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"Evaluating Vertical Components of Maxillary First Molar to Craniofacial Frame in Average and High Angle Subjects: A Lateral Cephalometric Study"

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KEYWORDS

Vertical molar heights

Dentoalveolar compensation

Hyper divergent skeletal patterns

Linear vertical measurements

Abstract:

Introduction: Hyperdivergent skeletal patterns, such as mandibular rotation and vertical maxillary excess, pose treatment challenges, often requiring compensatory dentoalveolar changes. Significant differences in dentoalveolar heights are observed in long versus short faces. Treatment options include orthodontics and orthognathic surgery, with skeletal anchorage systems offering improved non-surgical alternatives. One key factor in evaluating treatment outcomes is the vertical position of the upper molar.

Aim: This study aimed to evaluate the vertical position of the maxillary first molar (U6-SN) in relation to the cranial base in average and high mandibular plane angle cases.

Materials and Methods: Cephalometric radiographs of 120 volunteers (ages 16-25) were analyzed. Skeletal Class I patients were identified using the ANB, W, Yen, and Beta angles, and high- and average-angle groups were selected based on Jaraback's ratio, SN-MP, and FMA. Linear and angular measurements were taken from lateral cephalograms using AutoCAD 2024 to assess molar and maxillary positioning relative to cranial base parameters.

Results: Vertical molar heights (U6-SN, U6-PP) were significantly greater in high-angle cases. Angular measurements also showed higher values in high-angle cases, except for the upper gonial angle, Rickett's facial axis, and overbite depth. Calibrating with the posterior cranial base revealed a stronger correlation with vertical molar height. Males had greater vertical molar heights and certain linear measurements.

Conclusion: Vertical molar heights are higher in high-angle Class I cases. Angular and vertical characteristics, particularly S-PP and N-PP, influence vertical molar location, with gender differences aiding diagnosis and treatment planning.

1. Introduction

Orthodontic treatment deals with the correction of both skeletal and dental malocclusion. Skeletal malocclusion can occur in the transverse, sagittal and vertical plane. In the vertical plane, skeletal malocclusion appears as normodivergent, hypodivergent or hyperdivergent

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profiles. Hyperdivergency in the facial profile can be due to various factors such as clockwise rotation of the mandible, maxillary alveolar hyperplasia, vertical maxillary excess, increased posterior dentoalveolar height, and increased lower anterior facial height[1].

The causes of hyper divergent cases are multifactorial, often including environmental factors linked to postural adaptations resulting from weak masticatory muscles. In growing patients, a persistently lowered mandibular posture may lead to compensatory changes in the dentition, dentoalveolar heights, and mandibular position to address the vertical discrepancy. Hyperdivergent cases often exhibit excessive dentoalveolar heights, such as the supra eruption of posterior teeth. Orthodontic treatment for vertical discrepancies without resorting to orthognathic surgery involves artificially inducing dentoalveolar compensation[2].

Dentoalveolar compensation refers to the process by which the dental arches and alveolar processes develop a harmonious morphology that adapts to the proportions of the basal bone, thereby preserving normal occlusion during growth. This phenomenon is influenced by factors such as:

1.Physiological factors include tooth eruption, arch form, bone base growth, formation of alveolar process;

2.Pathological; and

3.Therapeutic factors include Orthodontic, functional and orthopaedic treatments.

To establish a stable occlusion within a balanced neuromuscular environment, orthodontists must account for dentoalveolar compensation in both diagnosis and treatment planning. Depending on the individual case, this phenomenon may need to be triggered, controlled, or halted to achieve optimal outcomes[3,4].

Singh and Sharma reported that there is a significant difference between dentoalveolar heights among normal, long and short faces[5]. Hyperdivergent cases can be treated either with orthodontic treatment alone or in conjunction with orthognathic surgery. Considering the orthodontic treatment of such cases, the skeletal discrepancy can be camouflaged by altering the posterior dentoalveolar heights through the intrusion of upper posterior teeth.

Intrusive tooth movement is difficult to achieve, but with the advent of TADs intrusive tooth movement is easily achievable, suggesting that posterior teeth intrusion is a viable alternative to surgery. Information regarding the range of intrusive tooth movement and post-treatment stability can be obtained based on the vertical height of the maxillary first molar from the cranial base[2].

The vertical height of the maxillary 1st molar is influenced by various skeletal growth patterns and that can be related to various vertical skeletal parameters. Adrani et al observed a significant relation between upper posterior dentoalveolar heights and vertical skeletal parameters. These parameters differ in high angle and average angle subjects which in turn can be correlated to the vertical position of the maxillary first molar.

