

COMPARISON OF ARTIFICIAL INTELLIGENCE AND MANUAL METHODS IN MEASURING UPPER AIRWAY DIMENSIONS ON VIETNAMESE ADULT LATERAL CEPHALOGRAMS

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Abstract

Objectives: This study aimed to (1) describe upper airway dimensions and their relationship with skeletal patterns in Vietnamese adults using manual cephalometric analysis, and (2) compare the effectiveness of artificial intelligence (AI) with manual measurements in assessing airway morphology on lateral cephalometric radiographs. **Materials and Methods:** A total of Seventy-eight lateral cephalometric radiographs of Vietnamese adults aged 18–35 years were analyzed. Subjects were classified into skeletal Class I, II, or III based on the ANB angle. Airway parameters—including nasopharyngeal width (NL), upper airway length (UAL), nasopharyngeal area (Nph), oropharyngeal area (Osp), pharyngeal space area (Phsp), and minimum airway spaces at the soft palate (PhW-UP) and tongue base (PhW-Tb)—were measured manually and automatically using Vincismile AI software. Statistical analyses included one-way ANOVA, paired t-tests, and intraclass correlation coefficients (ICC). **Results:** Manual analysis showed that oropharyngeal and hypopharyngeal dimensions (Osp, Phsp, PhW-UP, PhW-Tb)

were significantly larger in Class III compared to Class II subjects ($p < 0.05$), whereas nasopharyngeal parameters (NL, UAL, Nph) did not differ significantly among skeletal classes. When comparing manual and AI measurements, most parameters showed statistically significant differences ($p < 0.05$). AI analysis required approximately 10 seconds per case, compared to approximately 21 minutes for manual measurements, representing a substantial reduction in analysis time. **Conclusions:** Skeletal Class III individuals exhibited a smaller nasopharyngeal dimension, whereas Class II individuals showed relatively smaller oropharyngeal dimensions. Despite minor discrepancies in certain parameters, AI demonstrates strong potential as a rapid and reliable tool for clinical screening and longitudinal monitoring of upper airway morphology.

Keywords: Upper airway, cephalometry, artificial intelligence, Vincismile, skeletal pattern, orthodontics

SO SÁNH TRÍ TUỆ NHÂN TẠO VÀ PHƯƠNG PHÁP THỦ CÔNG TRONG ĐO KÍCH THƯỚC ĐƯỜNG HỒ HẤP TRÊN PHIM SỌ MẶT NGHIÊNG Ở NGƯỜI TRƯỞNG THÀNH

Tóm tắt

Mục tiêu: Mô tả kích thước đường hô hấp trên và mối liên quan với tương quan xương hàm ở người trưởng thành trên phim sọ mặt nghiêng bằng phương pháp thủ công, so sánh hiệu quả của trí tuệ nhân tạo với phương pháp thủ công trong đánh giá kích thước đường hô hấp trên. **Đối tượng và phương pháp:** 78 phim sọ mặt nghiêng của người trưởng thành Việt Nam từ 18–35 tuổi. Các đối tượng được phân loại thành các kiểu tương quan xương loại I, II và III dựa trên góc ANB.

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Date submitted: March 10, 2026

Date reviewed: March 23, 2026

Date accepted: April 2, 2026

Các thông số đánh giá gồm NL, UAL, Nph, Ovsp, Phsp, PhW-UP và PhW-Tb. Các phép đo được thực hiện bằng phương pháp thủ công và tự động bằng phần mềm Vincismile. Phân tích thống kê sử dụng ANOVA, Paired t-test và hệ số tương quan nội lớp (ICC). **Kết quả:** Phân tích thủ công cho thấy các kích thước vùng họng miệng và hạ họng khác biệt có ý nghĩa thống kê giữa nhóm tương quan xương loại III và loại II ($p < 0,05$), trong khi các thông số vùng họng mũi không khác biệt có ý nghĩa thống kê giữa các nhóm. Khi so sánh hai phương pháp đo, phần lớn các thông số có sự khác biệt có ý nghĩa thống kê ($p < 0,05$), tuy nhiên, mức độ tương đồng đạt từ trung bình đến tốt ($ICC = 0,56-0,89$). Thời gian phân tích bằng AI khoảng 10 giây mỗi trường hợp, trong khi đo thủ công khoảng 21 phút, nhanh hơn khoảng 120 lần. **Kết luận:** Người có kiểu hình xương loại III có kích thước họng mũi nhỏ nhất, trong khi kiểu xương loại II có kích thước vùng họng miệng nhỏ nhất. Mặc dù tồn tại một số sai khác nhỏ trong các phép đo diện tích, AI cho thấy tiềm năng lớn trong sàng lọc và đánh giá sự thay đổi kích thước đường hô hấp trên.

