# Relationship between the Nasopharyngeal Width and Hyoid Bone Position in Skeletal Malocclusion

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**Abstract**

Respiratory disturbances such as mouth breathing result in a more inferior position of the hyoid bone, enlarged tongue and soft palate, and decreased posterior pharyngeal space. The pharyngeal and hyoid bone position have a significant relationship with malocclusion. To determine the relationship between the nasopharyngeal width and hyoid bone position in skeletal Class I, II, and III malocclusions with normal growth patterns.

Lateral cephalometric radiographic was performed to measure the nasopharyngeal width and the position of the hyoid bone by using ImageJ software. The number of samples in this study was 82 samples divided into 3 groups: 36 subjects had skeletal Class I malocclusion with normal growth patterns, 30 subjects had skeletal class II, and 16 subjects had Class III.

The ANOVA test results showed that there was a significant relationship between the hyoid angle and skeletal Class I and II malocclusions (p=0.00) and Class II and III (p=0.01).

There was a positive correlation between the nasopharyngeal width and hyoid bone position (C3-H) in skeletal Class I with normal growth patterns.

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## Introduction

Malocclusion may be caused by a dental or skeletal misalignment. The psychosocial impact of malocclusion is strongly influenced by personal expectations, psychological resources and sociocultural factors.[1] Malocclusion is the result of orofacial adaptability to various etiological factors. These etiological factors can be divided into general factors and local factors.[2] One of the local etiological factors influencing malocclusion is a respiratory pattern.[2,3] A respiratory pattern is the main determinant of tongue and jaw posture. Disturbances in breathing patterns can disrupt the posture and balance of pressure exerted by the tongue and jaw so that it affects the growth of the jaw and the position of the teeth. One of the respiratory problems that are often found is breathing through the mouth.[2-8]

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Breathing through the mouth is a result of obstructions in the nasopharyngeal, which affects dentofacial growth.[7,6] When breathing through the mouth, the mandible will move downward, and the tongue will move downward and backward. If this condition continues, it can increase facial height, posterior teeth experiencing supra-eruption, the mandible will rotate down and backward, and increase the buccinator muscles pressure so that the maxillary arch becomes narrow.[3-6] Besides, the face and anterior cranial base also tend to experience retrusion, reduction of the cranial base angle, short or retrognathia mandible (or both), and an increase in the height of the lower face and the angle of the maxillomandibular plane.[4]

A lateral cephalometric radiograph can be used as a research material to look at growth patterns and craniofacial complexes, assess dentofacial proportions and clarify the anatomical basis for malocclusion.[2-4,9] Linear and angular measurements on lateral cephalometric radiographs to obtain more accurate measurement results are currently used by various types of software, one of which is ImageJ. The linear and angular measurements on lateral

cephalometric radiography can be done through image processing on a computerized radiograph using a filter on the ImageJ software.

The breathing pattern and the hyoid bone position also determine the posture of the tongue and jaw. The hyoid bones and their muscles have an important role in maintaining the pharyngeal.[2,3,5,10,11] Changes in the hyoid bones position tend to be related to the position of the mandible. Besides, in respiratory disorders, the hyoid bones will be located more inferiorly, the tongue and soft palate will enlarge, and the posterior pharyngeal space will decrease.[2,3,6] Furthermore, various studies have shown the relationship of the nasopharyngeal and the hyoid bone with malocclusion.

The study of Allhaijaa et al. showed a significant relationship between the length of the vertical pharyngeal and malocclusion. The length of the vertical pharyngeal was decreased in skeletal Class II malocclusion compared to Class III. The vertical position of the hyoid bone to the mandibular plane differs in skeletal Class II and III. Also, the anteroposterior position of the hyoid bone to the third cervical vertebra (C3) was found more anteriorly in skeletal Class II patients than in skeletal Class III patients.[5]

The study of Ucar et al. found that there were significant differences in craniofacial morphology and orofacial pharyngeal dimensions in Class I patients with different growth patterns.[12] Furthermore, a research by Alves Jr et al. found that the size of the oropharyngeal respiratory tract was significantly smaller in skeletal Class II than in skeletal Class I.[13] Because of the relationship between the nasopharyngeal and the position of the hyoid bone, dentists must understand this relationship to consider when making a diagnosis, determining the treatment plan, and evaluating the treatment results.

## Materials and methods

The researchers have obtained ethical clearance from the Health Research Ethics Commission with NO: 868/TGL/KEPK FK USU-RSUP HAM/2019. This was analytic observational research with cross-sectional design. This study used 82 lateral cephalometric radiographs divided into 3 groups: Class I malocclusion with a normal growth pattern with 36 samples, Class II with 30 samples, and Class III with 16 samples. Samples were obtained from medical records data of the orthodontic clinic, University of Sumatera Utara Dental Hospital patients from 2014 to 2019 with the purposive sampling method.