These linear values relate several higher skeletal structures to the vertical height of the maxillary first permanent molar. However, the linear values must be standardized by calibration because every person's head size varies greatly. The anterior cranial base length has been employed as a reference in several cephalometric research to calibrate in an anteroposterior direction [2]. The posterior cranial base length has not been used as a reference in many research that attempts to calibrate linear measurements. Therefore, the study's objective is to use vertical linear measures calibrated on anterior and posterior cranial base length to assess the vertical components of maxillary first permanent molars on the craniofacial frame in both average and high-angle situations.

2. Objectives

1. To evaluate the vertical position of maxillary 1st molar from cranial base in average and high-angle cases.

2. To evaluate vertical skeletal measurements and correlate them with the vertical position of maxillary 1st molars.

3. To identify the most significant variables, that affects the upper 1st molar vertical position.

4. To compare vertical molar heights, vertical linear measurements and angular measurements among gender to identify the gender dimorphism if any.

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3. Methods

The study titled "Evaluating Vertical Components of the Maxillary First Molar Relative to the Craniofacial Frame in Average and High Angle Subjects: A Lateral Cephalometric Study" was carried out in the Orthodontics Department at GDCHA, with approval from the institution's Ethical Committee. A total of 120 subjects (60 males and 60 females) aged 16–25 years, classified as Class I with average and high-angle profiles, were selected for the study.

Inclusion Criteria:

• Fully erupted permanent dentition.

• Skeletal Class I base and molar Class I occlusion subjects.

• Subjects with average and high mandibular plane angles.

Exclusion criteria:

• History of trauma.

• Previous history of maxillofacial surgery.

• Previous history of orthodontic treatment.

•Previous history of endodontic treatment, and prosthetic crown in maxillary 1st molar.

• Missing teeth except third molars.

• Supernumerary or malformed upper 1st molar.

• Low-angle subjects.

• Syndromic patients, cleft lip and palate and patients with systemic disorders.

Selection Criteria:

Standardized cephalometric radiographs of 120 subjects were taken in centric occlusion with lips relaxed and Frankfort horizontal plane oriented parallel to the floor by using a Vatech PHT 30 LFO smart machine. The skeletal Class I subjects were chosen based on ANB angle (20-40), W angle (51-56), Yen angle (117-123), and Beta angle (27-35). The skeletal Class I average and high angle subjects were selected based on Jaraback's ratio, SN-MP, and FMA. 30 males and 30 females were selected in each group. So, a total of 4 groups were selected such as average males, average females, high-angle males and high-angle females.

Measurements in AUTOCAD 2024 software:

AutoCAD is a computer-aided design (CAD) software, that offers various tools for creating and editing image designs. In this study, we used AUTOCAD software for accurately measuring linear and angular values in lateral cephalogram images. Following linear measurements and angular measurements depicting the maxillary molar vertical position, and vertical position of the maxilla in relation to cranial base parameters were recorded for evaluation.

Angular measurements (figure 1)

Saddle angle (N-S-Ar): The angle produced between the S-Ar and SN planes is used to measure it.

Articulare angle (S-Ar-Go): The angle produced between the S-Ar and Ar-Go planes is used to measure it.

Gonial angle (Ar-Go-Me): It is measured by angle formed between articulare to gonion and gonion to menton.

Upper gonial angle: It is measured by angle formed between articulare to gonion and gonion to nasion.

Lower gonial angle: It is measured by angle formed between nasion to gonion and gonion to menton.

Bjork's sum: It is the sum of saddle angle, articulare angle and gonial angle.

Rickett's facial axis (Ba-Na to Pt-Gn): It is measured by angle formed between posterior cranial base (Ba-Na) and Pt point to gnathion.

SN to Go-Me: The angle produced between SN plane to Go-Me plane.

SN to Y axis: It is measured by angle formed between SN plane to sella- gnathion.

Overbite depth indicator: It is measured by sum of AB-MP angle and FH-PP angle.

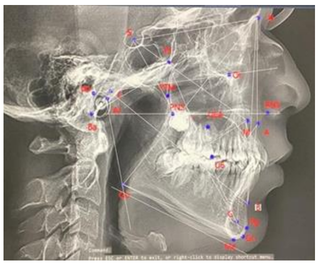

Fig 1. Angular measurements used in the study

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Linear measurements (figure 2)

Po-PP: Perpendicular line drawn from Porion point to palatal plane.

Ar-PP: Perpendicular line drawn from Ar point to palatal plane.

