

## Relationship Between Skeletal Malocclusion and Craniocervical Structure of Head Posture Using CBCT

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### Abstract:

**Objective:** Skeletal malocclusion may influence head posture and craniocervical balance in addition to facial aesthetics. Altered head posture has been associated with cervical muscle strain, airway compromise, and musculoskeletal imbalance. Cone Beam Computed Tomography (CBCT) allows more accurate evaluation of craniofacial–cervical relationships than conventional two–dimensional radiography. This preliminary exploratory study assessed the association between skeletal malocclusion and craniocervical posture using CBCT imaging.

**Material and Methods:** This preliminary exploratory analytic cross–sectional study used a limited sample of 16 CBCT radiographs of patients with skeletal Class I, II, and III malocclusions. Measurements were performed on nine cephalometric variables of head posture using OnDemand3D and CorelDRAW software. Statistical analysis was performed using Pearson and Spearman correlation tests.

**Results:** In skeletal Class I, OPT/CVT showed a strong positive correlation ( $r=0.893$ ,  $p\text{-value}=0.041$ ). In skeletal Class III, NL/VER showed a very strong negative correlation ( $r=-0.959$ ,  $p\text{-value}=0.003$ ), whereas NSL/OPT, NSL/CVT, NL/OPT, and NL/CVT showed very strong positive correlations ( $r=0.820\text{--}0.974$ ,  $p\text{-value}\leq 0.046$ ). No statistically significant correlations were observed for the remaining variables ( $p\text{-value}>0.05$ ).

**Conclusion:** Within the limitations of this small preliminary sample and cross–sectional design, selected craniocervical and cervical postural parameters showed significant correlations, whereas craniovertical angles and cervical column

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inclination did not. These findings should be interpreted cautiously and considered preliminary, hypothesis-generating evidence to inform future studies with larger samples.

**Keywords:** CBCT, craniocervical, craniovertical, head posture, skeletal malocclusion

## Introduction

Beyond malocclusion, alterations in body posture may influence craniofacial growth and development<sup>1</sup>. Head posture is therefore considered an important component of orthodontic diagnosis because of its relationship with mandibular size and position<sup>2</sup>. Functional processes such as respiration, deglutition, and phonation are also associated with craniocervical posture<sup>3,4</sup>. According to the functional matrix theory and neuromuscular adaptation, craniofacial growth is influenced by soft tissues, airway function, and cervical musculature. Changes in sagittal jaw relationships may induce compensatory craniocervical angulation to maintain visual orientation, airway patency, and postural balance; for example, mandibular retrusion is often associated with forward head posture, whereas mandibular prognathism may be accompanied by head extension<sup>5,6</sup>. These adaptations can be objectively assessed using craniovertical, cervicohorizontal, and craniocervical angular measurements, which provide reproducible indicators of head and neck alignment<sup>4,5</sup>.

However, evidence regarding the relationship between skeletal malocclusion and head posture remains inconsistent, likely due to heterogeneity in study design, population characteristics, skeletal classification, and measurement methods. Some epidemiological studies report altered head and neck posture in Class II and Class III malocclusions<sup>5,6</sup>, whereas an Indonesian study found no significant associations, except in cases of maxillary prognathism with mandibular retrognathism<sup>7</sup>. Several authors have reported postural alterations in malocclusion<sup>8-10</sup>. Taken together, these findings indicate that although an

association has been reported in certain populations, the evidence remains inconclusive due to heterogeneity in the measurement parameters, population demographics, and analytical approaches. All previously published studies have relied exclusively on two-dimensional cephalometric radiographs to evaluate head posture.

Comparisons among manual tracing, digitized lateral cephalograms, and Cone-beam computed tomography (CBCT) –derived lateral cephalograms show that all modalities are reliable for scientific investigation, with CBCT-based cephalograms demonstrating the highest reliability<sup>11</sup>. However, two-dimensional cephalometric analyses provide limited anatomical information because of structural superimposition, magnification, and projection distortion, which may obscure subtle craniocervical relationships<sup>12,13</sup>. CBCT-derived cephalograms generated with AI-based software (e.g., OnDemand 3D, Invivo5) have shown no significant differences from conventional lateral cephalograms, supporting CBCT with AI as an efficient diagnostic approach<sup>13</sup>. Unlike conventional radiographs, CBCT provides true three-dimensional visualization without superimposition, enabling more accurate spatial and angular assessment of craniocervical structures and reducing methodological bias<sup>14,15</sup>. Previous CBCT-based studies have also demonstrated associations between skeletal malocclusion and craniofacial functional structures, including airway dimensions and temporomandibular joint (TMJ) morphology, supporting the broader relevance of three-dimensional imaging in evaluating malocclusion-related craniofacial adaptations<sup>16,17</sup>. Accordingly, this study integrates craniovertical, cervicohorizontal, and