Từ khóa: Đường hô hấp trên, phim sọ mặt nghiêng, trí tuệ nhân tạo, Vincismile, tương quan xương, nắn chỉnh răng.

I. INTRODUCTION

Since Angle's 1907 report describing upper airway narrowing in patients with Class II malocclusion, the relationship between airway morphology and craniofacial skeletal patterns has remained a central topic in orthodontics¹. Numerous studies have investigated the influence of sagittal and vertical skeletal discrepancies (Class I, II, III), facial height patterns (short, average, long face), and functional factors on upper airway dimensions². Chronic upper airway obstruction and habitual mouth breathing are recognized as important factors influencing craniofacial development,

leading to conditions such as maxillary constriction, crossbite, and long-face syndrome. Prolonged mouth breathing may also increase the risk of obstructive sleep apnea syndrome (OSAS)³. Consequently, in modern dental practice, the evaluation of soft tissues and airway dimensions has become an integral part of diagnosis and treatment planning. Among current imaging modalities, lateral cephalometric radiographs remain a cost-effective standard tool for airway assessment, despite their two-dimensional limitations. The major drawback of manual analysis lies in the time required for each case, which increases the workload for clinicians. Furthermore, measuring airway areas on two-dimensional images of a complex three-dimensional structure is challenging and often requires specialized software. With the advent of AI, upper airway analysis has become faster and more objective, reducing human-related errors and overcoming many difficulties of manual measurement. However, evidence supporting the reliability of AI-based airway measurements remains limited, and their accuracy compared with traditional manual tracing still requires further investigation.

Therefore, the present study aimed to (1) describe upper airway dimensions and their association with skeletal patterns in adults, and (2) compare the effectiveness of artificial intelligence (AI) with manual measurements in assessing airway morphology on lateral cephalometric radiographs.

II. Materials and methods

2.1. Study design and setting

A cross-sectional analytical study was conducted using archived lateral cephalometric radiographs collected between December 2024 and April 2025 at the Clinical Center of the Faculty of Odonto-Stomatology, Hanoi University of Business and Technology

Data were collected at a single past time point, reflecting only the status at that moment, without long-term follow-up or analysis of associations between risk factors and outcomes. Ethical approval and participant consent were obtained prior to data use.

2.2. Participants:

Lateral cephalometric radiographs of adults aged 18–35 years were included if they demonstrated clear visualization of nasopharyngeal and oropharyngeal anatomical landmarks, with the tongue in a resting position, an open epiglottis, and acceptable image quality (adequate contrast and proper head alignment). Standardized lateral cephalometric radiographs were obtained from the orthodontics department's database.

Subjects stood in a relaxed posture with the head in a natural position, Frankfort plane and interpupillary line parallel to the floor. Ear rods stabilized the head vertically, while a frontal device prevented anterior or posterior tilt. Radiographs were taken in maximum intercuspation, with subjects breathing calmly and refraining from swallowing. Exclusion criteria included a history of or ongoing orthodontic treatment or maxillofacial surgery, craniofacial anomalies, or chronic airway disorders (e.g., tonsillar hypertrophy, nasal septum deviation, chronic sinusitis, obstructive sleep apnea syndrome [OSAS], or cervical spine deformities). The radiograph selection process and study workflow are illustrated in Figure 1.