The inclusion criteria in this study were skeletal Class I malocclusion patients (ANB = 2° ± 2°), skeletal Class II (ANB > 4°), and skeletal Class III (ANB < 0°). Normal growth pattern (Y-axis = 65° ± 3°). The patients were aged 18 to 30 years, had a complete number of teeth, and had no history of orthodontic appliances use and/or functional orthopedic treatment. The patients have never had surgery on the respiratory system, and there were no respiratory problems. The lateral cephalometric radiographs had good and clear sharpness and contrast, so it was easy to identify the structures to be studied, and there was no distortion on the radiography. The exclusion criteria in this study were that the patients refused to participate in the study, and the patients had a systemic disease.

The research procedure was conducted by determining landmark points and reference lines then tracing lateral cephalometric radiographs to measure SNA, SNB, ANB, and Y-axis. Next, the lateral cephalometric radiographs were taken, which were placed on the viewer using a Nikon D90 camera with an AF-S DX 18-105 mm f/3.5-5.6G ED VR lens placed on a tripod with a distance of 50 cm. Afterward, the point landmarks and reference lines for linear measurement of the nasopharyngeal width were determined by using ImageJ software. The nasopharyngeal width was determined as the minimum distance between the upper soft palate and the closest point from the wall of the posterior pharyngeal using the McNamara method (Figure 1).

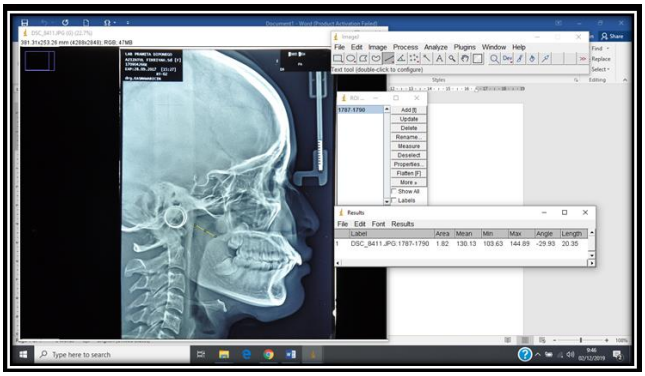

**Figure 1.** Measurement of the nasopharyngeal width using ImageJ software (personal documentation).

The landmark points and reference lines for linear and angular measurements of hyoid bone position were determined by using the Bibby and Preston methods; C3: A point at the most inferior anterior position in the third cervical vertebra. RGn (retrognation): The most inferior posterior point in the symphysis of the mandible. H (hyoidale): The most superior anterior point of the hyoid bone's body. Hyoid plane: The plane of H along the long axis of the largest horn of the hyoid bone. Hyoid plane angle: The most superior posterior angle formed by the intersection of the hyoid plane with C3-RGn. The anteroposterior position was determined by measuring the length of the H-RGn and H-C3 lines, the vertical position of the hyoid was determined by placing a perpendicular line from the C3-RGn plane to the hyoidale (H-H'), and the angular position was determined by measuring the angle formed by the hyoid axis to the C3-RGn plane (Figure 2).

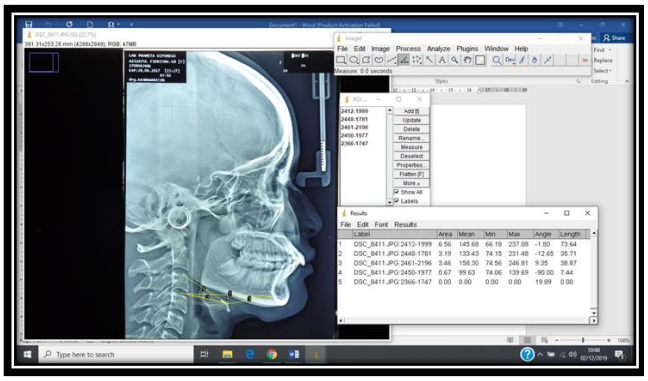

**Figure 2.** Measurement of the hyoid bone position using ImageJ software. (1). C3-RGn (2). C3-H (3). H-RGn (4). H-H' (5). Hyoid angle (personal documentation).

The data were analyzed to see normality using the Shapiro-Wilk test and then normally distributed data were analyzed by ANOVA one way. The Pearson correlation test was utilized to determine the relationship between the nasopharyngeal width and hyoid bone position. The results were considered to be significant at $p<0.05$. All statistical analysis was performed with the Statistical Package for the Social Sciences (SPSS), version 22.0 (IBM® Inc, New York, USA).