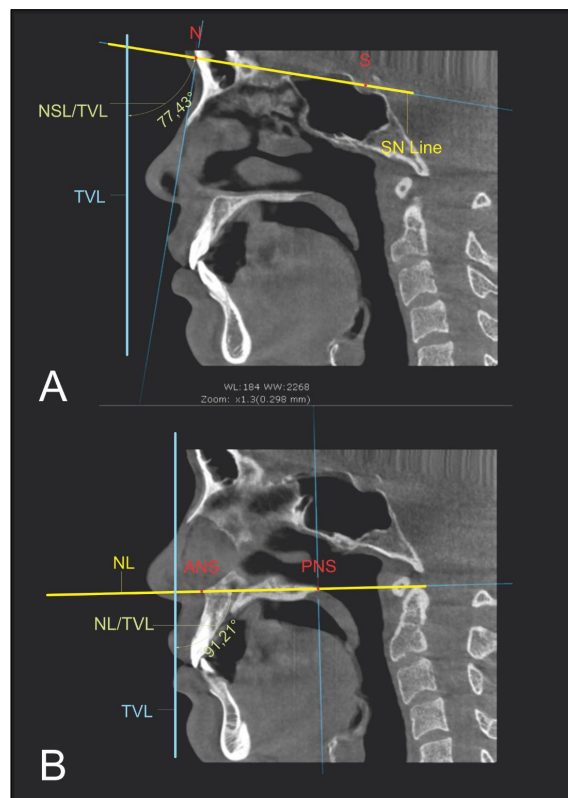
craniocervical angular analyses within a standardized skeletal classification framework to provide a comprehensive three-dimensional evaluation of craniocervical relationships across sagittal malocclusions. Given the heterogeneity and methodological limitations of previous studies, CBCT-based evidence on the relationship between skeletal malocclusion and head posture remains limited. Therefore, this exploratory study was conducted using a small preliminary sample to investigate potential associations rather than establish causal relationships. The limited sample size should be considered when interpreting the findings. On this basis, the present study investigated the relationship between skeletal malocclusion and head posture using CBCT.

## Material and Methods

This study used an analytic cross-sectional design aimed at assessing head posture in relation to skeletal malocclusion based on CBCT imaging. All participants were positioned in the Natural Head Position (NHP) during CBCT acquisition by standing or sitting comfortably and looking straight ahead at a mirror placed at eye level, allowing the head to adopt a physiologically neutral orientation. The Frankfort Horizontal Plane (FHP) was kept approximately parallel to the floor, and the head was stabilized using the CBCT head holder without forced positioning, ensuring reproducibility of craniovertical angles and minimizing variability due to head posture. Although natural head position reflects a functional and clinically relevant posture, some degree of physiological variability is inherent. To minimize this variability, all scans were acquired using the same CBCT unit, standardized positioning instructions, mirror-guided eye-level orientation, and consistent operator supervision throughout the study period.

CBCT images were acquired using an Orthopantomograph OP300 (Instrumentarium Dental, Tuusula, Finland) with standardized exposure parameters of 90 kVp tube voltage, 5.0 mA tube current, 8.1 s exposure time, a 13×15 cm field of view (FOV), and an isotropic

voxel size of 0.38 mm. All scans were reconstructed under identical acquisition settings to ensure consistency across participants. CBCT images were analyzed using OnDemand3D to identify anatomical landmarks, and angular measurements were calculated using CorelDRAW (Figures 1 and 2). CorelDRAW was used exclusively as a digital measurement tool to calculate angles based on standardized landmark coordinates exported from OnDemand3D and was not used for landmark identification or image manipulation. Although CorelDRAW is primarily a graphic design software, its precision tools were used solely to compute angular measurements from the coordinates obtained in OnDemand3D. This approach ensured consistent and reproducible measurements while maintaining accuracy in evaluating craniovertical, cervicohorizontal, and craniocervical postural relationships. All measurements were performed by a single calibrated examiner under standardized conditions to maintain consistency. To assess measurement reliability, intra-examiner reproducibility was evaluated by re-measuring a subset of CBCT images after a two-week interval under identical conditions. Because all measurements were performed by a single examiner, inter-examiner reliability assessment was not applicable. The CBCT radiographic acquisition procedures and data measurements were carried out at the Dental Radiology Unit of the Universitas Sumatera Utara Dental and Oral Hospital. The study was conducted between July 2025 and September 2025. The population of this study consisted of all CBCT radiographs available in the Dental Radiology Unit of the Universitas Sumatera Utara Dental and Oral Hospital. The sample included CBCT radiographs of patients classified into three groups: Group 1 (skeletal Class I malocclusion), Group 2 (skeletal Class II malocclusion), and Group 3 (skeletal Class III malocclusion). The inclusion criteria were CBCT radiographs with a minimum field of view of 13–15 cm (Large FOV), which provided coverage of the cranial base and upper cervical vertebrae (C1–C4), enabling identification of odontoid process tangent (OPT)



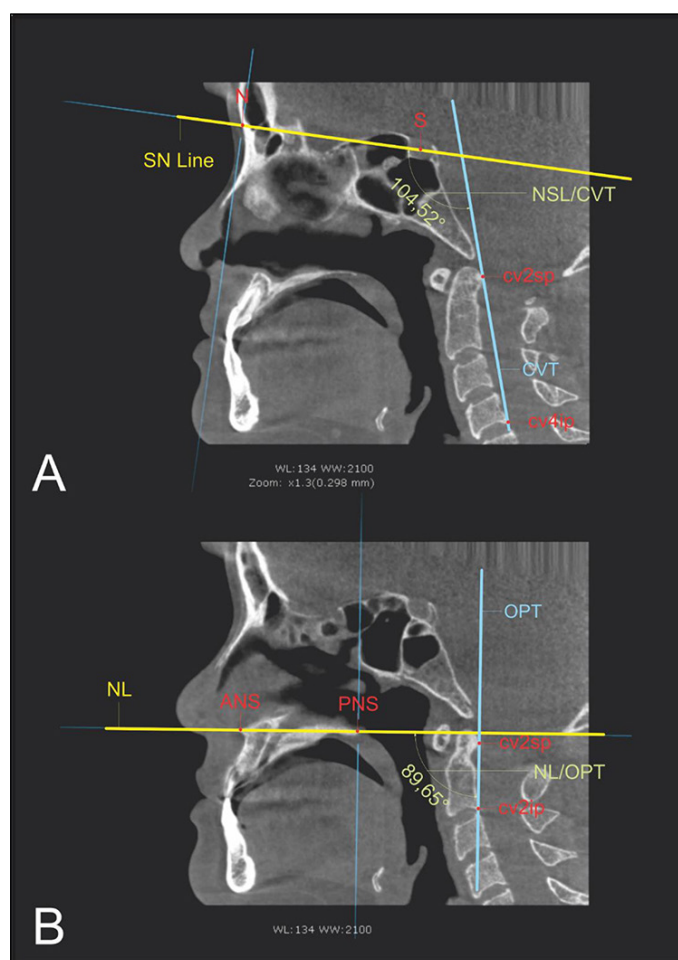
CBCT=cone-beam computed tomography, NSL/CVT=nasion-sella line/cervical vertebral tangent, NL/OPT=nasal line/odontoid process tangent

