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Relationship between hyoid bone position and class III sagittal skeletal pattern: A retrospective study

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Abstract:
The position of the hyoid bone influences craniofacial morphology and is important in the assessment of skeletal Class III malocclusion. Therefore, it is of interest to evaluate the 90 lateral cephalometric radiographs of individuals aged 18–30 years with skeletal Class III malocclusion. The mean S–N distance was 69.5 ± 4.5 mm, while the increased Hy–D distance indicated an anterior displacement of the hyoid bone. The mean NSAr angle was 128.2° ± 10.69° and SNA angle was 78.6° ± 4.49°, with males demonstrating a significantly longer cranial base ($p = 0.03$). The hyoid bone showed anterior and inferior positional changes, providing clinically relevant information for orthodontic diagnosis, treatment planning and orthognathic surgery.

Keywords: Hyoid bone, skeletal Class III, malocclusion, cephalometric analysis, cranial base, mandible

Background:
Orthodontic professionals need to understand the skeletal anomalies linked to malocclusion. A connection between cranial base anatomy and jaw interaction has been confirmed by several investigations using cephalometric radiographs. The cranial basis defines the skeletal structure of the skull and the facial skeleton **[1].** The anterior cranial base is associated with the nasomaxillary complex, whereas the posterior cranial base is associated with the mandible **[2].** The shape and structure of the anterior cranial base, therefore, have a significant impact on the position of the maxilla and changes in the cranial base are closely associated with sagittal misalignment of the jaws. However, differences in hyoid position between Class I and Class III malocclusions have also been reported and an important lacuna remains regarding whether the observed malocclusion is primarily attributable to mandibular deficiency/excess or maxillary deficiency/excess, which should also be accounted for in the study **[3, 4].** The growth and maturation of the cranium have a major impact on the alignment of the jaws **[5].** Researchers have always been interested in HB since it is a bone that does not have any sutural, synchondral or articulating connections to other skeletal structures, which is particularly noteworthy when considering its position **[6].** Dinçer *et al.* determined that HB was positioned posteriorly than normal in the Class II (C2M) malocclusion and more anteriorly in the Class III (C3M) malocclusion **[7].** Consequently, understanding the relationships between the jaw and cranial bases is essential to comprehending the reasons for malocclusion. The relationship between HB's position and face patterns has garnered a lot of attention over the last 20 years **[8].** Speaking, breathing and swallowing are among the physiological functions that rely on HB. It is a crucial part of the diagnostic instrument used to assess the prognosis of orthodontic treatment and the chance of recurrence after treatment **[9].** Therefore, it is of interest to evaluate the position and orientation of the HB about the cranial base, mandible and third cervical vertebra in Class III malocclusion.

Materials and Methods:
Study design:
The present retrospective study was carried out at the Orthodontic Department, Faculty of Dentistry, Sana'a University, among a group of Yemeni adults after obtaining ethics approval from the Medical Ethics Committee of the Faculty of Dentistry at Sana'a University. And the procedures complied with the ethical principles outlined in the Declaration of Helsinki.

Sample size:
A total of 90 lateral cephalometric radiographs were included in this retrospective analysis. This sample size was determined based on the availability of patient records that strictly satisfied the predefined inclusion and exclusion criteria.
The sample size formula for quantitative variable that used in calculation of sample size in this study is:

Sample size = $(Z_{1-\alpha/2})^2\, p\,(1-p) / d^2$

Inclusion and exclusion criteria:
The study included lateral cephalometric radiographs from adult Yemeni patients aged between 18 and 30 years, diagnosed with skeletal Class III malocclusion characterized by an ANB angle of less than 0°. Additionally, only high-quality cephalometric radiographs, clearly depicting all essential anatomical landmarks were obtained using a consistent radiographic machine were utilised for the study. Patients who had previously undergone orthodontic or orthognathic treatment, presented congenital craniofacial anomalies such as cleft lip and palate, or exhibited severe facial asymmetry were excluded. Additionally, patients with missing teeth, supernumerary teeth, prosthetic replacements, implants, or poor-quality radiographic images were also excluded from the study. The lateral cephalometrics were taken from the AL-Waleed X-ray Center, Sana'a.