## Results

The measurement results in all samples found that the highest mean value of nasopharyngeal width was in skeletal Class III malocclusion with a value of 17.50 ± 2.51 mm (Table 1).

| Pharyngeal | Malocclusion | N | Mean (mm) | SD |
|---|---|---|---|---|
| Nasopharyngeal Width | Class I | 36 | 16.02 | 3.25 |
| | Class II | 30 | 15.79 | 2.27 |
| | Class III | 16 | 17.50 | 2.51 |

**Table 1.** The mean and standard deviation of the nasopharyngeal width in skeletal Class I, II, and III malocclusions with normal growth patterns.

The analysis results showed the mean value of C3-RGn was greater in the skeletal Class II with 77.63 ± 6.56 mm. Similarly, the mean of C3-H was greater in the skeletal Class II with 40.19 ± 4.59 mm. The mean of H-RGn had a similar value in skeletal Class I with 39.81 ± 4.68 mm and Class III with 39.63 ± 5.63 mm. The mean of H-H' was greater in Class II with 5.77 ± 4.39 mm. The mean of the hyoid angle was also greater in the skeletal Class II with 37.59 ± 5.9 mm (Table 2).

| Hyoid Bone Position | | Malocclusion | N | Mean (mm) | SD |
|---|---|---|---|---|---|
| Anteroposterior Position | C3-RGn | Class I | 36 | 77.30 | 6.42 |
| | | Class II | 30 | 77.63 | 6.56 |
| | | Class III | 16 | 75.86 | 8.53 |
| | C3-H | Class I | 36 | 38.85 | 5.02 |
| | | Class II | 30 | 40.19 | 4.59 |
| | | Class III | 16 | 37.46 | 3.85 |
| | H-RGn | Class I | 36 | 39.81 | 4.68 |
| | | Class II | 30 | 38.63 | 4.69 |
| | | Class III | 16 | 39.36 | 5.63 |
| Vertical Position | H-H' | Class I | 36 | 4.32 | 3.92 |
| | | Class II | 30 | 5.77 | 4.39 |
| | | Class III | 16 | 4.40 | 3.08 |
| Angular Position | Hyoid Angle | Class I | 36 | 30.41 | 5.65 |
| | | Class II | 30 | 37.59 | 5.91 |
| | | Class III | 16 | 32.89 | 6.94 |

**Table 2.** The mean and standard deviation of the hyoid bone position in skeletal Class I, II, and III malocclusions with normal growth patterns.

| Pharyngeal | Malocclusion | N | Mean (mm) ± SD | p-value |
|---|---|---|---|---|
| Nasopharyngeal Width | Class I | 36 | 16.02 ± 3.25 | 0.12 |
| | Class II | 30 | 15.79 ± 2.27 | |
| | Class III | 16 | 17.50 ± 2.51 | |

**Table 3.** ANOVA test results of the nasopharyngeal width in skeletal Class I, II, and III malocclusions with normal growth patterns.

The analysis results with the one way ANOVA test found no significant relationship between the nasopharyngeal width in skeletal Class I, II, and III malocclusions with value of p = 0.12 (Table 3). Significant differences were found between skeletal Class I, II, and III malocclusions with hyoid angles with a value of p = 0.00 (Table 4). Based on the analysis of the Least Significance Difference of the relationship

at the hyoid angle, there was a significant relationship between Class I and II malocclusions with value of p=0.00, Class II and III malocclusion with value of p=0.01 (Table 5).

| Hyoid Bone Position | | Malocclusion | N | Mean (mm) ± SD | p-value |
|---|---|---|---|---|---|
| Anteroposterior Position | C3-RGn | Class I | 36 | 77.30 ± 6.42 | 0.70 |
| | | Class II | 30 | 77.63 ± 6.56 | |
| | | Class III | 16 | 75.86 ± 8.53 | |
| | C3-H | Class I | 36 | 38.85 ± 5.05 | 0.16 |
| | | Class II | 30 | 40.19 ± 4.59 | |
| | | Class III | 16 | 37.46 ± 3.85 | |
| | H-RGn | Class I | 36 | 39.81 ± 4.68 | 0.62 |
| | | Class II | 30 | 38.63 ± 4.69 | |
| | | Class III | 16 | 39.63 ± 5.63 | |
| Angular Position | Hyoid Angle | Class I | 36 | 36.44 ± 8.33 | 0.00* |
| | | Class II | 30 | 36.92 ± 8.16 | |
| | | Class III | 16 | 23.82 ± 8.59 | |