**Figure 1** Example of CBCT ondemand images and reference lines using CorelDRAW A. Measured NSL/TVL angle  
B. Measured NL/TVL angle

and cervical vertebral tangent (CVT) reference lines for craniocervical angular measurements. The exclusion criteria were CBCT radiographs of patients with syndromic conditions based on medical records, patients still in the growth and development period, and CBCT scans obtained using a bite block. These inclusion and exclusion criteria were applied to ensure skeletal maturity, image standardization, and sample homogeneity; however, they may limit the representativeness of the sample and introduce potential selection bias, which should be considered when interpreting the findings. The sample size was determined

using a hypothesis test and the pooled standard deviation, resulting in a minimum required sample of 16 subjects.

The sample size was calculated a priori using a hypothesis test for comparison of means among three independent groups, based on previously reported standard deviation values of craniocervical angles in similar populations. Using a confidence level of 95% ( $\alpha$  0.05) and a statistical power of 80% ( $\beta$ =0.20), the pooled standard deviation was applied to estimate the minimum required sample size, resulting in a minimum of 16 subjects. Due to the limited availability of eligible CBCT records meeting the



CBCT=cone-beam computed tomography, NSL/CVT=nasion-sella line/cervical vertebral tangent, NL/OPT=nasal line/odontoid process tangent

**Figure 2** Example of CBCT ondemand images and reference lines using CorelDRAW A. Measured NSL/CVT angles  
B. Measured NL/OPT angle

inclusion criteria within the study period, the final sample was restricted to the available cases. This limitation may affect statistical power and should be considered when interpreting the findings.

Prior to inferential analysis, data distribution was assessed for normality. For variables meeting parametric assumptions, one-way Analysis of Variance (ANOVA) was applied to compare means among the three skeletal groups. For variables not meeting normality assumptions, the

Kruskal–Wallis test was used. When statistically significant differences were identified, appropriate post hoc multiple comparison tests were performed to determine intergroup differences. Given the relatively small subgroup sizes, both parametric and non-parametric approaches were employed to enhance the robustness and validity of the statistical analysis.

Nine cephalometric variables representing the craniovertical, cervicohorizontal, and craniocervical postural

relationships, as well as cervical curvature, were assessed using the nasion–sella line (NSL), nasal line (NL), OPT, CVT, true vertical reference (VER), and true horizontal reference (HOR) (NSL/VER, NL/VER, OPT/HOR, CVT/HOR, NSL/OPT, NSL/CVT, NL/OPT, NL/CVT, and OPT/CVT). Head posture was defined using craniovertical angles (NSL/VER and NL/VER), cervical inclination was determined through cervicohorizontal angles (OPT/HOR and CVT/HOR), craniocervical posture was evaluated using craniocervical angles (NSL/OPT, NSL/CVT, NL/OPT, NL/CVT), and cervical curvature was represented by the OPT/CVT angle.

#### Measurement reliability

All measurements were performed by a single examiner. Intra-examiner reliability was assessed by repeating measurements on a subset of CBCT images after a short interval. Reliability was evaluated using the Intraclass Correlation Coefficient (ICC).

#### Statistical analysis

Normality was assessed using the Shapiro–Wilk test for samples <50 and the Kolmogorov–Smirnov test for samples >50. Normally distributed data ( $p$ -value>0.05) were analyzed using one-way ANOVA with LSD post hoc testing, whereas the non-normally distributed data ( $p$ -value<0.05) were analyzed using the Kruskal–Wallis and Mann–Whitney tests. Correlations were evaluated using Pearson's or Spearman's tests as appropriate. Pearson correlation was applied when both variables were continuous and normally distributed, whereas Spearman correlation was used when at least one variable was non-normally distributed or ordinal.

Given the small sample size and multiple comparisons, analyses were considered exploratory and interpreted cautiously; effect sizes were reported alongside  $p$ -values. No formal adjustment for multiple comparisons was applied due to the exploratory design; therefore,

$p$ -values, particularly those near the significance threshold, should be interpreted cautiously.

Post-hoc power analysis in Statistical Package for the Social Sciences (SPSS) indicated approximately 70–80% power for the main significant correlations, while smaller effects showed lower power due to the limited sample. Post-hoc power was reported descriptively to contextualize the observed effect sizes and does not mitigate the limitations associated with the small sample size.

Primary outcomes were the correlations between skeletal malocclusion classification and head posture parameters. Secondary outcomes included intergroup comparisons and additional exploratory correlations.