S-PP: Perpendicular line drawn from S point to palatal plane.

Ptm-PP: Perpendicular line drawn from Ptm point to palatal plane.

Or-PP: Perpendicular line drawn from Or point to palatal plane.

N-PP: Perpendicular line drawn from N point to palatal plane.

Upper anterior facial height (UAFH): From the nasion point to the ANS point, it is measured.

Lower anterior facial height (LAFH): From the ANS point to the Me point, it is measured.

Total anterior facial height (TAFH): From the nasion point to Me point, it is measured.

Posterior facial height (PFH): From the Sella point to the Go point, it is measured.

Maxillary 1st molar height from anterior cranial base (U6-SN): It is measured from mesio-buccal cusp tip of maxillary 1st molar to SN plane perpendicular to SN.

Maxillary 1st molar dentoalveolar height (U6-PP): It is measured from mesio-buccal cusp tip of maxillary 1st molar to palatal plane perpendicular to palatal plane.

Jaraback's ratio: PFH/AFH X 100.

Facial height ratio: UFH/LFH X 100.

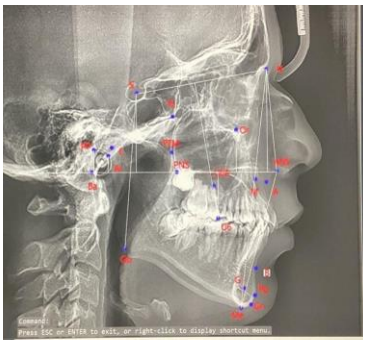

Fig 2. Linear measurements used in the study

4.Results

The results of this study were rigorously analyzed statistically to explore the differences and correlations between various measurements associated with maxillary molars in average and high-angle cases.

1. Vertical Molar Height and Angular Measurements:

Table I highlights a statistically significant difference in vertical molar height (U6-SN and U6-PP) between average angle and high angle cases, with high angle cases exhibiting greater heights. All angular measurements (Gonial angle, Lower Gonial angle, Bjork sum, SN-GoMe, and Y-axis) were also significantly greater in high-angle cases. However, the upper gonial angle, Rickett's facial axis, and overbite depth indicator were found to be lower in high-angle cases. Additionally, vertical linear measurements (UAFH, LAFH, TFH, Facial height index, Ar-PP, Po-PP, S-PP, Ptm-PP, Or-PP, and N-PP) were greater in high-angle cases, except for posterior facial height, which decreased.

2. Correlations between U6-SN and Angular Measurements:

Table II indicates a strong positive correlation between U6-SN and Gonial angle in both average and high angle cases [(r=0.896, p=0.001) and (r=0.870, p=0.001), respectively]. Both U6-SN and Upper Gonial Angle showed a significant negative correlation [(r=-0.768, p=0.001) and (r=-0.930, p=0.001)], while U6-SN and Lower Gonial Angle showed a strong positive correlation (r=0.746, p=0.001) in high angle cases and no correlation (r=0.234, p=0.086) in average angle cases.

Other notable correlations include:

- **Bjork's sum:** significant correlation with U6-SN in both the subgroups (average r=0.583, p=0.001; and high angle r=0.73, p=0.001).
- **SN-GoMe:** U6-SN and SN-GoMe have a notable correlation (r=0.531, p=0.001 for high angle; r=0.599, p=0.001 for average angle).
- **Ricketts facial axis:** No significant correlation with U6-SN in both cases.

U6-PP did not show significant correlations with Gonial angles or Rickett's facial axis. However, it had a weak positive correlation with Lower gonial angle in average

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angle cases (r=0.262, p=0.040) and a strong correlation in high angle cases (r=0.948, p=0.001).

3. Correlations with Linear Measurements:

Table III presents the correlation results of U6-SN with various vertical linear measurements. Notably, no significant correlation was observed between U6-SN and UAFH in either angle case. However, significant correlations were found:

- **LAFH:** Strong positive correlation in average angle cases (r=0.943, p=0.001) and moderate in high angle cases (r=0.325, p=0.011).
- **TAFH:** moderately correlated with high angles (r=0.323, p=0.012) and strongly correlated with average angles (r=0.871, p=0.001).
- **PFH:** a substantial connection with average angles (r=-0.936, p=0.001) and mild negative correlation with high angles (r=-0.270, p=0.037).

Additionally, a strong positive correlation was observed between U6-SN and S-PP (r=0.799, p=0.001 for average; r=0.310, p=0.001 for high).