**Table 4.** ANOVA test results of the hyoid bone position in skeletal Class I, II, and III malocclusions with normal growth patterns.
*significant p-value (p<0.05).

| Hyoid Bone Position | | Malocclusion | | $\bar{X}$ | p-value |
|---|---|---|---|---|---|
| Anteroposterior Position | C3-Rgn | Class I | Class II | -0.32 | 0.85 |
| | | | Class III | 1.44 | 0.49 |
| | | Class II | Class I | 0.32 | 0.85 |
| | | | Class III | 1.76 | 0.41 |
| | | Class III | Class I | -1.44 | 0.49 |
| | | | Class II | -1.76 | 0.41 |
| | C3-H | Class I | Class II | -1.33 | 0.25 |
| | | | Class III | 1.38 | 0.32 |
| | | Class II | Class I | 1.33 | 0.25 |
| | | | Class III | 2.72 | 0.06 |
| | | Class III | Class I | -1.38 | 0.32 |
| | | | Class II | -2.72 | 0.06 |
| | H-RGn | Class I | Class II | 1.17 | 0.33 |
| | | | Class III | 0.45 | 0.75 |
| | | Class II | Class I | -1.17 | 0.33 |
| | | | Class III | -0.72 | 0.63 |
| | | Class III | Class I | 0.45 | 0.75 |
| | | | Class II | 0.72 | 0.63 |
| Angular Position | Hyoid Angle | Class I | Class II | -7.18* | 0.00* |
| | | | Class III | -2.48 | 0.17 |
| | | Class II | Class I | 7.18* | 0.00* |
| | | | Class III | 4.69* | 0.01* |
| | | Class III | Class I | 2.48 | 0.17 |
| | | | Class II | -4.69* | 0.01* |

**Table 5.** Analysis results of the relationship of Least Significance Difference (LSD) of the hyoid bone position in skeletal Class I, II, and III malocclusions with normal growth patterns.
* significant p-value (p<0.05)

| Hyoid Bone Position | | Malocclusion | N | $\bar{X}$ | p-value |
|---|---|---|---|---|---|
| Vertical Position | H-H' | Class I | 36 | 4.32 | 0.17 |
| | | Class II | 30 | 5.77 | |
| | | Class III | 16 | 4.40 | |

**Table 6.** Kruskal Wallis test results of the relationship of the hyoid bone position (H-H') in skeletal Class I, II and III malocclusions with normal growth patterns.

The analysis results by the Kruskal Wallis test found no significant difference between the position of the hyoid bone (H-H') with skeletal Class I, II, and III malocclusions with value of p=0.17 (p>0.05) (Table 6). The Pearson correlation test showed that there was a relationship between the nasopharyngeal width and the hyoid bone position (C3-H) with value of p=0.03 (p<0.05) (Table 7).

| Pharyngeal | Hyoid Bone Position | Malocclusion | N | r (Pearson) | p-value |
|---|---|---|---|---|---|
| Nasopharyngeal Width | C3-RGn | Class I | 36 | 0.25 | 0.13 |
| | | Class II | 30 | 0.31 | 0.87 |
| | | Class III | 16 | 0.02 | 0.45 |
| | C3-H | Class I | 36 | 0.35** | 0.03* |
| | | Class II | 30 | 0.00 | 0.97 |
| | | Class III | 16 | 0.18 | 0.49 |
| | H-RGn | Class I | 36 | 0.12 | 0.47 |
| | | Class II | 30 | 0.02 | 0.90 |
| | | Class III | 16 | -0.43 | 0.09 |
| | H-H' | Class I | 36 | 0.13 | 0.44 |
| | | Class II | 30 | -0.12 | 0.50 |
| | | Class III | 16 | -0.91 | 0.73 |
| | Hyoid Angle | Class I | 36 | 0.00 | 0.99 |
| | | Class II | 30 | -0.15 | 0.40 |
| | | Class III | 16 | 0.20 | 0.44 |

**Table 7.** Bivariate test results between the nasopharyngeal width and hyoid bone position in skeletal Class I, II dan III malocclusions with normal growth patterns.
*significant p-value (p<0.05)
**r-value: 1.00=perfect correlation, 0.91-0.99=very strong, 0.71-0.90=strong, 0.41-0.70=moderate, 0.21-0.40=weak correlation, there is relationship, 0.00-0.20=very weak correlation.