## Results

The sample consisted of 16 CBCT radiographs categorized into skeletal Class I, Class II, and Class III malocclusions. Based on the observations obtained in this study, the mean values of head posture angles across all groups showed that the NSL/VER and NL/VER parameters were highest in the skeletal Class III malocclusion group ( $81.52 \pm 1.92$ ), whereas the lowest values were observed in the skeletal Class II group (Table 1). Standard deviations indicated considerable within-group variability for several parameters, particularly in Class II measurements (Table 1). Conversely, OPT/HOR, CVT/HOR, NSL/OPT, NSL/CVT, NL/OPT, NL/CVT, and OPT/CVT showed the highest values in the skeletal Class II group ( $88.1 \pm 6.3$ ;  $83.9 \pm 5.9$ ;  $104.5 \pm 2.8$ ;  $112.0 \pm 5.7$ ;  $95.5 \pm 6.5$ ;  $102.6 \pm 5.0$ ;  $6.4 \pm 1.5$ , respectively), and the lowest values in the skeletal Class III group (Table 1). These descriptive trends were confirmed by inferential analysis, which showed statistically significant intergroup differences only for NSL/VER and NL/VER (Table 2).

One-way ANOVA indicated statistically significant differences among malocclusion classes for NSL/VER and NL/VER (Table 2). Post-hoc analysis showed that NSL/

**Table 1** Differences in the mean head posture angles across skeletal malocclusion groups

| Variable | Skeletal class I |      | Skeletal class II |      | Skeletal class III |      | p-value            |
|----------|------------------|------|-------------------|------|--------------------|------|--------------------|
|          | Mean             | S.D. | Mean              | S.D. | Mean               | S.D. |                    |
| NSL/VER  | 78,1             | 1,1  | 76,9              | 1,8  | 81,5               | 1,9  | 0,001 <sup>a</sup> |
| NL/VER   | 87,2             | 2,7  | 88,1              | 6,3  | 90,7               | 3,8  | 0,024 <sup>a</sup> |
| OPT/HOR  | 87,9             | 6,3  | 88,1              | 6,3  | 86,1               | 7,0  | 0,863              |
| CVT/HOR  | 81,0             | 4,7  | 83,9              | 5,9  | 79,6               | 6,3  | 0,743              |
| NSL/OPT  | 102,6            | 5,0  | 104,5             | 2,8  | 102,4              | 5,3  | 0,711              |
| NSL/CVT  | 106,0            | 6,0  | 112,0             | 5,7  | 107,0              | 5,1  | 0,280              |
| NL/OPT   | 93,9             | 6,9  | 95,5              | 6,5  | 94,0               | 5,9  | 0,906              |
| NL/CVT   | 101,2            | 6,9  | 102,6             | 5,0  | 99,5               | 5,0  | 0,676              |
| OPT/CVT  | 5,9              | 2,7  | 6,4               | 1,5  | 5,5                | 2,0  | 0,817              |

<sup>a</sup>One-way ANOVA test; \*Kruskal-Wallis test; significance level p-value<0.05, S.D.=standard deviation, NSL=nasion-sella line, VER=vertical reference, NL=nasal line, OPT=odontoid process tangent, HOR=horizontal reference, CVT=cervical vertebral tangent

**Table 2** Post-hoc comparisons among skeletal malocclusion groups

| Variable | Skeletal class | Skeletal class | Mean                  | p-value            |
|----------|----------------|----------------|-----------------------|--------------------|
| NSL/VER  | I              | II             | 1,16400               | 0,291              |
|          |                | III            | -3.45433 <sup>a</sup> | 0,005 <sup>a</sup> |
|          | II             | III            | -4.61833              | 0,001 <sup>*</sup> |
| NL/VER   | I              | II             | 1,73800               | 0,350              |
|          |                | III            | -3,54733              | 0,059              |
|          | II             | III            | -5.28533 <sup>*</sup> | 0,009 <sup>a</sup> |

\*Mann-Whitney test, <sup>a</sup> Post-hoc analysis, significance level p-value<0.05, NSL=nasion-sella line, VER=vertical reference, NL=nasal line

VER differed significantly between Class I-III and Class II-III, while NL/VER differed between Class II-III. All other angular parameters (OPT/HOR, CVT/HOR, NSL/OPT, NSL/CVT, NL/OPT, NL/CVT, OPT/CVT) showed no significant intergroup differences (p-value>0.05) (Table 2). This variability likely contributed to the absence of significant intergroup differences for most parameters.

Intra-examiner reliability was good, with an ICC of 0.81. Correlation analysis within skeletal malocclusion groups showed mostly non-significant associations, with a limited number of significant correlations (Table 3). In

the Class I group, a significant positive correlation was observed for OPT/CVT ( $r=0.893$ ,  $p\text{-value}<0.05$ ). In the Class III group, NL/VER showed a significant negative correlation ( $r=-0.959$ ,  $p\text{-value}<0.05$ ). Additional significant positive correlations in Class III were observed for NSL/OPT ( $r=0.944$ ), NSL/CVT ( $r=0.820$ ), NL/OPT ( $r=0.974$ ), NL/CVT ( $r=0.941$ ), and OPT/CVT ( $p\text{-value}<0.05$ ) (Table 3). Given the small subgroup sample sizes, these high correlation coefficients should be interpreted with caution and considered exploratory. No significant correlations were observed in the Class II group.