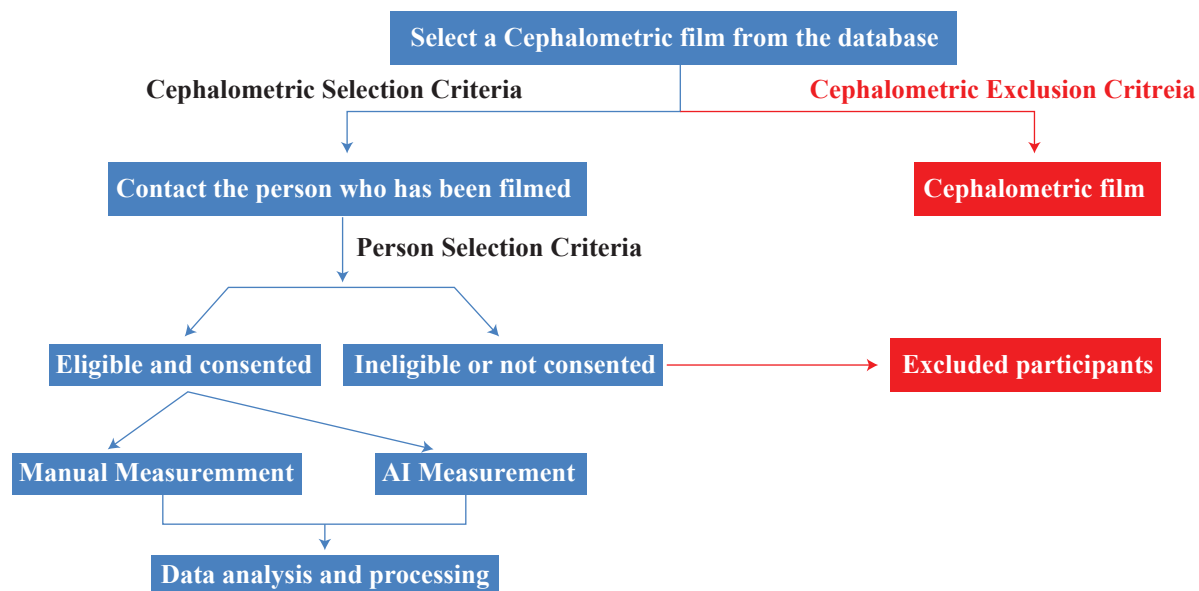


Figure 1. Research process flow.

2.3. Sample size

A convenience sampling method was applied. The minimum sample size was calculated using the formula for estimating a population mean: $n = \frac{Z^2 \cdot p \cdot (1-p)}{d^2}$, where based on a previous study⁴, and ($d = 1$) represents the acceptable margin of error. The calculated minimum sample size was 71 subjects. To account for a potential 10% exclusion rate, a total of 78 radiographs

were included in the final analysis, with an approximately equal distribution among skeletal Classes I, II, and III.

Measurement parameters: Measurement parameters were defined according to the protocol described by Neelapu et al. (2016)⁵. Anatomical landmarks, Reference plane and Airway variables are presented in Table 1.

Anatomical landmarks	
Point N	The most anterior point on the frontonasal suture in the midsagittal plane
Point Po	The highest point of the external auditory meatus
Point Or	The lowest point of the infraorbital rim
Point ANS	Anterior nasal spine
Point PNS	Posterior nasal spine
Point A	The most posterior point of the maxillary alveolar bone in the midsagittal plane
Point B	The most posterior point of the mandibular alveolar bone in the midsagittal plane
Point Go	The most inferior and posterior point of the mandibular angle
Point ATA	Most anterior point of the anterior arch of the atlas
Point UP	The most posterior convex point of the soft palate
Point Tb	Tongue base
Point Et	The highest point of the epiglottis
Point H	The most anterior and superior point of the hyoid bone
Pharyngeal boundaries (PhW)	Posterior boundary of the pharyngeal wall in the vertical plane. Reference planes
Reference planes	
Frankfort horizontal (FH)	Line passing through Po and Or;
Palatal horizontal plane	Line passing through ANS and PNS
Aiway variables	
NL	Nasopharyngeal width (mm)
UAL	Upper airway length (mm)
Nph	Nasopharyngeal area (cm ²)
OpSP	Oropharyngeal area (cm ²)
PhSP	Total pharyngeal space area (cm ²)
PhW-UP	Minimum airway space at the soft palate and posterior pharyngeal wall (mm)
PhW-Tb	Minimum airway at the tongue base and posterior pharyngeal wall (mm)

Table 1: The anatomical landmarks, reference planes, and upper airway dimensions used in this study.