4. Calibration of Measurements:

Tables IV and V show that, in comparison to raw values and values calibrated with the Anterior Cranial Base (ACB), both angular and linear values calibrated with the Posterior Cranial Base (PCB) length showed greater relationships with vertical molar height.

5. Regression Analysis:

Tables VI and VII reveal that the linear regression analysis identified S-PP and N-PP, when calibrated to PCB, as significantly correlated with vertical molar height (U6-SN and U6-PP).

6. Gender Differences:

Table VIII summarizes the gender differences observed in the study:

- **Vertical Molar Heights:** In both average and high-angle cases, statistically significant differences were observed between males and females in U6-SN and U6-PP measurements, with males exhibiting greater heights.
- **Angular Measurements:** No significant gender differences were found in angular measurements, except for the upper gonial angle, which was larger in females in high-angle cases.
- **Vertical Linear Measurements:** In average angle cases, measurements such as UAFH, LAFH, TAFH, PFH, S-PP, Or-PP, and N-PP were significantly greater in males. In high angle cases, Ar-PP, S-PP, and Or-PP also showed significant gender differences, favoring males.

<u>Discussion:</u>

Treatment should be tailored to each patient's growth pattern, considering dental and skeletal factors. The maxillary first molar's height is vital for orthodontic planning, especially in patients with vertical facial growth. This study aims to analyze angular and linear factors affecting maxillary molar height using AutoCAD 2024 for cephalometric evaluation.

The mean and standard deviation of linear, angular, and vertical molar height measurements in average and high-angle cases are shown in Table I. The upper first molar to SN plane (U6-SN) showed significant differences between average angle (67.60 mm) and high angle cases (70.47 mm) (p = 0.0001). Similar significant differences were found in U6-PP (20.92 mm vs. 24.25 mm, p = 0.001). In the study conducted by Ah Reum Han et al, the maxillary molar height was measured from U6 (maxillary 1st molar mesiobuccal cusp tip) to SN plane, as they considered SN plane for its distinctiveness of measurements and its anatomical stability.[2]

Gonial angles also differed significantly, with the average angle group at 126.45° compared to 134.78° in the high angle group (p = 0.0001). The lower gonial angle showed a notable increase from 74.63° to 80.95° (p = 0.0001). Bjork's sum was greater in high-angle cases (402.46 vs. 394.96, p = 0.01), suggesting a vertical growth pattern. These findings are similar to the present study. This is in accordance with Ibrahim Alsharani et al[6], Kaveri Kranti Gandhi et al[7] and Mayury kuramae et al[8] who also found increased mean values for high angle group in comparison to average angle group but they were not statistically significant (P=0.17, P=0.225 respectively).

Facial height ratios showed a decrease in posterior facial height and a substantial increase in higher (49.59 mm vs. 53.33 mm, p = 0.0001) and lower anterior (64.84 mm vs. 70.96 mm, p = 0.0001) facial heights. This is in

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accordance with the studies by Umer UL Hasan et al[9], Kaveri Kranti Gandhi et al [7] and Supriya satpute et al [10], who observed that the mean values for LAFH and TAFH is statistically highly significantly greater in high angle group as compared to the average angle group

Significant anatomical differences between the two groups were highlighted by the consistently higher linear measurements (e.g., Po-PP, Ar-PP) in high angle cases, which aids in orthodontic assessment and treatment planning. A study conducted by Ah rheum et al [2] used the above parameters as new linear measurements to identify the vertical distance of maxilla from the upper skeletal structures on Class I skeletal base with normal overbite and overjet to correlate vertical position of maxillary molar with vertical distance of maxilla to upper skeletal structures. In this study comparison of these new linear measurements was done between Class I average and Class I high angle cases to identify the difference in vertical distance of maxilla from higher skeletal structures was done. It was observed that, the mean values of Po- PP, Ar-PP, S-PP, Ptm – PP, Or-PP and N-PP in all high angle cases were greater than average angle cases.

Pearson correlation analysis of Vertical molar heights with Angular measurements in Average and High angle cases was shown in Table II. The findings demonstrate a robust positive correlation between U6-SN and gonial angles, corroborating the hypothesis that increased maxillary molar heights significantly influence occlusal planes and mandibular morphology. This is in line with the findings of Posnick et al., who observed that higher molar heights may cause the jaw to rotate backward, steepening the mandibular plane and raising gonial angles [50]. Additionally, the findings of Ah-Reum-Han et al. [2] are consistent with the considerable negative connection between U6-SN and upper gonial angles, particularly in hyperdivergent instances, indicating that counterclockwise rotation of the mandibular corpus is common in these individuals.

