

RELATIONSHIP BETWEEN MALOCCLUSION, LOSS OF CERVICAL LORDOSIS AND ATLANTO-OCCIPITAL INSTABILITY: A RANDOMIZED CONTROLLED TRIAL

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Abstract

This study aims to investigate the relationship between malocclusion, cervical lordosis, and atlanto-occipital instability (AOI). By analyzing cephalometric and cervical spine measurements, this research seeks to provide insights into how malocclusion may influence cervical posture and to emphasize the importance of considering postural alignment in orthodontic diagnosis and treatment planning.

This study aimed to investigate the relationship between malocclusion (ANB angle) and loss of cervical lordosis (cervical Cobb angle). A total of 155 patients (77 female, 78 male) who applied to Kastamonu Training and Research Hospital were included in the study. SNA, SNB, and ANB angles were measured using full-head tomography, and skeletal classification was performed. Cervical lordosis was evaluated using the Cobb method. Additionally, to analyze atlanto-occipital instability, measurements of the basion-dental apex distance, Atlas Anterior Tubercle-Posterior Dens (ADI) distance, lateral mass steps in the rotational plane, Powers Ratio, and clivus canal angle were performed.

Statistical analyses revealed a moderate negative correlation between skeletal class and cervical Cobb angle (Pearson correlation coefficient $r = -0.32$, $p = 0.001$; Spearman correlation coefficient $r = -0.29$, $p = 0.002$). Similarly, a negative correlation was found between the ANB angle and cervical Cobb angle (Pearson correlation coefficient $r = -0.28$, $p = 0.003$; Spearman correlation coefficient $r = -0.26$, $p = 0.004$). These findings suggest that malocclusion may

not only affect dental and maxillofacial structures but also influence cervical spine posture.

The study found that cervical lordosis angle increased in skeletal Class 2 individuals, and this condition may be associated with postural disorders. Additionally, the prevalence of skeletal Class 3 malocclusion has increased by approximately 50% since 2004. These findings highlight the importance of considering cervical spine posture in orthodontic treatment planning and the need for a multidisciplinary approach between orthodontists and orthopedists.

This study demonstrates a relationship between skeletal class, ANB angle, and cervical lordosis. Future studies with larger sample sizes will provide a more detailed understanding of this relationship.

Key words: malocclusion, cervical lordosis, atlantoaxial instability, atlanto-occipital instability, postural disorders

Introduction. When the spine in the neck area does not have the healthy C-shaped curve it should have, this condition is referred to as loss of cervical lordosis and the neck becomes flat. Loss of cervical lordosis or straight cervical spine is a common finding visible on lateral cervical x-ray, and this condition is a cause of structural overload and degeneration of muscles, tendons, and discs in the cervical region [1].

The atlantoaxial joint, one of the most mobile joints, consists of the atlas (C1) and axis (C2) and provides the greatest possible movement and flexibility, both in providing support for the occiput and maintaining stability [2, 3].

According to GRADE et al. [4] the temporomandibular joint (TMJ) represents the attachment of the mandible to the base of the skull, which in turn provides muscular and ligamentous connections with the cervical region. Together, they form a functional system called the crania-cervico-mandibular. Studies of this close connection are designed to confirm that changes in the posture of the head and other body parts can lead to functional changes of the masticatory system and vice versa [5–10]. It has been observed that the molar relationship plays an important role in this connection and that certain malocclusion problems may be more related to changes in head posture than others [11]. As seen in the literature, there is a close relationship between malocclusion and the cervical region [12]. In this study, the relationship between malocclusion and cervical lordosis and atlanto-occipital instability was evaluated.

Methods and analysis. Study design and participants. This randomized controlled trial was conducted at Kastamonu Training and Research Hospital. A total of 200 patients aged between 18 and 30 years were initially recruited. After applying exclusion criteria (unclear imaging, complete edentulism, trauma history, etc.), 155 participants (77 females, 78 males) were included in the final analysis. The study was approved by the Kastamonu University Clinical Research Ethics Committee (approval number: 2024-KAEK-159), and all participants provided informed consent.

Data collection.