Continuous variables were expressed as mean $\pm$ standard deviation (SD).

Normality of data distribution was assessed using the Shapiro–Wilk test.

Differences among skeletal classes were analyzed using one-way analysis of variance (ANOVA), followed by Tukey’s post hoc test for multiple comparisons

Agreement between manual and AI measurements was assessed by Paired T-tests. Statistical significance was set at $p < 0.05$.

2.4. Ethical Consideration

The study protocol was reviewed and approved by the Research Proposal Review Committee of the Faculty of Odonto-Stomatology, Hanoi University of Business and Technology (Hanoi, Vietnam).

All procedures were conducted in accordance with relevant ethical guidelines and regulations. All participants were fully informed about the study and provided written informed consent prior to participation.

Participant confidentiality was strictly maintained, and all data were anonymized and used solely for research purposes.

III. Results

3.1. General Characteristics of the Participants

The mean age of the study population was 24.8 ± 3.09 years, with no significant difference between males ($n = 38$, 49%) and females ($n = 40$, 51%; $p = 0.912$). The distribution of skeletal relationships among participants was equal (1:1:1), with 26 individuals in each group.

3.2. Airway dimensions by skeletal pattern

Table 2: Upper airway dimension measurement results obtained using a manual method.

Upper Airway Measurement	X $\pm$ SD			p (ANOVA test)	Tukey HSD Post Hoc test
	Skeletal Class I (n=26)	Skeletal Class II (n=26)	Skeletal Class III (n=26)		
NL (mm)	30.30 $\pm$ 3.07	29.44 $\pm$ 3.55	28.77 $\pm$ 4.68	0.350	
UAL (mm)	59.04 $\pm$ 6.49	58.96 $\pm$ 7.42	56.81 $\pm$ 6.07	0.404	
Nph (cm ²)	4.43 $\pm$ 0.92	4.24 $\pm$ 1.23	4.12 $\pm$ 0.97	0.567	
Opsp (cm ²)	7.10 $\pm$ 1.83	6.02 $\pm$ 1.1	7.98 $\pm$ 3.05	0.006*	II<III
Phsp (cm ²)	8.28 $\pm$ 2.05	6.84 $\pm$ 1.41	8.70 $\pm$ 2.17	0.002*	II<III
PhW-Tb(mm)	13.96 $\pm$ 3.99	12.17 $\pm$ 3.16	15.90 $\pm$ 3.89	0.002*	II<III
PhW-UP(mm)	12.07 $\pm$ 3.09	9.76 $\pm$ 2.58	13.26 $\pm$ 3.32	0.000*	II<III

*: Statistically significant ($p < 0.05$).

Only statistically significant pairwise comparisons ($p < 0.05$) are presented in the post hoc (Tukey’s test) column. Manual measurements indicated that the nasopharyngeal parameters (NL, UAL, Nph) were smallest in the Class III skeletal group and largest in the Class I group; however, these differences were not statistically significant ($p > 0.05$). In contrast, one-way ANOVA followed by Tukey’s post hoc test demonstrated that oropharyngeal and

hypopharyngeal dimensions (Opsp, Phsp, PhW-UP, and PhW-Tb) were significantly greater in the Class III group compared with the Class II group ($p < 0.05$). Additionally, the Class II group exhibited significantly smaller Phsp and PhW-UP values than the Class I group ($p < 0.05$). No statistically significant differences were observed between the Class I and Class III groups.

3.3. Comparison between manual and AI-based measurements

Table 3: Comparison of manual and AI-based measurements of upper airway dimensions