**Table 3** Correlation analysis within skeletal malocclusion groups

| Variable | Correlation in skeletal class I |         | Correlation in skeletal class II |         | Correlation in skeletal class III |                    |
|----------|---------------------------------|---------|----------------------------------|---------|-----------------------------------|--------------------|
|          | Correlation coefficient         | p-value | Correlation coefficient          | p-value | Correlation coefficient           | p-value            |
| NSL/VER  |                                 |         |                                  |         | -0.959                            | 0,003 <sup>*</sup> |
| NL/VER   |                                 |         |                                  |         |                                   |                    |
| OPT/HOR  |                                 |         |                                  |         |                                   |                    |
| CVT/HOR  |                                 |         |                                  |         |                                   |                    |
| NSL/OPT  |                                 |         |                                  |         | 0.944                             | 0,005 <sup>*</sup> |
| NSL/CVT  |                                 |         |                                  |         | 0.820                             | 0,046 <sup>*</sup> |
| NL/OPT   |                                 |         |                                  |         | 0.974                             | 0,001 <sup>*</sup> |
| NL/CVT   |                                 |         |                                  |         | 0.941                             | 0,005 <sup>*</sup> |
| OPT/CVT  | 0.893 <sup>*</sup>              | 0,041   |                                  |         |                                   |                    |

\*Spearman correlation test, significance level p-value<0.05. Non-significant correlations have been omitted, NSL=nasion-sella line, VER=vertical reference, NL=nasal line, HOR=horizontal reference, OPT=odontoid process tangent

## Discussion

This study evaluated the association between skeletal malocclusion and head posture using CBCT. The small sample (N=16) limits statistical power and generalizability; thus, findings should be considered preliminary and interpreted cautiously pending larger studies. Several methodological factors that may influence head posture measurements should also be considered. Using NHP during CBCT acquisition reduces craniovertical variability and improves measurement reliability, consistent with evidence from conventional cephalometric and CBCT-based head orientation studies<sup>18-20</sup>. Age was not analyzed; however, previous evidence indicates that adult postural angles and cervical curvature are relatively age-stable<sup>21</sup>. Although some referenced studies involved younger populations, craniocervical posture relationships have been reported across age groups; therefore, these findings remain relevant for contextual interpretation. Gender may exert some influence on head posture; however, the differences are typically modest and are generally overshadowed by other determinants, such as individual postural habits and underlying musculoskeletal factors<sup>22</sup>. Group differences in age and sex distribution were unlikely to materially influence

the results, despite fewer males in each group. Taken together, age, sex, and individual postural characteristics represent potential interacting confounders that may influence head posture independently of skeletal morphology and should be considered when interpreting the present associations.

The reference lines identified on the CBCT images were subsequently transferred and processed in CorelDRAW. Although CorelDRAW is not a validated medical imaging software, its use in the present study was limited to the construction of reference lines and angular measurements based on predefined anatomical landmarks. Calibrated digital cephalometric measurements using graphic-based landmark construction can be comparable to conventional methods<sup>23,24</sup>, although these studies were conducted using dedicated cephalometric software rather than general graphic programs. Non-medical software may introduce minor variability, and this should be considered when interpreting the findings. Hassan et al. reported that digital cephalometric measurements performed using graphic software can yield results comparable to manual methods, provided that calibration procedures and the standardization of anatomical landmark identification are

applied consistently<sup>23</sup>. Narkhede et al. also reported that digital tracing provides reliable, efficient, and accurate measurements for specific cephalometric parameters<sup>24</sup>. The good intra-examiner reliability supports the consistency of the measurement protocol.

The ANOVA results showed statistically significant differences in craniocervical angles (NSL/VER and NL/VER) between the malocclusion classes. Post-hoc analyses indicated that NSL/VER differed significantly between Class I and Class III, and between Class II and Class III, while NL/VER differed significantly only between Class II and Class III. These findings indicate differences in craniocervical head posture across skeletal malocclusion groups. Class I malocclusion represents a more typical jaw relationship, with fewer postural deviations. Class II and III malocclusions show more contrasting jaw morphologies (retrusion and protrusion, respectively), which may relate to the observed craniocervical differences; however, this represents a literature-based interpretation rather than a direct finding of the present study<sup>4,25,26</sup>. However, given the small sample size and preliminary nature of this study, these observations should be interpreted cautiously. In addition, the reliance on two-dimensional angular projections derived from CBCT volumes may influence craniocervical measurements, which should be considered when interpreting these group differences. Although other postural parameters did not reach statistical significance, likely due to smaller effect sizes and limited power, the observed patterns are consistent with previous findings<sup>26,27</sup>. Bjork reported that individuals with retrognathic facial profiles tend to maintain the head in slight extension, with the forehead backward and the chin forward. In contrast, individuals with prognathic profiles position the chin forward and downward<sup>26</sup>. These observations are consistent with the present findings of craniocervical differences across skeletal malocclusion groups<sup>25</sup>. Overall, these results provide preliminary evidence of differences in craniocervical

head posture across malocclusion types and require confirmation in larger studies. These observations align with recent systematic evidence indicating heterogeneous and inconclusive associations between sagittal malocclusion and craniocervical head posture across populations and measurement methods<sup>5,28</sup>.