Conversely, U6-PP demonstrated weaker correlations with gonial angles, indicating different mechanisms affecting vertical growth patterns. This is in agreement with Hadeel A. Yousif et al[11]., who reported similar findings regarding the limited influence of U6-PP on gonial angles. The absence of significant correlations with Ricketts facial axis and overbite depth further emphasizes the intricate relationships between dental and skeletal structures, as supported by Nabila Anwar et al[4].

Overall, these results contribute to our understanding of vertical skeletal patterns in orthodontic assessments, underscoring the critical role of maxillary molar positioning as elucidated by IGAW Adrani et al[5].

Correlation Analysis of Vertical molar heights with Vertical linear measurements in Average angle cases and High angle cases is shown in Table III. The correlation analysis highlights distinct relationships between vertical molar heights and linear measurements. As noted by IGAW Adrani et al. [5], who highlighted that increased molar height contributes to enhanced facial height due to downward and backward rotation of the mandible, U6-SN showed a strong positive correlation with both lower anterior facial height (LAFH) and total anterior facial height (TAFH) in average angle cases. This view is reinforced by R. Mangla et al. [12], who pointed out that in hyperdivergent cases, this rotational pattern may be caused by a decrease in posterior facial height combined with an increase in LAFH.

Conversely, the lack of significant correlation between U6-SN and upper anterior facial height (UAFH) reflects findings by Hadeel A. Yousif et al[11], suggesting that while LAFH and TAFH are influenced by molar heights, UAFH remains relatively unaffected. Additionally, the observed weak negative correlation between U6-SN and posterior facial height (PFH) in high angle cases contrasts with studies by Nabila Anwar et al.[4], indicating ethnic variability and developmental differences in these measurements.

Furthermore, the consistent positive correlations between U6-PP and various linear measurements (Po-PP, Ar-PP, S-PP, Ptm-PP, Or-PP, and N-PP) underscore the influence of maxillary position relative to cranial structures on molar height. This reinforces the contributions of Ah-Reum-Han et al[2], who introduced these measurements to elucidate the vertical relationships in the craniofacial complex. Collectively, these findings affirm the critical role of vertical skeletal relationships in orthodontic diagnosis and treatment planning, emphasizing the interconnectedness of molar positioning and overall facial growth.

Correlation Analysis of Vertical molar heights with angular measurements on Raw values, values with ACB length (Anterior cranial base) and PCB length (Posterior cranial base) calibration in Average angle group and High angle group was shown in Table IV. The correlation analysis highlights the intricate relationships between vertical molar heights (U6-SN and U6-PP) and angular measurements, emphasizing the importance of calibration methods. The observed positive correlations of U6-SN with angular measurements—particularly Gonial angle, Bjork's sum, and SN-GoMe—underscore the relevance of molar heights in craniofacial morphology, consistent with findings by Ah-Reum-Han et al[2], who noted that calibrated measurements provide more reliable correlations.

The significant negative correlation between U6-SN and upper gonial angle across raw and calibrated values reflects the compensatory mechanisms in hyperdivergent cases, aligning with the observations of IGAW Adrani et al[5]. The calibration against posterior cranial base (PCB) yielded the strongest correlations, supporting Ah-Reum-Han et al.'s assertion that vertical measurements are better assessed in relation to PCB, as it captures the vertical aspect of craniofacial dimensions more effectively than anterior cranial base (ACB) length.

For U6-PP, the significant positive correlations with lower gonial angle and Y-axis, both in raw and calibrated forms, further reinforce the notion that vertical molar positioning plays a critical role in determining facial morphology. The consistent negative correlations with Rickett's facial axis across measurements highlight the complexity of facial relationships in various growth patterns. Collectively, these findings contribute valuable insights into the interplay between molar height and angular dimensions, underscoring the necessity for precise calibrations in orthodontic evaluations.

Table V shows correlation analysis of Vertical molar heights with Vertical Linear Measurements on Raw values, values with ACB (Anterior cranial base) and PCB (Posterior cranial base) calibration in Average angle and High angle cases. It shows a steady trend for both average and high angle situations. For both U6-SN and U6-PP, significant positive correlations with LAFH, TAFH, and other calibrated measurements indicate that increased vertical molar height is associated with enhanced anterior facial dimensions. These findings align with Ah-Reum Han et al[2]., who similarly identified strong correlations between U6-SN and various linear measures across raw and calibrated values.