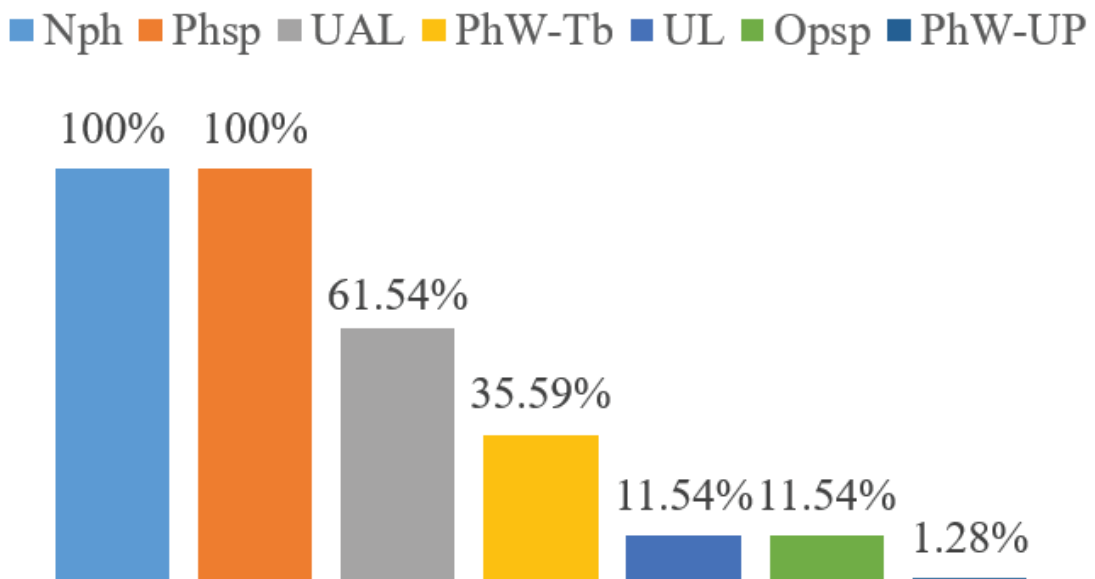
Upper Airway Measurement	X±SD		Paired Samples T-test	
	Manual Measurement	AI-Assisted Measurement	X±SD	p
NL (mm)	29.52±3.81	28.14±3.57	1.37±3.44	0.001*
UAL (mm)	58.31±6.70	56.48±6.31	1.82±2.96	0.000*
Nph (cm ²)	4.27±1.04	4.04±0.75	0.23±0.96	0.036*
Osp (cm ²)	7.01±2.25	6.64±1.57	0.37±1.77	0.064
Phsp (cm ²)	7.92±2.04	6.61±1.67	1.31±1.47	0.000*
PhW-Tb(mm)	13.97±3.95	12.81±2.93	1.15±2.32	0.000*
PhW-UP(mm)	11.66±3.03	12.13±2.97	-0.36±1.64	0.056

*: Statistically significant ($p < 0.05$).

Most variables showed statistically significant differences between manual and AI measurements (paired t-test, $p < 0.05$). Only Osp and Phw-TB showed no statistically significant differences between the two methods ($p > 0.05$). The mean processing time for manual measurements was approximately 20.8 minutes per radiograph,

whereas AI-based analysis required approximately 0.17 minutes (≈ 10 seconds). Thus, AI reduced measurement time by approximately 122-fold while maintaining acceptable agreement with manual measurements.

3.5. AI-based airway narrowing detection

**Figure 2:** AI-based assessment of upper airway dimensions

According to the Vincismile output, as shown in Figure 2, all AI analyzed cases (100%) showed reduced nasopharyngeal area (Nph) and pharyngeal space area (Phsp) compared with reference values. A total of 61.5% of cases demonstrated reduced upper airway length (UAL), and 35.9% showed decreased minimum airway space at the soft palate (PhW-UP). Only one case (1.3%) exhibited marked narrowing at the tongue base (PhW-Tb).

IV. Discussion

The bidirectional relationship between respiratory function and craniofacial morphology has been well established. The soft-tissue stretching theory proposed by Solow and Kreiborg (1997), together with experimental models by Harvold (1981), demonstrated that airway obstruction can induce craniofacial skeletal adaptations. However, the extent to which skeletal configuration influences airway dimensions remains controversial^{6,7}. The present findings are consistent with previous studies (Neelapu et al., 2016; Sfondrini et al., 2024)^{5,8}, showing that individuals with Class III skeletal patterns tend to exhibit larger oropharyngeal and hypopharyngeal dimensions compared with Class II individuals. This may be attributed to mandibular prognathism, which advances the tongue and hyoid bone, thereby enlarging the hypopharyngeal airway. In contrast, Phan Thi Tinh et al. (2023) reported greater nasopharyngeal width in Class II individuals compared with Class I4. This discrepancy may be explained by variations in skeletal morphology, particularly mandibular retrusion and increased soft palate thickness, which are commonly associated with reduced airway dimensions below the velopharyngeal region. In the present study, nasopharyngeal dimensions did not differ significantly among skeletal classes, which is consistent with findings by Wenzel et al. (1989) and Kirjavainen et al.