The correlation analysis demonstrated that skeletal Class III malocclusion showed significant positive associations with craniocervical posture parameters (NSL/CVT, NL/CVT, NSL/OPT, and NL/OPT). These associations indicate greater craniocervical angulation within the Class III subgroup. Such postural characteristics have been described in the literature as patterns possibly related to functional or anatomical factors<sup>25,27</sup>, although these factors were not directly evaluated in the present study. The present findings are consistent with these previous reports describing increased craniocervical angulation in skeletal Class III patterns<sup>26,29</sup>. However, these interpretations should be considered cautiously, given the exploratory nature of the present study and its cross-sectional design. In skeletal Class III malocclusion, differences in posture are reflected by increased craniocervical rotation and alterations in lower cervical alignment in the present measurements, without implying adaptive or compensatory mechanisms. Accordingly, craniocervical angular parameters (NSL/OPT, NSL/CVT, NL/OPT, and NL/CVT) appear to be particularly responsive to variations in craniocervical posture<sup>4</sup>. These angles describe the spatial relationship between cranial or maxillary reference planes and the orientation of the cervical column relative to the horizontal plane. Previous studies suggest that forward or upright head orientation may be reflected in these angles; however, this could not be confirmed in the present sample<sup>3</sup>. Because the present study is cross-sectional, these postural differences should be interpreted as associations rather than evidence of adaptive or compensatory mechanisms. Furthermore, the small sample size may have amplified subgroup correlations and

should be considered when interpreting the strength of Class III associations. Systematic reviews have similarly reported tendencies toward increased craniocervical angulation in Class III skeletal patterns, although overall evidence remains inconsistent and methodologically heterogeneous<sup>5,28</sup>.

No significant correlations were observed for the craniovertical angles (NSL/VER, NL/VER) in skeletal Class I, II, or III subjects. These parameters depend on an external vertical reference and are influenced by the orientation of the head during image acquisition. Consequently, they may be more susceptible to individual variations in head positioning, which could contribute to increased measurement variability. This absence of significant craniovertical correlations contrasts with some previous cephalometric studies and may partly reflect limited statistical power in the present sample<sup>4,30</sup>.

The cervicohorizontal angles (OPT/HOR and CVT/HOR) did not exhibit significant associations across the three skeletal classes. This finding may be related to the fact that cervicohorizontal angles primarily reflect the orientation of the cervical column relative to the horizontal plane rather than craniocervical compensatory mechanisms<sup>4,31</sup>. Despite CBCT's anatomical accuracy, measurement variability, acquisition posture, and individual differences may still obscure correlations, although these influences were not specifically measured in this study. In addition, head orientation during CBCT acquisition may affect cervicohorizontal angles, which should be considered when interpreting the absence of significant associations. Previous studies report mixed cervicohorizontal findings; the present non-significant results are consistent with those showing limited or no associations<sup>13,32</sup>. This variability is consistent with meta-analytic findings demonstrating substantial heterogeneity in posture measurements and limited reproducibility across studies evaluating malocclusion-posture relationships<sup>27</sup>.

The significant correlation of OPT/CVT in the skeletal Class I group indicates a relatively consistent relationship

between upper and lower cervical segments in individuals with balanced jaw relationships. In agreement with DiPalma et al., the OPT/CVT angle tends to remain stable in subjects with normal (Class I) skeletal patterns because it does not rely on craniofacial structural variation<sup>28</sup>. Cervical curvature demonstrated a significant correlation only in the skeletal Class I group, which may reflect a more consistent relationship between head posture and cervical alignment in individuals with balanced craniofacial relationships, rather than a directly measured mechanism in the present study. In contrast, skeletal Class II and Class III groups showed different postural patterns, which is consistent with previously reported head orientation tendencies in the literature. Relative to skeletal Class II and Class III groups, skeletal Class I subjects may exhibit less variable craniocervical alignment, which may be associated with a more consistent relationship between lower cervical curvature (OPT/CVT) and craniofacial structures<sup>10</sup>. However, this finding is based on a small subgroup and should be interpreted cautiously. These functional and neuromuscular determinants were not directly measured in the present study; therefore, their role remains hypothetical and literature-based. Demographic factors such as age and sex may confound the relationship between skeletal pattern and craniocervical alignment.

Head posture is influenced by multiple functional and neuromuscular factors beyond skeletal morphology<sup>4,33</sup>. Respiratory function has been reported to affect craniofacial and craniocervical posture, as individuals may adopt a forward head position to maintain airway patency<sup>34</sup>. Cervical muscle tone and neuromuscular balance also play a critical role in head posture stabilization and may contribute to interindividual variability in postural measurements<sup>35</sup>. Visual orientation represents another important determinant, as head position is frequently adjusted to preserve a horizontal visual axis<sup>4</sup>. Furthermore, habitual posture and daily ergonomic behaviors may influence craniocervical alignment over time<sup>33</sup>. These factors were not directly assessed in the present study and may have contributed

to the observed variability in head posture measurements. Collectively, demographic (age, sex), neuromuscular, and habitual postural factors represent a multifactorial confounding framework that may influence craniocervical posture independently of skeletal malocclusion.

The use of CBCT in this study offers the advantage of generating more accurate anatomical data compared with conventional radiography<sup>15,36,37</sup>. However, several limitations should be considered when interpreting the findings. Although CBCT provides 3D data, measurements were taken from standardized lateral projections derived from CBCT volumes to maintain consistency with conventional 2D cephalometric references commonly used in craniocervical assessment<sup>15,23,24,37</sup>. Using CBCT-based two-dimensional projections improves landmark visualization and anatomical accuracy compared with conventional lateral cephalograms, while preserving methodological comparability with previous studies<sup>15,23,24,37</sup>. The CBCT volumes serve as accurate 3D anatomical references, ensuring that the underlying structures are reliably represented, which allows for precise identification of craniofacial landmarks and facilitates reproducible angular measurements. Alfaily et al. showed that CBCT has higher accuracy than 2D imaging for localizing impacted canines, supporting its use for orthodontic postural analysis even with 2D projections<sup>37,38</sup>.