Cephalometric procedure:
Tracing was done by a .05 mm HB lead pencil, eraser, millimeter ruler, geometric protractor with half-degree approximation for the recording of linear and angular measurements and 8″x 10″matte acetate papers of 0.003mm thickness. Intra observer reliability was measured by tracing 20% of cephalograms that were selected randomly after a month and were retraced and measured and the measurements were determined using intraclass Correlation Coefficient (ICC) **[10].** The Manual tracings were done by the researcher to reduce the measurement variability. The five linear measurements (in mm) analyzed in this study were Sella-Nasion (S-N), Capitulare-Xi (C-Xi), C3-Hy

(C3-Hy), Hyoidale-Pt. D (Hy-D) and AA′-PNS. The seven Angular Measurements (in degrees) that are used in this study were Saddle angle (NSAr), Articular angle (SArGo), Gonial angle (ArGoMe), SNA, SND, Hyoidale angle (C3 HyD) and Hyoid plane angle. All points are described in (**Table 1).**

Statistical analysis:

The data was collected and analyzed and coded before being input into the statistical software (SPSS) application. Data was analyzed using statistical software R version 4.4.0 and Microsoft Excel. Continuous variables are given in Mean ± SD / Median form. Pearson's Correlation analysis was used to assess the relationships between different skeletal parameters. Intraclass correlation coefficient (ICC) with 95% confidence intervals (CI) was used to check the reliability of 10 randomly selected samples. P-value less than or equal to 0.05 indicates statistical significance.

Results:

The study analyzed lateral cephalometric radiographs from 90 patients, equally distributed by gender with 45 (50%) females and 45 (50%) males. Linear measurements indicated a mean S-N distance of 69.5 ± 4.5 mm. The distance from hyoidale to mandibular reference (Hy-D) was 43.6 ± 7.87 mm, suggesting an anterior positioning of the hyoid bone. Additionally, the mean C3-Hy distance was 37.3 ± 5.68 mm, indicative of increased pharyngeal airway dimension. The other linear measurements, including C-Xi and AA′-PNS, were 35.2 ± 4.23 mm and 32.6 ± 3.82 mm, respectively, providing further information regarding the craniofacial and upper airway relationships in the skeletal Class III group (**Table 2).** The angular measurements, including NSAr (Nasion-Sella-Articular angle), were 128.2° ± 10.69°, while SArGo and ArGoMe were 140.0° ± 6.75° and 131.0° ± 10.75°, respectively. The SNA (Sella-Nasion-A point angle) was about 78.6° ± 4.49° in the Class III group, while SND was 77.4° ± 5.22°. The C3HyD and hyoid plane angles were 158.8° ± 12.58° and 90.2° ± 4.82°, respectively. These measurements describe the cranial-base, maxillomandibular, mandibular and hyoid angular relationships in the study group (**Table 3).** The Paired sample Student's t-test is used to compare the mean values of two independent groups. In this study, it helps determine whether significant differences exist between males and females. A statistically significant difference was found in the S-N length ($p = 0.03$), indicating a longer cranial base in males. No statistically significant differences were observed for C-Xi, C3-HY, Hy-D, or AA′-PNS, suggesting comparable linear measurements between males and females for these parameters (**Table 4).** Comparison of the angular measurements showed no statistically significant differences between males and females for NSAr, SArGo, ArGoMe, SNA, SND, or hyoid plane angle. However, C3HyD showed a statistically significant difference ($p < 0.001$), with a higher mean value among females (168.9° ± 11.58°) compared with males (147.9° ± 15.98°). This indicates a notable sex-related difference in the C3HyD angular relationship (**Table 5).** Intraclass Confidence intervals (95% CI) help determine reliability. The linear measurements showed moderate to good reliability, with ICC values ranging from 0.626 to 0.772 S-N showed the highest ICC (0.772), followed by AA′-PNS (0.759), whereas C3-HY and Hy-D showed ICC values of 0.626. These findings indicate generally acceptable reproducibility of the linear cephalometric measurements (**Table 6).** The angular measurements also demonstrated variable levels of reproducibility. ArGoMe showed the highest ICC (0.921), indicating excellent agreement, while NSAr, SND and hyoid plane angle showed good reliability. C3HyD showed the lowest ICC (0.252), indicating comparatively lower reproducibility for this measurement (**Table 7).** Pearson's correlation coefficient (r) was calculated for linear measurements to assess relationships. In females, the S-N distance correlated strongly with C3-HY ($r = 0.73$), while C-Xi also showed a strong correlation with C3-HY ($r = 0.67$). C3-HY demonstrated a strong positive correlation with Hy-D ($r = 0.64$), while AA′-PNS showed negative correlations with S-N ($r = -0.65$), C-Xi ($r = -0.73$) and C3-HY ($r = -0.55$) (**Table 8).** Among males, C-Xi showed a high positive correlation with Hy-D ($r = 0.82$), representing the strongest association among the linear measurements. S-N showed moderate positive correlations with C-Xi, C3-HY, Hy-D and AA′-PNS C3-HY was also positively correlated with AA′-PNS ($r = 0.55$)., while most other relationships were weak (**Table 9).** The total sample showed moderate correlations between several linear measurements. S-N correlated positively with C-Xi ($r = 0.42$) and C3-HY ($r = 0.55$), while C-Xi correlated with C3-HY ($r = 0.53$) and Hy-D ($r = 0.37$). AA′-PNS showed a significant negative correlation with C-Xi ($r = -0.33$)., whereas its correlations with the other parameters were weak (**Table 10).** The correlation analysis of angular measurements in females showed several strong relationships. NSAr correlated positively with SNA ($r = 0.69$) and the hyoid plane angle ($r = 0.69$), while ArGoMe demonstrated a strong negative correlation with SNA ($r = -0.91$). SNA showed a very strong positive correlation with the hyoid plane angle ($r = 0.94$), whereas SND showed a strong negative correlation with the hyoid plane angle ($r = -0.79$). These findings indicate substantial interrelationships among cranial-base, maxillomandibular and hyoid angular parameters (**Table 11).** The linear measurements parameters in the skeletal Class III group are presented graphically, showing the distribution and variability of S-N, C-Xi, Hy-D, C3-HY and AA′-PNS measurements (**Figure 1).** The angular measurements parameters in the skeletal Class III group are presented graphically, showing the distribution of the cranial-base, maxillomandibular, mandibular and hyoid-related angular measurements (**Figure 2).**