(2007)^{10,11}. This regional variation likely reflects the differing anatomical constraints: the nasopharynx is bounded by rigid cranial structures, whereas the oropharynx and hypopharynx are influenced by soft tissues and hyoid-related musculature. The mean upper airway length observed in this Vietnamese adult cohort (UAL = 58.3 mm) was lower than that reported in European populations (63–67 mm)¹², suggesting potential ethnic differences in craniofacial and cervical morphology. These findings highlight the importance of population-specific reference values in airway assessment. Although the association between gender and upper airway dimensions was not the main focus of this study, previous evidence consistently shows that OSAS is more prevalent in men, possibly due to hormonal factors^{13, 14}. However, Pradhan, Resina et al. (2021), in a study of 125 lateral cephalograms of patients aged 18–27, reported mean upper airway dimensions of 11.40±1.84 mm in males and 11.68±1.96 mm in females, indicating nearly identical pharyngeal airway sizes between genders¹⁵. Artificial intelligence (AI) applications in dentistry have expanded rapidly, including cephalometric landmark detection, tooth segmentation, and pathology recognition. Previous studies have primarily focused on AI-based detection of adenoid hypertrophy, reporting high accuracy (> 0.9)^{16–18}. However, evidence evaluating AI performance in upper airway measurement remains limited. In this study, although significant differences were identified between manual and AI-based measurements across several parameters, consistency was observed only for the indices Osps and PhW-Tb. These findings indicate that notable discrepancies remain between the two measurement methods. Such differences may be attributable to the limited sample size, which may not have been sufficiently large to represent and evaluate the variations between the methods.

Despite these discrepancies, AI offers substantial advantages in terms of speed and objectivity. The Vincismile system required approximately 10 seconds per radiograph, significantly reducing analysis time compared with manual measurements, while maintaining acceptable agreement. From a clinical perspective, evaluation of upper airway dimensions facilitates early identification of individuals at risk of airway compromise or obstructive sleep apnea syndrome (OSAS), enabling timely referral and multidisciplinary management. Furthermore, AI-based tools may support longitudinal monitoring during orthodontic or orthognathic treatment by providing objective and reproducible measurements. However, AI-derived results should be interpreted with caution, as variations in landmark detection, image scaling, and boundary definition may introduce systematic bias. Therefore, AI should be considered an adjunct rather than a replacement for expert clinical assessment.

This study has several limitations. First, restricting the sample to high quality radiographs with clearly defined anatomical landmarks may introduce selection bias and reduce generalizability. Moreover, its retrospective design and the inability to fully control head positioning during radiograph acquisition represent the most significant constraints. Second, the use of two-dimensional radiographs may not fully capture the complex three-dimensional structure of the airway. Third, only skeletal relationships were considered, without accounting for potential confounding factors such as age, sex, tongue size, hyoid position, or jaw morphology. Finally, the limited availability of comparable studies, particularly in Vietnamese populations, may restrict the generalizability of the findings and the interpretation of AI-based measurements. Further research using three-dimensional imaging and larger, more diverse samples is warranted.

V. Conclusion

Although AI provided rapid results, significant differences were observed compared with manual measurements. Only PhW–UP demonstrated comparable results to the manual method. Further improvements in accuracy are required for future development of the AI model. Regarding skeletal patterns, Class II individuals exhibited relatively reduced airway dimensions in the oropharyngeal and hypopharyngeal regions, with several parameters reaching statistical significance compared to Class I and Class III. In contrast, no statistically significant differences were observed between Class I and Class III groups. These findings suggest that the influence of skeletal pattern on airway dimensions may be more pronounced in Class II within the present sample. Nevertheless, the use of two-dimensional cephalometric analysis may limit the ability to characterize the complex three-dimensional morphology of the upper airway fully. Therefore, further studies with larger sample sizes and three-dimensional imaging modalities are warranted to provide a more comprehensive evaluation and to elucidate these relationships better.

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