1. Cephalometric measurements:

- Full-head tomography was performed for each participant.
- The following angles were measured using Steiner analysis:
 - **SNA Angle:** Formed by Sella (S), Nasion (N), and Point A (deepest point of the maxillary concavity).
 - **SNB Angle:** Formed by Sella (S), Nasion (N), and Point B (deepest point of the mandibular concavity).
 - **ANB Angle:** The difference between SNA and SNB, used to classify skeletal malocclusion:
 - **Class 1:** ANB 0–4°
 - **Class 2:** ANB > 4°
 - **Class 3:** ANB < 0°

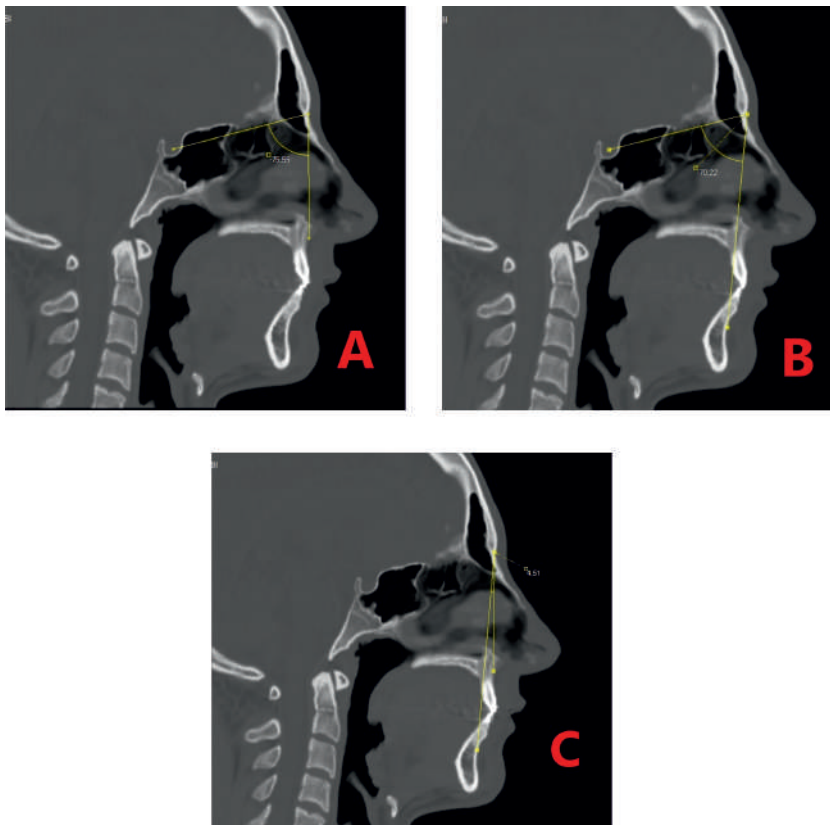


Fig. 1. Angles SNA (A), SNB (B), and ANB (C) in cephalometric analysis

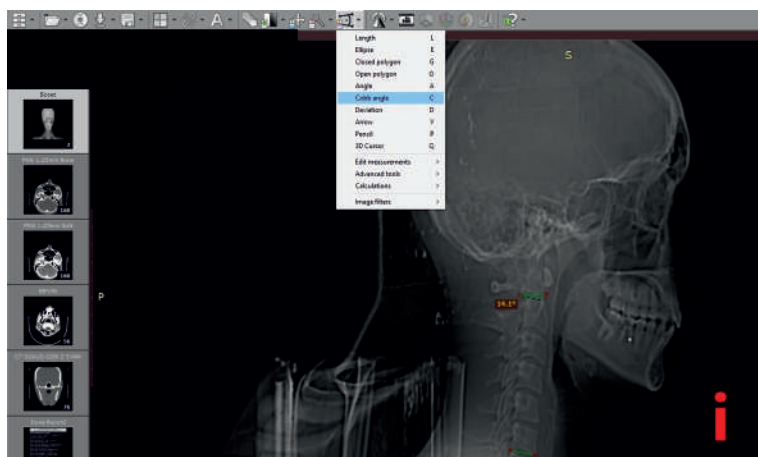


Fig. 2. Cobb method (i) Using the Radiant Dicom Viewer Program, sagittal section is taken and Cobb angle measurement mode is selected. It can be measured automatically or manually

Cervical lordosis assessment.

- Cervical lordosis was measured using the Cobb method (C2–C7) on lateral cervical radiographs. The angle was formed by lines drawn along the inferior endplates of C2 and C7 vertebrae [10].