Table 1: The Definition of the following cephalometric landmarks was utilized in this study

Nasion (N)	The anterior point of the intersection between the nasal and frontal bones.
Sella (S)	Sella Turcica: the midpoint of the hypophyseal fossa, determined by inspection.
Articulare (Ar)	A point at the junction of the posterior border of

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	the ramus and the inferior border of the posterior Cranial base (occipital bone).
Gonion (GO)	The midpoint of the contour connecting the ramus and body of the mandible.
Menton (Me)	The most inferior point on the symphysis of the mandible
Capitulare (C):	Center of the head of the condyle
Xi	Geometrically determined centroid of the ramus
Pt. D	Located by inspection as the center of the body of the mandibular symphysis, seen on the lateral cephalogram
C3	The point is at the most inferior anterior position on the third cervical vertebra.
Hyoidale (Hy):	The most superior, anterior point on the body of HB.
AA'	The most anterior point on the body of the atlas vertebra, seen on the lateral cephalogram.
PNS	Posterior nasal spine
Subspinale (Point 'A').	The deepest midline point on the premaxilla between the anterior nasal spine and prosthion

Table 2: Comparison of linear measurements parameters in skeletal groups

Parameters	Class III
	Mean±SD
S-N	69.5±4.5
C-Xi	35.2±4.23
Hy-D	43.6±7.87
C3-HY	37.3±5.68
AA'-PNS	32.6±3.82

Table 3: Comparison of angular measurement parameters in skeletal groups

Parameters	Class III
	Mean±SD
NSAr	128.2±10.69
SArGo	140±6.75
ArGoMe	131±10.75
SNA	78.6±4.49
SND	77.4±5.22
C3HyD	158.8±12.58
Hyoid Plane Angle	90.2±4.82

Table 4: The Paired sample Student's t-test to check for sexual dimorphism in linear measurements