## Discussion

The main structure of the craniofacial bone that determines the dimensions of the pharyngeal is the mandible and the hyoid bone which act by providing a retaining structure as a place to attach to muscle and soft tissue.[2,14] Ceylan and Oktay reported that changes in the ANB angle affect the dimensions of pharyngeal. A large ANB angle will result in reduced dimensions of the respiratory tract.[12,15]

Table 1 shows the mean value of the nasopharyngeal width in which skeletal Class I malocclusion was 16.02 ± 3.25 mm, Class II was 15.79 ± 2.27 mm, and Class III was 17.50 ± 2.51 mm. This study was in accordance with the research results by McNamara in 1984, in which the average width of the nasopharyngeal was 17.4 ± 3.4 mm.[2,9] The width of the nasopharyngeal was greater or less than 5 mm indicating that there was a disruption in the nasopharyngeal.[9]

Table 2 shows that the mean value of H-H' in skeletal Class I malocclusions with normal growth patterns was 4.32 ± 3.92 mm, which was the same results with a study conducted by Biby and Preston. The mean values of C3-RGn, C3-H,

H-RGn, H-RGn, and hyoid angle in this study were not suitable because there was an age difference among the research samples, whereas previous studies recruited samples with the age of 12.5 ± 1.9 years for male and 13 ± 2.4 years for female.[14]

Table 3 depicted analysis results using the one-way ANOVA, which found no significant relationship (p>0.05) between the nasopharyngeal width and skeletal Class I, II, and III malocclusions with normal growth patterns with value of p = 0.12. This research is in accordance with the research results conducted by Freitas et al., where the results showed no relationship between the nasopharyngeal width and skeletal Class I and II malocclusions with normal growth patterns, but a significant relationship was seen in the vertical growth pattern that showed the narrower nasopharyngeal.[13,16]

A research conducted by Opadebeck et al. showed that there was a significant relationship in the position of the hyoid bone in the anteroposterior direction with a vertical face height difference.[11] Tarkar et al. found a longer hyoid bone (H-RGn) in samples with horizontal growth patterns than the normal and vertical growth patterns.[19]

In Table 5, the analysis results showed a significant value (p<0.05) at the hyoid angle between skeletal Class I and II malocclusions with a value of p = 0.00, in which skeletal Class II and III had a value of p = 0.01, whereas there was no significant difference in Class I and III malocclusions. The hyoid angle was smaller in Class I malocclusion than Class II as well as in Class III compared to Class II.

Based on linear and sagittal measurements, the position of the hyoid bone was slightly anterior until the age of 18 years. The movement of the hyoid bone to anterior was related to the mandibular translation towards the front which occurred during the growth period.[2] The movement of the mandible forward and upward causes the suprahyoid muscle to pull the hyoid bone more anteriorly, and when there is a rotation of the mandible downward and backward, the hyoid bone will move more to the posterior.[18]

Table 6 shows the results of the Kruskal Wallis test related to the nasopharyngeal width and the position of the hyoid bone (H-H') in skeletal Class I, II, and III malocclusions with normal growth patterns. Statistical test results showed that there were differences but not significant with p = 0.17 (p<0.05). The results of this study are consistent with research conducted by Jena et al., which states that the position of the hyoid bone lies further down in skeletal Class II malocclusions with normal growth patterns.[18]

Table 7 shows the results of a bivariate test between the width of the nasopharyngealand the position of the hyoid bone in skeletal Class I, II, and III malocclusions with normal growth patterns. This study showed no significant relationship (p>0.05) between the width of the nasopharyngeal and the position of the hyoid bone (C3-Rgn, C3-H, H-Rgn, H-H ') in Class I, II and III malocclusions skeletal with normal growth patterns.

The Pearson correlation test results showed that there was a relationship between the width of the nasopharyngealand the position of the hyoid bone (C3-H) in skeletal Class I malocclusion. The greater the value of the nasopharyngeal width, the greater the value of the hyoid position (C3-H distance) (weak correlation), whereas there was no relationship found in skeletal Class II and III malocclusions. Furthermore, the results of this study are not consistent with a study conducted by Tarkar et al., which stated that the skeletal position of the hyoid bone in Class II malocclusion was located more posteriorly accompanied by a narrower nasopharyngeal, whereas the position of the hyoid bone in Class III skeletal malocclusion was more anterior.[19]

## Conclusions

There was a significant relationship between hyoid angles and skeletal class I and II malocclusions with normal growth patterns (p=0.00) as well as class II and III (p=0.01). The results also showed that there was no significant relationship between the width of the nasopharyngealand skeletal Class I, II, and III malocclusions with normal growth patterns with a p-value of 0.12. However, there was a positive correlation between the width of the nasopharyngealand the hyoid position (C3-H), although the correlation was weak, which was 35%.

## Declaration of Interest

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

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