A three-dimensional retrospective study. Angle Orthod. 2022;92(5):619-27. Doi: 10.2319/090721-692.1. Epub ahead of print. PMID: 35653223; PMCID: PMC9374362.
[9] Malkoc S, Sari Z, Usumez S, Koyuturk AE. The effect of head rotation on cephalometric radiographs. Eur J Orthod. 2005;27(3):315-21. Doi: 10.1093/ejo/cjh098. PMID: 15947234.
[10] Kravitz ND, Miller S. Anterior cranial base fundamentals: Understanding the anatomy, rationale for use, and cephalometric landmarks. Orthodontic products. 2020;27(1):20-22.
[11] Rino Neto J, de 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(2):17.e1-7. Doi: 10.1590/s2176-94512013000200005. PMID: 23916445.

PARTICULARS OF CONTRIBUTORS:
1. Associate Professor, Department of Oral Pathology, Vishnu Dental College, Bhimavaram, Andhra Pradesh, India.
2. Professor and Head, Department of Oral Pathology, Vishnu Dental College, Bhimavaram, Andhra Pradesh, India.
3. Professor, Department of Orthodontics, Vishnu Dental College, Bhimavaram, Andhra Pradesh, India.
4. Professor, Department of Oral Pathology, Vishnu Dental College, Bhimavaram, Andhra Pradesh, India.
5. Associate Professor, Department of Oral Pathology, Vishnu Dental College, Bhimavaram, Andhra Pradesh, India.
6. Associate Professor, Department of Oral Pathology, Vishnu Dental College, Bhimavaram, Andhra Pradesh, India.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:
Dr. Gandikota Kartheek,
Associate Professor, Department of Oral Pathology, Vishnu Dental College,
Bhimavaram-534202, Andhra Pradesh, India.
E-mail: kartheek.g@vdc.edu.in

PLAGIARISM CHECKING METHODS: [Jain H et al.]
- Plagiarism X-checker: Nov 09, 2024
- Manual Googling: Jan 11, 2025
- iThenticate Software: Jan 22, 2025 (9%)

ETYMOLOGY: Author Origin

EMENDATIONS: 7

AUTHOR DECLARATION:
- Financial or Other Competing Interests: None
- Was Ethics Committee Approval obtained for this study? Yes
- Was informed consent obtained from the subjects involved in the study? NA (Waived by the Institutional Review Board)
- For any images presented appropriate consent has been obtained from the subjects. NA

Date of Submission: **Nov 08, 2024**
Date of Peer Review: **Dec 13, 2024**
Date of Acceptance: **Jan 24, 2025**
Date of Publishing: **Mar 01, 2025**