Parameter	Sex	N	Mean	SD	Median	T value	df	p
S-N	**Female**	15	69.7	2.09	69	-2.283	28	0.03
	Male	15	72.1	3.62	71			
C-Xi	**Female**	15	35.3	3.39	34	0.104	28	0.918
	Male	15	35.2	3.61	36			
C3-HY	**Female**	15	37.5	12.48	35	-0.354	28	0.726
	Male	15	38.7	4.01	38			
Hy-D	**Female**	15	42.3	5.46	43	0.103	28	0.918
	Male	15	42.1	5.13	41			
AA'-PNS	**Female**	15	30.7	4.56	32	-1.85	28	0.075
	Male	15	34	5.1	33			

Table 5: Student's t-test to check for sexual dimorphism in angular measurements

Parameter	Sex	N	Mean	SD	Median	T value	df	p
NSAr	**Female**	15	125.3	6.29	127	-0.559	28	0.581
	Male	15	126.5	5.45	125			
SArGo	**Female**	15	143.7	7.58	143	-0.17	28	0.867
	Male	15	144.1	7.49	145			
ArGoMe	**Female**	15	128.7	6.32	130	1.044	28	0.305
	Male	15	126.2	6.61	127			
SNA	**Female**	15	80	3.38	80	0.336	28	0.739
	Male	15	79.6	3.14	79			
SND	**Female**	15	74.6	5.01	75	-0.293	28	0.772
	Male	15	75.1	3.61	74			
C3HyD	**Female**	15	168.9	11.58	175	4.109	28	**<.001***
	Male	15	147.9	15.98	153			
Hyoid plane angle	**Female**	15	92.2	4.48	92	-0.396	28	0.695
	Male	15	93.3	9.42	90			

**Statistically significant*

Table 6: Intraclass correlation coefficient (ICC) for linear measurements

Factor	Before (Mean±SD)	After (Mean±SD)	ICC	Confidence Interval (95% CI)
S-N	71.2±3.16	70.3±3.59	0.772	0.344-1.37
C-Xi	33.7±2.75	33.6±3.10	0.709	0.377-1.21
C3-HY	36.2±3.39	37.6±5.23	0.626	0.650-1.09
Hy-D	44.6±3.66	42.5±4.55	0.626	0.0615-1.11

AA'-PNS	33.0±2.11	32.6±2.01	0.759	0.401-1.28

Table 7: Intraclass correlation coefficient (ICC) For Angular Measurements

Factor	Before (Mean±SD)	After (Mean±SD)	ICC	Confidence Interval (95% CI)
NSAr	129.8±7.22	127.8±7.81	0.719	0.403-1.12
SArGo	140.8±6.83	141.3±6.02	0.616	0.104-1.35
ArGoMe	130.0±5.16	128.7±5.74	0.921	0.738-1.13
SNA	79.9±5.15	78.7±4.50	0.692	0.281-1.25
SND	75.5±3.17	74.9±3.90	0.770	0.521-1.16
C3HyD	156.5±14.52	156.2±12.35	0.252	-0.356-0.982
Hyoid Plane Angle	91.6±3.41	92.6±4.43	0.765	0.4

Table 8: Correlation matrix for linear measurements – female (95% CI)

	S-N	C-Xi	C3-HY	Hy-D	AA'-PNS
S-N	**1.00**				
C-Xi	**0.23**	**1.00**			
C3-HY	**0.73***	**0.67***	**1.00**		
Hy-D	**0.27**	**0.06**	**0.64***	**1.00**	
AA'-PNS	**-0.65***	**-0.73***	**-0.55***	**0.29**	**1.00**

**Statistically Significant*

Table 9: Correlation matrix for linear measurements – male (95% CI)

	S-N	C-Xi	C3-HY	Hy-D	AA'-PNS
S-N	**1.00**				
C-Xi	**0.44***	**1.00**			
C3-HY	**0.45***	**0.43***	**1.00**		
Hy-D	**0.47***	**0.82***	**0.21**	**1.00**	
AA'-PNS	**0.51***	**0.06**	**0.55***	**-0.06**	**1.00**

**Statistically Significant*

Table 10: Correlation matrix for linear measurements – total (95% CI)

	S-N	C-Xi	C3-HY	Hy-D	AA'-PNS
S-N	**1.00**				
C-Xi	**0.42***	**1.00**			
C3-HY	**0.55***	**0.53***	**1.00**		
Hy-D	**0.32***	**0.37***	**0.31***	**1.00**	
AA'-PNS	**-0.05**	**-0.33***	**-0.03**	**0.17**	**1.00**