2. Atlanto-occipital instability (AOI) evaluation:

- The following parameters were assessed:
 - **Basion-Dental Apex Distance (BDI):** > 10 mm in the sagittal plane.
 - **Atlas-Dens Interval (ADI):** > 5 mm in the sagittal plane.
 - **Lateral Mass Steps (LMS):** Sum > 7 mm in the coronal plane.
 - **Powers Ratio:** Calculated as the ratio of basion-posterior atlas arch to opisthion-anterior atlas arch distances.
 - **Clivus-Canal Angle:** Measured between the clivus and the dens axis.

Statistical analysis.

- **Correlation analysis:** Pearson and Spearman correlation tests were used to evaluate relationships between skeletal class, ANB angle, and cervical Cobb angle.
- **Chi-Square test:** Assessed the association between AOI indicators and skeletal classification.

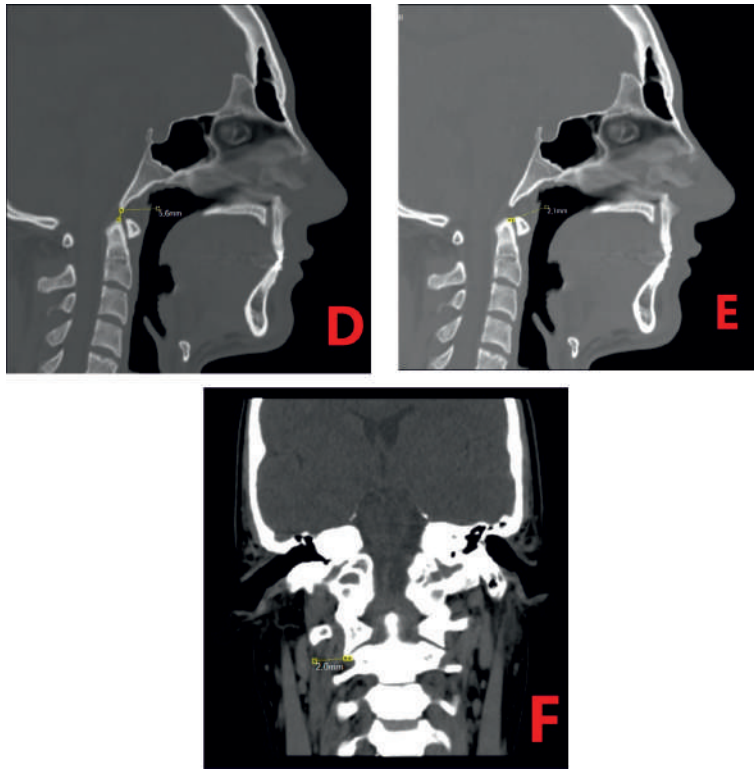


Fig. 3. Basion-Dental Apex Distance (D), Atlas-Dens Interval (E), Lateral Mass Steps (F)

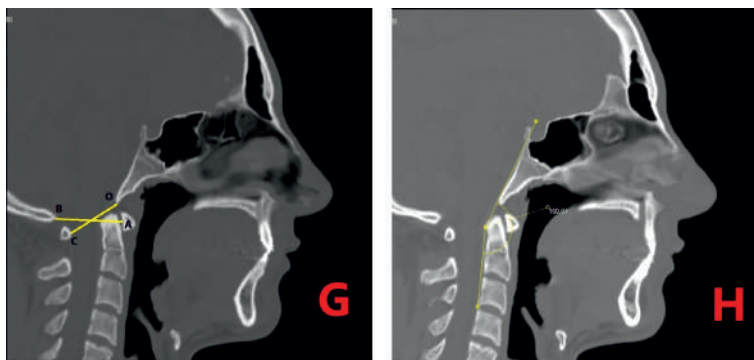


Fig. 4. Powers Ratio (G), Clivus-Canal Angle (H)

- **Power analysis:** Conducted using G*Power software (version 3.1) with the following parameters:
 - Effect size ($r = -0.32$), $\alpha = 0.05$, sample size = 155.
 - The calculated statistical power was 92.5%, confirming adequate sample size.

Quality control.

- All measurements were performed by two trained researchers to ensure inter-rater reliability.
- Intra-class correlation coefficients (ICC) were calculated for cephalometric and cervical measurements, with values > 0.85 indicating high reliability.