The head posture assessment was performed using lateral projections derived from CBCT data; therefore, the representation of craniocervical positioning remains essentially two-dimensional and does not fully capture the three-dimensional complexity of cranial and cervical spatial orientation<sup>36,39</sup>. Moreover, the identification of anatomical landmarks was performed manually, and despite prior calibration procedures, this approach remains susceptible to examiner-dependent subjective variation<sup>40</sup>. However, these findings should be interpreted with caution due to the limited sample size, which restricts statistical power and generalizability. Accordingly, the results should be

considered preliminary in nature. Future studies with larger sample sizes and more comprehensive three-dimensional analyses are required to confirm these preliminary observations and to further clarify the relationship between skeletal malocclusion and head posture.

Inter-examiner reliability was not assessed in the present study, as all measurements were performed by a single calibrated examiner; this should be addressed in future studies. The cross-sectional design of this study also limits the ability to understand potential changes in head posture that may occur with growth or long-term functional adaptation. Other factors, such as postural habits, cervical muscle tone, visual conditions, and demographic variation (age and sex) that can influence head position, were not evaluated in this study and therefore represent potential confounders in the observed associations between skeletal malocclusion and head posture. Nevertheless, the findings of this investigation provide a preliminary basis for future research employing longitudinal designs and comprehensive three-dimensional analyses.

## Conclusion

Skeletal Class III malocclusion was associated with differences in craniocervical angular measurements in this small preliminary cross-sectional sample. These findings indicate statistical associations rather than adaptive postural mechanisms. Skeletal Class I subjects showed a more consistent cervical curvature, while no meaningful correlations were observed in skeletal Class II. Craniovertical and cervicohorizontal angles showed limited associations due to their sensitivity to head orientation and individual variability. Although CBCT provides enhanced anatomical visualization, limitations related to manual landmark identification, two-dimensional projection analysis, cross-sectional design, and small sample size restrict the generalizability and clinical interpretation of these findings. Overall, these results are preliminary and

require confirmation in larger, longitudinal, and fully three-dimensional studies.

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## Conflict of interest

The authors declare that there is no conflict of interest regarding the publication of this manuscript.

## References

1. Šidlauskienė M, Smailienė D, Lopatienė K, Čekanauskas E, Pribušienė R, Šidlauskas M. Relationships between malocclusion, body posture, and nasopharyngeal pathology in pre-orthodontic children. *Med Sci Monit* 2015;21:1765–73.
2. D'Attilio M, Caputi S, Epifania E, Festa F, Tecco S. Evaluation of cervical posture of children in skeletal class I, II, and III. *Cranio* 2005;23:219–28.
3. Sandoval C, Díaz A, Manríquez G. Relationship between craniocervical posture and skeletal class: a statistical multivariate approach for studying class II and class III malocclusions. *Cranio* 2021;39:133–40.
4. Solow B, Tallgren A. Head posture and craniofacial morphology. *Am J Phys Anthropol* 1976;44:417–35.
5. Peng H, Liu W, Yang L, Zhong W, Yin Y, Gao X, et al. Does head and cervical posture correlate to malocclusion? a systematic review and meta-analysis. *PLoS One* 2022;17:1–16.
6. Tankhiwale A, Rahalkar JS, Agarkar S, Deshmukh S, Manerikar R. Relationship between extended head posture and malocclusion. *IP Indian J Orthod Dentofac Res* 2020;4:35–40.
7. Rhiyanthy F, Lubis MM, Yusuf M, Sofyanti E, Bahirrah S. Relationship head posture in class II skeletal malocclusion against canal width breath and hyoid bone position. *J Int Dent Med Res* 2023;17:247–52.
8. Tauheed S, Shaikh A, Fida M. Cervical posture and skeletal malocclusions – is there a link? *J Coll Med Sci* 2019;15:5–9.
9. Daryanani JD, Vijay N, Shetty KS, Chawla R. Changes in pharyngeal airway after mandibular setback surgery: a retrospective cephalometric study. *J Indian Orthod Soc* 2019;53:256–63.
10. Bindayel NA, Bindayel NA. The impact of postural changes on dental occlusion. *Pak Oral Dent J* 2017;37:583–8.
11. Navarro R de L, Oltramari-Navarro PVP, Fernandes TMF, de Oliveira GF, Conti AC de CF, de Almeida MR, et al. Comparison of manual, digital and lateral CBCT cephalometric analyses. *J Appl Oral Sci* 2013;21:167–76.
12. Harrell WE. Limitations of two-dimensional cephalometric analysis in orthodontic diagnosis and treatment planning: the future of three-dimensional analysis. *ResearchGate* [homepage on the Internet]. 2005 [cited 2025 Sep 3]. Available from: <https://www.researchgate.net/publication/259707627>
13. Chung EJ, Yang BE, Park IY, Yi S, On SW, Kim YH, et al. Effectiveness of cone-beam computed tomography-generated cephalograms using artificial intelligence cephalometric analysis. *Sci Rep* 2022;12:1–8.
14. Kaasalainen T, Ekholm M, Siiskonen T, Kortensniemi M. Dental cone beam CT: an updated review. *Phys Med* 2021;88:193–217.
15. Singh D. Cone-beam computed tomography: a new era in clinical orthodontics. *Int J Health Sci* 2021;5:411–27.
16. Mohamad Y, Rani MAB, Gaballah K, Badran S, Manila N, Shetty SR, et al. A study on the association between skeletal malocclusion, upper airway cross-sectional area, and upper airway volume using CBCT scans. *Eur J Gen Dent* 2026;15:89–98.
17. Anagnostopoulos I, Pattanaik S, Zaky A, El-motayam A, Shetty SR, Sadek MM. Assessment of upper airway and temporomandibular joint changes in growing patients with Class II Division 1 malocclusion, treated with the twin block appliance: a retrospective cone-beam computed tomography study. *Arch Craniofac Surg* 2025;26:92–101.
18. Wani MA, Amir M, Siddiqui S, Shukla D. Significance of natural head position (NHP) in orthodontic diagnosis: a review. *J Dent Panacea* 2023;5:149–54.
19. Meiyappan N, Tamizharasi S, Senthilkumar KP, Janardhanan K. Natural head position: an overview. *J Pharm Bioallied Sci* 2015;7:424–7.
20. Verma SK, Maheshwari S, Gautam SN, Prabhat KC, Kumar S. Natural head position: key position for radiographic and photographic analysis and research of craniofacial complex. *J Oral Biol Craniofac Res* 2012;2:46–9.
21. Tecco S, Festa F. Cervical spine curvature and craniofacial morphology in an adult caucasian group: a multiple regression analysis. *Eur J Orthod* 2007;29:204–9.