Notably, both U6-SN and U6-PP exhibited significant negative correlations with posterior facial height (PFH), reinforcing the notion that vertical growth patterns in molar height may lead to a reduction in PFH, consistent with the downward rotation of the mandible as proposed by Posnick et al[13]. Additionally, the superiority of posterior cranial base (PCB) calibration in correlating with vertical molar heights underscores its relevance for vertical measurements, as noted by Ah-Reum Han et al[2]. This suggests that vertical skeletal relationships significantly influence the positioning of maxillary molars.

All things considered, these associations show how closely molar height and facial form are related, highlighting how crucial it is to take cranial base calibrations into account while performing orthodontic evaluations.

The multiple linear regression analysis used to determine the factors affecting the maxillary first molar's position in both average and high angle situations is shown in Tables VI and VII. To determine the key variables impacting vertical molar position, linear regression was performed on raw variables, as well as on values calibrated to anterior cranial base (ACB) length and posterior cranial base (PCB) length. The dependent variable in this analysis was maxillary molar height, while the independent variables included statistically significant factors from correlation analysis and sex.

The regression analysis revealed that Sella-PP and Nasion-PP emerged as the most significant predictors, with sex being non-significant. The adjusted R^2 values for raw values, ACB-calibrated values, and PCB-calibrated values were 0.692, 0.748, and 0.796, respectively, in average angle cases. In high angle cases, the values were 0.638, 0.720, and 0.774. Notably, Sella-PP and Nasion-PP calibrated to PCB length are the most reliable measures for predicting the vertical position of the maxillary first molar, as indicated by the higher R2 values linked to PCB length calibration.

TABLE VIII- shows comparison of vertical molar height, angular measurements, and vertical linear measurements between males and females in average and high angle subjects. In patients with average and high angles, Table VIII compares the vertical molar heights, angular measures, and vertical linear measurements between both genders. In average angle cases, males exhibited significantly greater U6-SN and U6-PP (p=0.006, p=0.05), aligning with findings from Hadeel A. Yousif et al[11] and Luis Ernesto Arriola-Guillen et al[14]. In high angle cases, U6-SN and U6-PP also favored males (p=0.04, p=0.03). Most angular measurements, including the Gonial angle, were not significantly different between genders, except for the upper gonial angle, which was greater in females, as noted by Eyas Abuhijleh et al[15]. Additionally, vertical linear measurements such as UAFH, LAFH, TAFH, and PFH showed significant differences favoring males, consistent with findings from Supriya Satpute et al[10] and Yemitan TA et al[16].

CONCLUSION:

• There is an increased vertical height of upper 1st permanent molars in Class I high angle cases as compared to Class I average angle cases.

• Angular characteristics including gonial angle, upper gonial angle, lower gonial angle, Bjork's sum, and SN-GoMe influence the vertical location of the upper first molar.

• Vertical linear characteristics including LAFH, TAFH, PFH, Po-PP, Ar-PP, S-PP, Ptm-PP, Or-PP, and N-PP influence the vertical location of the upper first molar.

• When associated with vertical molar height, sella to palatal plane (S-PP) and nasion to palatal plane (N-PP) demonstrated the highest degree of significance.

• In terms of vertical molar height, vertical linear measures, and angular measurements, there are gender variations between average and high angle participants.

The vertical position of maxillary permanent 1st molar can be ascertained by using various vertical skeletal parameters which affect it, contributing to diagnosis and treatment planning of high angle cases.

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TABLES:

Table I: Comparison of mean values of vertical molar height, vertical angular measurements, and vertical linear measurements in Overall average angle and Overall high angle cases

S. No	**Parameters**	**Average Angle (Overall)**		**High Angle (Overall)**		**P-Value**
	Vertical molar height	**Mean**	**S. D.**	**Mean**	**S. D.**	
1	U6-SN	67.60	3.21	70.47	2.04	**0.0001***
2	U6-PP	20.92	2.64	24.25	1.72	**0.001***
	Vertical angular measurements					
3	Gonial angle	126.45	4.47	134.78	4.77	**0.0001***
4	UGA (Upper gonial angle)	53.85	5.01	52.1	3.80	**0.03***
5	LGA (Lower gonial angle)	74.63	1.88	80.95	2.44	**0.0001***
6	Bjork's sum	394.96	4.63	402.46	4.94	**0.01***
7	RFA (Ricketts facial axis)	90.06	2.77	84.16	2.62	**0.0001***
8	SN to Go-Me	34.13	6.27	40.18	2.46	**0.0001***
9	SN to Y axis	64.91	2.55	71.21	2.85	**0.0001***
10	ODI (Overbite depth indicator)	76.85	2.50	70.05	2.02	**0.0001***
	Vertical linear measurements					
11	UAFH (Upper anterior facial height)	49.59	4.43	53.33	2.34	**0.0001***
12	LAFH (Lower anterior facial height)	64.84	4.36	70.96	3.02	**0.0001***
13	TAFH (Total anterior facial height)	112.47	6.67	117.09	5.04	**0.0001***
14	PFH (Posterior	74.22	5.26	66.59	3.40	**0.0001***