**Statistically Significant*

Table 11: Correlation matrix for angular measurements – female (95% CI)

	NSAr	SArGo	ArGoMe	SNA	SND	C3HyD	Hyoid Plane Angle
NSAr	**1.00**						
SArGo	**-0.52***	**1.00**					
SNA	**0.69***	**0.09**	**-0.91***	**1.00**			
SND	**-0.60***	**-0.26**	**0.59***	**-0.55***	**1.00**		
C3HyD	**0.31**	**-0.76***	**0.16**	**0.17**	**0.56***	**1.00**	
Hyoid Plane Angle	**0.69***	**0.23**	**-0.92***	**0.94***	**-0.79***	**-0.13**	**1.00**

Discussion:

Current orthodontic practices consider the harmony of the entire dentofacial structure and the location of the hyoid bone in connection with various types of malocclusion has captivated many scientists **[11].** This research specifically examines how the position of the hyoid bone relates to the cranial base, mandible and third cervical vertebra in the sagittal skeletal pattern of C3M. In the present research, the S-N (sella-nasion) measurement was recorded as being the smallest measurement in C3M at 69.5 mm. This indicates that there are differences in cranial base lengths across different skeletal Classes. Therefore, our results are consistent with the research conducted by Breh and Kamat, **[12]** which indicated that the anterior cranial base (S-N) is the shortest in C3M and the longest in C2M, with Class 1 (C1M) in between. Additionally, Adamidis *et al.* **[13]** reported that there was a notable difference in the position of the hyoid bone between skeletal Classes I and III, with the hyoid bone being positioned more forward in the C3M group. Furthermore, in this study, the distance from the hyoid to the mandible was observed to be slightly greater in C3M, measuring 43.6. This suggests that the hyoid bone may have shifted forward. In addition, the distance between the hyoid and the third cervical vertebra, also known as the anteroposterior dimension of the pharynx. Conversely, this distance increased to 37.3 in C3M. In a prior study by saeed *et al.*, **[14]** it was shown that the hyoid to C3 distance was also lowest in C2M, matching the results of our study, while it was greatest in C1M. Another investigation by Chauhan *et al.*, **[15]** highlighted that the position of the hyoid bone was similar between C1M and C2M malocclusions. In the C3M group, the position of the hyoid relative to the third cervical vertebra and epiglottis was the same as that in the C1M group; however, measurements taken from point B and the mention indicated an increase in these measurements. According to a study conducted by Haque *et al.*, **[8]** the position of the

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hyoid bone was found to be lower for C3M malocclusions compared to C1M and C2M when considering the anterior cranial base (SN plane) and the Frankfort plane (P-Or plane) in a vertical perspective. Additionally, in research examining the sagittal plane, males with either C1M or C3M skeletal traits had a similar hyoid bone position, but males with C1M displayed a more posterior location, influenced by the development of the mandibular bone. In our research regarding angular measurements, it was found that the highest NSAr angle was recorded in C2M at 129.4, followed by C3M and then C1M. Conversely, the highest SArGo angle was observed in C1M, then C2M and lastly, C3M. However, Fatima *et al.* **[16]** discovered no notable differences between the cranial base angle and the anteroposterior jaw relationship in connection with C2M. About C3M, another research by Al Maaitah *et al.*, **[17]** indicated that the skeletal relationships. This aligns with the results from earlier studies **[18–20].** There were no significant differences in the saddle angle between C1M and C2M or between C1M and C3M groups. According to Al Maaitah *et al.* **[17]** pointed out that the articular angle was consistent across different anterioposterior skeletal relationships and was larger in C1M compared to others. On the other hand, the Gonial angle was more prominent in C3M when contrasted with C2M, which is consistent with Gasgoos's *et al.* finding **[21].** Research conducted by Karadede Ünal *et al.* **[22]** and Ceylan *et al.* **[23]** showed that the hyoid bone sits higher in females and lower in males.Clinically, the anterior positioning of the HB observed in this study has significant implications. Such positional adaptations could influence airway dynamics, tongue posture and potentially impact treatment planning, especially for borderline surgical cases. In surgical orthodontic treatments, the HB's positioning could serve as a critical diagnostic parameter for predicting airway changes post-treatment and potential relapse. Hence, orthodontists should incorporate these anatomical considerations into comprehensive treatment planning. A notable limitation of the present study is the absence of Class I and Class II control groups, which restricts direct comparative analyses. Future research should consider incorporating these groups to allow for broader generalization and better understand positional shifts specific to Class III malocclusion. Additionally, longitudinal studies examining changes in HB position pre and post orthodontic intervention could further illuminate its clinical significance.