22. Peng L, Cooke MS. Fifteen-year reproducibility of natural head posture: a longitudinal study. *Am J Orthod Dentofacial Orthop* 1999;116:82–5.
23. Hassan MM, Alfaifi WH, Qaysi AM, Alfaifi AA, AlGhafli ZM, Mattoo KA, et al. Comparative evaluation of digital cephalometric tracing applications on mobile devices and manual tracing. *Med Sci Monit* 2024;30:1–12.
24. Narkhede S, Rao P, Sawant V, Sachdev SS, Arora S, Pawar AM, et al. Digital versus manual tracing in cephalometric analysis: a systematic review and meta-analysis. *J Pers Med* 2024;14:1–23.
25. Sikandar S, Chaudhry NA, Rahbar MI, Riaz A, Kamal MM, Ali F. Relationship between craniocervical posture and vertical face pattern in class II division 1 malocclusion. *Esculapio J Serv Inst Med Sci* 2023;19:241–6.
26. Bjork A. Some biological aspects of prognathism and occlusion of the teeth. *Acta Odontol Scand* 1950;9:1–40.
27. Alexa VT, Fratila AD, Szuhaneck C, Jumanca D, Lalescu D, Galuscan A. Cephalometric assessment regarding craniocervical posture in orthodontic patients. *Sci Rep* 2022;12:1–15.
28. Dipalma G, Inchingolo AD, Pezzolla C, Sardano R, Trilli I, Di Venere D, et al. Head and cervical posture in sagittal skeletal malocclusions: insights from a systematic review. *J Clin Med* 2025;14:1–21.
29. Khalil N, Bizdikian AJ, Bakouny Z, Salameh M, Bou Zeid N, Yared F, et al. Cervical and postural strategies for maintaining horizontal gaze in asymptomatic adults. *Eur Spine J* 2018;27:2700–9.
30. Solow B, Siersbaek-Nielsen S. Growth changes in head posture related to craniofacial development. *Am J Orthod* 1986;89:132–40.
31. Peng H, Liu W, Yang L, Yan P, Zhong W, Gao X, et al. Craniocervical posture in patients with skeletal malocclusion and its correlation with craniofacial morphology during different growth periods. *Sci Rep* 2024;14:1–11.
32. Cassi D, De Biase C, Tonni I, Gandolfini M, Di Blasio A, Piacino MG. Natural position of the head: review of two-dimensional and three-dimensional methods of recording. *Br J Oral Maxillofac Surg* 2016;54:233–40.
33. Straker LM, O'Sullivan PB, Smith A, Perry M. Computer use and habitual spinal posture in Australian adolescents. *Public Health Rep* 2007;122:634–43.
34. Fathi H, Mohammad-Rabei E, Kabiri S, Baghban A, Soheilifar S, Nouri M. Craniofacial and airway growth in 9–11 years old normal dental occlusion in Iranian adolescents: a longitudinal cephalometric study. *Dent Hypotheses* 2017;8:8–16.
35. Goodarzi F, Rahnama L, Karimi N, Baghi R, Jaberzadeh S. The effects of forward head posture on neck extensor muscle thickness: an ultrasonographic study. *J Manipulative Physiol Ther* 2018;41:34–41.
36. Kadioglu O, Currier GF. *Craniofacial 3D imaging*. Cham: Springer; 2019.
37. Polizzi A, Serra S, Leonardi R. Use of CBCT in orthodontics: a scoping review. *J Clin Med* 2024;13:1–18.
38. Hajeer MY, Al-Homsi HK, Alfailany DT, Murad RMT. Evaluation of the diagnostic accuracy of CBCT-based interpretations of maxillary impacted canines compared to those of conventional radiography: an in vitro study. *Int Orthod* 2022;20.
39. van Vlijmen OJC, Maal T, Bergé SJ, Bronkhorst EM, Katsaros C, Kuijpers-Jagtman AM. A comparison between 2D and 3D cephalometry on CBCT scans of human skulls. *Int J Oral Maxillofac Surg* 2010;39:156–60.
40. Wen J, Liu S, Ye X, Xie X, Li J, Li H, et al. Comparative study of cephalometric measurements using 3 imaging modalities. *J Am Dent Assoc* 2017;148:913–21.