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	facial height)					
15	FHI (Facial Height Index)	69.44	5.09	78.88	2.87	**0.04***
16	Po-PP	22.16	2.14	26.56	3.25	**0.0001***
17	Ar-PP	10.70	2.64	16.88	1.20	**0.0001***
18	S-PP	37.19	2.65	44.14	3.12	**0.0001***
19	Ptm-PP	8.32	1.36	13.68	2.65	**0.0001***
20	Or-PP	22.97	3.54	29.80	3.06	**0.0001***
21	N-PP	49.58	4.45	53.26	2.36	**0.0001***

Table II - Pearson correlation analysis of vertical molar heights with angular measurements in average and high-angle cases

		Average angle subjects		**High angle subjects**	
Vertical molar height	Angular Measurements	r value	p value	r value	p value
	Gonial angle	$.896^{**}$	0.001	0.87	**0.001**
U6-SN	Upper gonial angle	$-.768^{**}$	0.001	-0.93	**0.001**
	Lower gonial angle	0.234	0.086	0.746	**0.001**
	Bjork's sum	$.583^{**}$	0.001	0.73	**0.001**
	Rickett's facial axis	-0.391	0.72	-0.011	0.937
	SN to Go-Me	$.599^{**}$	0.001	0.531	**0.001**
	Y axis	0.329	0.792	0.051	0.701
	Overbite depth indicator	-0.106	0.312	-0.042	0.75
	Gonial angle	0.216	0.092	0.16	0.223
U6-PP	Upper gonial angle	-0.133	0.304	-0.172	0.188
	Lower gonial angle	$.262^{*}$	**0.04**	0.948	**0.001**
	Bjork's sum	$.477^{**}$	**0.01***	0.837	**0.001**

Rickett's facial axis	-0.094	0.466	-0.049	0.71
SN to Go-Me	.864**	**0.001***	0.233	**0.001**
Y axis	.396**	**.001***	0.401	**0.001**
Overbite depth indicator	-0.223	0.082	-0.005	0.969

Table III - Pearson correlation analysis of vertical molar heights with vertical linear measurements in average and high-angle cases

		Average angle subjects		High angle subjects	
Vertical molar height	**Vertical linear measurements**	r value	p value	r value	p value
U6-SN	UAFH	.169	**.**082	.128	.329
	LAFH	.943**	**.001**	.325*	**.011**
	TAFH	.871**	**.001**	.323*	**.012**
	PFH	-.936**	**.001**	-.270*	**.037**
	Facial height index	-.063	0.09	-.122	.353
	Po-PP	.446**	**.001**	.290*	**.025**
	Ar-PP	.271*	**.033***	.261*	**.029**
	S-PP	.799**	**.001**	.310*	**.001**
	Ptm-PP	.212	.099	.557**	**.001**
	Or-PP	.421**	**.001**	.437**	**.001**
	N-PP	.869**	**.001**	.308*	**.001**
U6-PP	UAFH	.661	0.08	.169	.195
	LAFH	.428**	**.001***	.314*	**.015**
	TAFH	.050	**.001**	.831**	**.001**
	PFH	-.281*	**.001**	-.305*	**.018**
	Facial height index	-.153	0.92	-.024	.857
	Po-PP	.904**	**.001**	.408**	**.001**
	Ar-PP	.927**	**.001**	.435**	**.001**
	S-PP	.744**	**.001**	.287*	**.026**

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Ptm-PP	.927**	**.001**	.605**	**.001**
Or-PP	.932**	**.001**	.884	**.001**
N-PP	.659**	**.001**	.576**	**.001**

Table IV - Pearson correlation analysis of vertical molar heights with angular measurements on Raw values, values calibrated with ACB (Anterior cranial base) length, and values calibrated with PCB (Posterior cranial base) length: in Average angle and High angle cases