Ethical considerations. The study adhered to the Declaration of Helsinki. Participants were anonymized, and data were stored securely. In the statistical analysis, Pearson and Spearman correlation tests were applied through artificial intelligence.

Results. In the analyses performed to evaluate the relationship between skeletal class and cervical Cobb angle, Pearson correlation coefficient was found as $r = -0.32$, $p = 0.001$, Spearman correlation coefficient was found as $r = -0.29$, $p = 0.002$. Pearson correlation between ANB angle and cervical Cobb angle was found to be $r = -0.28$, $p = 0.003$ and Spearman correlation was found to be $r = -0.26$, $p = 0.004$.

Power Analysis review with Gpower:

- 1) Test Family:
 - a) Correlation: Bivariate normal model is selected.
- 2) Statistical Test:
 - a) Pearson correlation is selected.
- 3) Type of Power Analysis:
 - a) Post hoc is selected. (Power is calculated using the available sample size and effect size.)
- 4) Input Parameters:
 - a) Effect size (r): -0.32 (Pearson correlation coefficient found in the study.)
 - b) α err prob: 0.05 (Generally accepted significance level).
 - c) Total sample size: 155 (Total sample size used in the study).
- 5) Output:
 - a) Power ($1 - \beta$): This value will indicate the statistical power for the current sample size and effect size of the study.

6) Calculation result:

In the calculation using GPower software, the following results are obtained:

- i) Effect size (r): -0.32
- ii) α err prob: 0.05
- iii) Total sample size: 155
- iv) Power ($1 - \beta$): 92.5% (approx. 0.925)

Power ($1 - \beta$) value of the study was calculated as 92.5% . This value indicates that the study has a high statistical power. Generally, a power value of 80% or higher indicates that the study has an adequate sample size and has a high probability of detecting an effect that actually exists.

This result supports the validity of the findings of the study. However, it may be recommended to use larger samples to detect smaller effect sizes in future studies.

Furthermore, when we analysed the relationship between the atlanto-occipital instability (AOI) indicator and skeletal classification using methods such as chi-square test or Fisher's Exact Test, the following results were obtained:

Patients with AOI indicator:

- **Skeletal class 1:** 28 patients
- **Skeletal class 2:** 17 patients
- **Skeletal class 3:** 6 patients
- **Total patients with AOI indicator:** 51 patients

Patients without AOI indicator:

- **Skeletal class 1:** 54 patients
- **Skeletal class 2:** 28 patients
- **Skeletal class 3:** 22 patients
- **Total patients without AOI indicator:** 104 patients

Total number of patients:

- **Total Patients:** 155 patients

Analysis steps:

1. Observed frequencies table:

T a b l e 1

Analysis of the relationship between the atlanto-occipital instability (AOI) indicator and skeletal classification

	Skeletal class 1	Skeletal class 2	Skeletal class 3	Total
AOI indicator present	28	17	6	51
AOI indicator absent	54	28	22	104
Total	82	45	28	155

2. Expected frequencies table:

Expected frequencies are calculated assuming there is no relationship between AOI indicator and skeletal classification. The formula for expected frequency is:

$$\text{Expected Frequency} = \frac{\text{Row Total} \times \text{Column Total}}{\text{Grand Total}}$$

◦ **AOI indicator present & Skeletal class 1:**

$$\frac{51 \times 82}{155} \approx 26.99$$

◦ **AOI indicator present & Skeletal class 2:**

$$\frac{51 \times 45}{155} \approx 14.81$$

◦ **AOI indicator present & Skeletal class 3:**

$$\frac{51 \times 28}{155} \approx 9.20$$

◦ **AOI indicator absent & Skeletal class 1:**

$$\frac{104 \times 82}{155} \approx 55.01$$

◦ **AOI indicator absent & Skeletal class 2:**

$$\frac{104 \times 45}{155} \approx 30.19$$

◦ **AOI indicator absent & Skeletal class 3:**

$$\frac{104 \times 28}{155} \approx 18.80$$

3. Chi-Square test:

The chi-square statistic (χ^2) is calculated as:

$$\chi^2 = \sum \frac{(\text{Observed} - \text{Expected})^2}{\text{Expected}}$$

- AOI indicator present & Skeletal class 1:

$$\frac{(28 - 26.99)^2}{26.99} \approx 0.04$$

- AOI indicator present & Skeletal class 2:

$$\frac{(17 - 14.81)^2}{14.81} \approx 0.33$$

- AOI indicator present & Skeletal class 3:

$$\frac{(6 - 9.20)^2}{9.20} \approx 1.13$$

- AOI indicator absent & Skeletal class 1:

$$\frac{(54 - 55.01)^2}{55.01} \approx 0.02$$

- AOI indicator absent & Skeletal class 2:

$$\frac{(28 - 30.19)^2}{30.19} \approx 0.16$$

- AOI indicator absent & Skeletal class 3:

$$\frac{(22 - 18.80)^2}{18.80} \approx 0.55$$

Total Chi-Square statistics (χ^2):

$$\chi^2 \approx 0.04 + 0.33 + 1.13 + 0.02 + 0.16 + 0.55 = 2.23$$

4. Degrees of freedom (df)

$$df = (\text{Number of Rows} - 1) \times (\text{Number of Columns} - 1) = (2 - 1) \times (3 - 1) = 2$$

5. Critical value and p -value

- **Critical value** (from χ^2 table, $df = 2$ and $\alpha = 0.05$): **5.99**

◦ **Calculated χ^2 value: 2.23**

Since the calculated χ^2 value (2.23) is less than the critical value (5.99), we conclude that there is no significant relationship between AOI indicator and skeletal classification. Bonferroni correction was not used.

Discussion. Our study shows that there is a moderate negative relationship between skeletal class and cervical lordosis. In addition, it was determined that the ANB angle showed a similar negative relationship with cervical lordosis. Similarly, AKÇAM et al. [13] reported that cervical lordosis angle increased in skeletal Class 2 individuals. However, TÜRKMEN [14] reported that the postural adaptation mechanism of the cervical region may vary between individuals. Our findings suggest that cervical region posture should be taken into consideration in orthodontic diagnosis and treatment processes.

In this study, an increase in the ANB angle was found to be associated with a loss of cervical lordosis. This suggests that malocclusion may affect not only dental and maxillofacial structures but also cervical spine posture. Similarly, SOLOW and SANDHAM [15] reported that malocclusion may be associated with postural disorders.

Similarly, HUGGARE and HOUGHTON [16] emphasised that malocclusion may affect cervical spine curvature and this may lead to postural disorders.

In this study, the fact that malocclusion was associated with loss of cervical lordosis suggests that orthodontic treatments may not only correct dental and maxillofacial structures but also improve cervical spine posture. This finding emphasises the importance of a multidisciplinary treatment approach, especially in patients with malocclusion and postural disorders. MICHELOTTI et al. [17] reported that orthodontic treatments may have positive effects on cervical spine posture and such treatments may reduce postural disorders.

SAYIN and TÜRKKAHRAMAN [18] who analysed the Turkish population in 2004, found 64% Class 1, 24% Class 2, 12% Class 3 malocclusion. In this study, Class 1 was 53%, Class 2 was 29% and Class 3 malocclusion was 18%.

Similar studies (e.g., [13]) report comparable effect sizes, yet their findings have influenced clinical guidelines advocating for postural screening in orthodontic patients. Our results reinforce this emerging consensus.

To evaluate the statistical power of our study, a power analysis was performed using GPower software. Considering the Pearson correlation coefficient ($r = -0.32$) and sample size ($n = 155$), the statistical power of the study was calculated as 92.5%. This value indicates that the study has sufficient sample size and supports the validity of the findings.

Although orthodontists are knowledgeable about cephalometry, it may be beneficial for them to be familiar with the Cobb method and Atlanto-Occipital Instability (AOI) determination methods.

Conclusions.

- 1) Skeletal class and ANB angle showed a moderate negative correlation with cervical lordosis. In other words, as the skeletal class changed (especially as it shifted to Class 2), certain changes were observed in the Cobb angle of cervical lordosis. This emphasises the importance of the link between skeletal structure and postural balance.
- 2) There has been an increasing trend in Class 3 skeletal malocclusions since 2004, and it is recommended that treatment plans be created accordingly.
- 3) There is no significant relationship between AOI indicator and skeletal classification.
- 4) When planning orthodontic treatment, we should keep in mind that cervical spine curvature differs from person to person. Further research with larger groups will help us better understand the connection between skeletal class, ANB angle, and cervical posture.

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