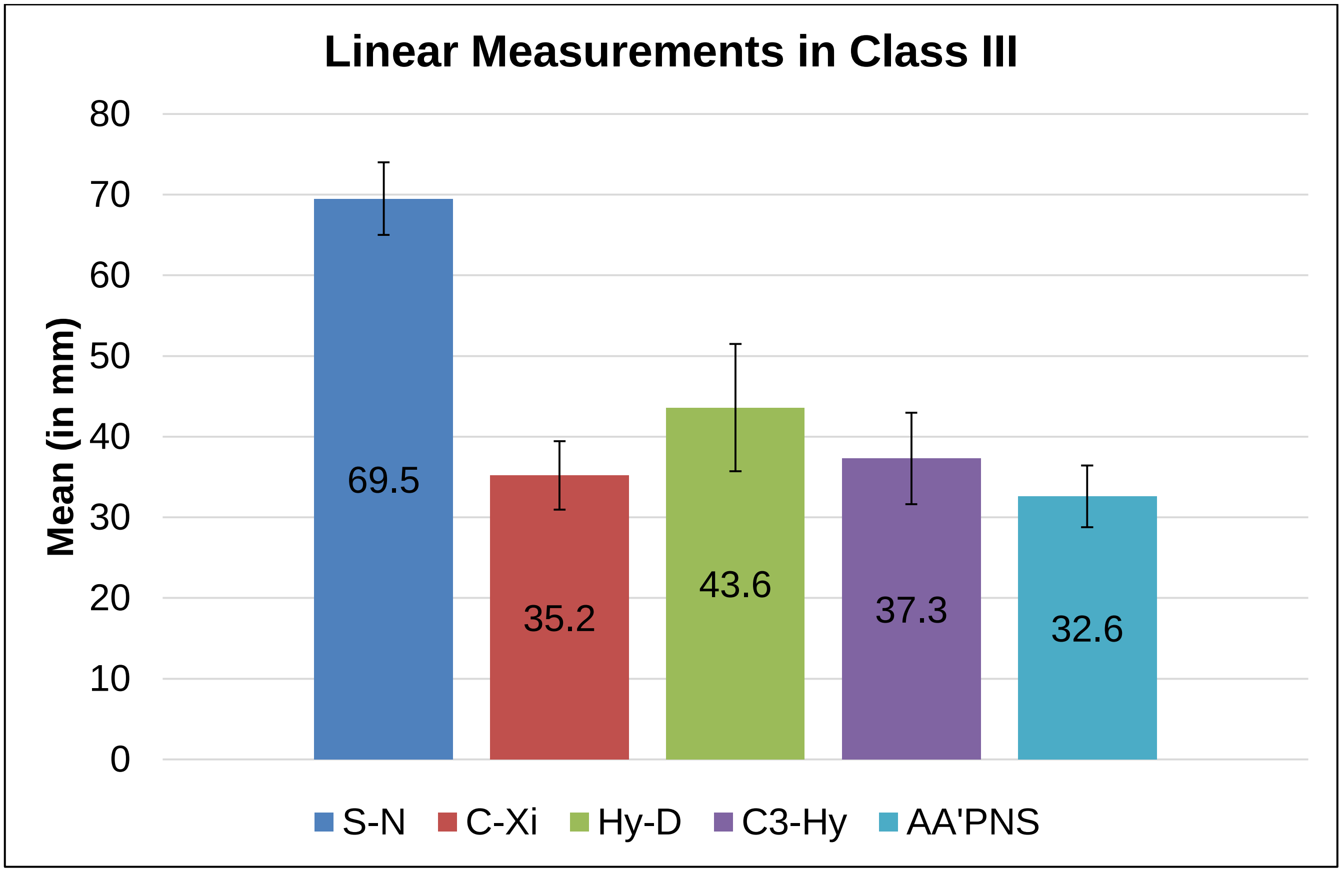

Figure 1: Linear Measurements parameters in Class III skeletal group

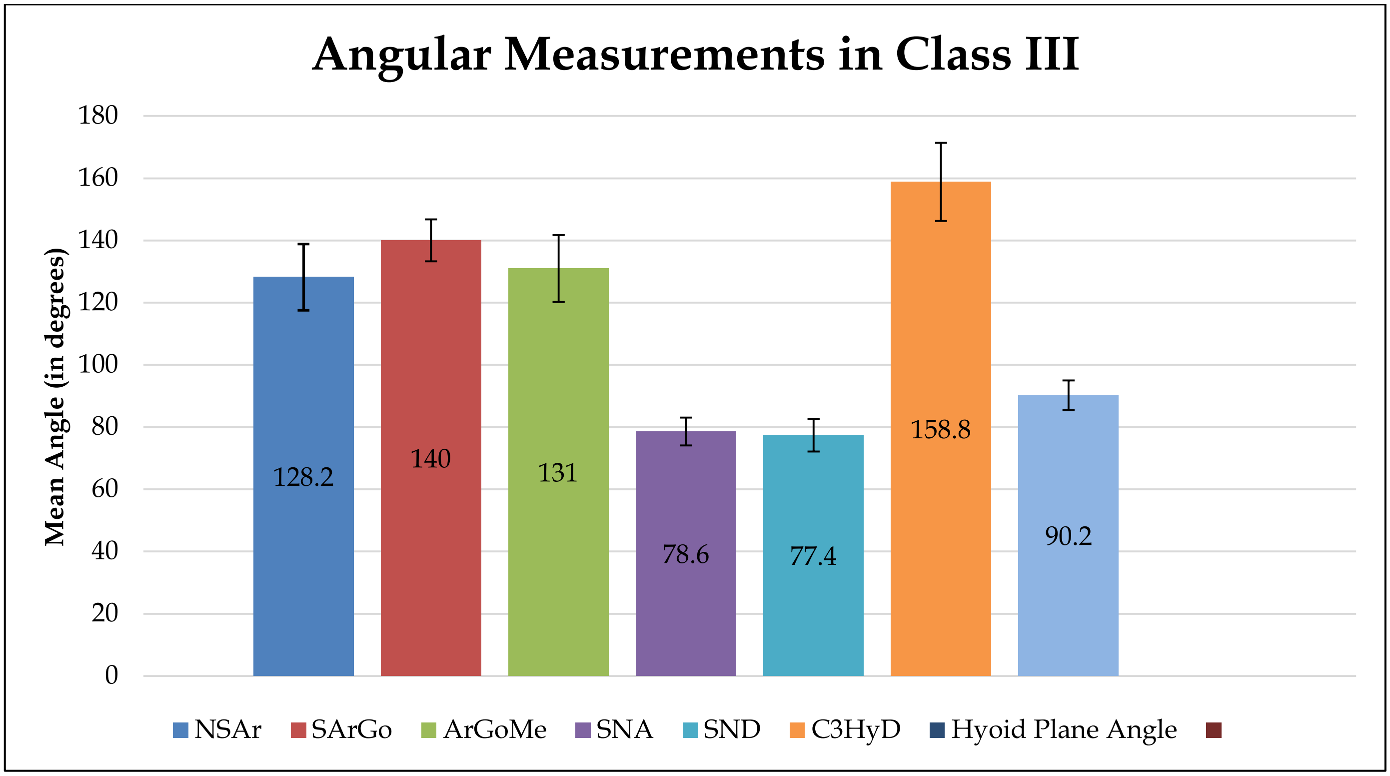

Figure 2: Angular measurements parameters in Class III skeletal group

Conclusion:

We show the positional and angular variations of the hyoid bone in patients with skeletal Class III malocclusion, highlighting its relevance to orthodontic assessment. Anterior displacement of the hyoid bone may influence airway dynamics and treatment decisions regarding surgical versus non-surgical management. These findings support incorporating hyoid bone position and orientation into orthodontic assessment to improve diagnostic precision and treatment planning.

Conflict of interest: None

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