	Average angle cases			High angle cases								
Vertical												
molar heights		Angular measurements			RAW VALUE		Calibrated to ACB			Calibrated to PCB		
	RAW VALUE		Calibrated		to ACB	Calibrated to PCB						
		r value	p value	r value	p value	r value	p value	r value	p value	r value	p value	r
value	P value											
U6-SN	Gonial angle		.896*	.001	.574*	0.03	0.576	0.0001	.870	.001	.376*	.003
	.935*	0.0001										
	Upper gonial angle			-.768	.001	-.794	.001	-.596	0.0001	-.930	.001	-
.367	.004	-.753	0.0001*									
	Lower gonial angle			.234	0.086	.476**	.001	.771**	0.0001	.746	.001	
	.589**	.000	.949**	0.0001*								
	Bjork's sum		.583**	.001	.028	.830	.760	0.0001	.73	.001	.408**	.001
	.967**	0.0001										
	Rickett's facial axis			-.391	0.72	-.308	.017	-.759	0.0001	-.011	.937	-
.089	0.32	-.945	0.0001									
	SN to Go-Me		.599**	.001	.299	0.432	.666	0.0001	.531	.001	.578**	.001
	.854**	0.0001										
	Y axis	.329	0.792	.409**	.001	.695**	0.0001	.051	.701	.607**	.001	.025
	0.064											
	Overbite depth indicator			-.106	0.312	-.267*	0.60	-.712*	0.0001	-.042	.750	-
.053	0.08	-.947	0.0001*									
U6-PP	Gonial angle		.216	.092	.715	.001	.690**	0.0001	.160	.223	.477**	.001
	.846**	0.0001*										
	Upper gonial angle			-.133	.304	-.089	.500	-.760	0.0001	-.172	.188	-
.034	0.07	-.685*	0.0001*									
	Lower gonial angle			.262*	.040	.081	.537	.873**	0.0001	.948	.001	.064
	0.32	.857**	0.0001*									
	Bjork's sum		.477**	0.01*	.860**	.001	.963	0.0001	.837	.001	.539**	.001
	.861**	0.0001*										
	Rickett's facial axis			-.094	.466	-.312*	.015	-.900*	0.0001	-.049	.710	-
.687*	.001	-.858*	0.0001*									
	SN to Go-Me		.864**	0.001*	.857**	.001	.213	.103	.233	.001	.675**	.001
	.774**	0.0001*										
	Y axis	.396**	.001*	.380**	.003	.789**	0.0001*	.401	.001	.667**	.0001	
	.825**	0.0001*										
	Overbite depth indicator			-.223	.082	-.046	.729	-.830	0.0001*	-.005	.969	-
.082	0.47	-.831	0.0001*									

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Table V- Pearson correlation analysis of vertical molar heights with linear measurements on Raw values, values calibrated with ACB (Anterior cranial base) length, and values calibrated with PCB (Posterior cranial base) length: in Average angle and High angle cases:

		Average angle cases						High angle cases					
Vertical molar heights	**Vertical linear measurement**	**RAW VALUE**		**Calibrated to ACB**		**Calibrated to PCB**		**RAW VALUE**		**Calibrated to ACB**		Calibrated to PCB	
		r value	**P value**	**r value**	**P value**	**r value**	**P value**	**r value**	**P value**	**r value**	**P value**	**r value**	P value
U6-SN	UAFH	.169	**.**082	.389**	**.002**	.557**	**.0001***	.128	.329	.587**	**.001**	.920**	0.0001*
	LAFH	.943**	**.001**	.483**	**.001**	.812**	**.0001***	.325*	**.011**	.410**	**.001**	.908**	0.0001*
	TAFH	.871**	**.001**	.261*	**.044**	.884**	**.0001***	.323*	**.012**	.322*	**.012**	.934**	0.0001*
	PFH	-.936**	**.001**	-.062	0.95	-.834**	**.0001***	-.270*	**.037**	-.463**	0.09	-.899**	0.0001*
	Facial height index	-.063	0.09	-.224	.086	-.402**	**.0001***	-.122	.353	-.580**	0.75	-.943**	0.0001*
	Po-PP	.446**	**.001**	.232	**.001**	.234	**.0001***	.290*	**.025**	.680**	**.001**	.783**	0.0001*
	Ar-PP	.271*	**.033***	.228	**.001**	.472**	**.0001***	.261*	**.029**	.640**	**.001**	.411**	0.001*
	S-PP	.799**	**.001**	.278*	**.032**	.376**	**.0001***	.310*	**.001**	.508**	**.001**	.836**	0.0001*
	Ptm-PP	.212	.099	.156	**.001**	.559**	**.0001***	.557**	**.001**	.676**	**.001**	.523**	0.0001*

Or-PP	.421**	**.001**	.232	**.001**	.206	**.0001***	.437**	**.001**	.445**	**.001**	.708**	0.0001
N-PP	.869**	.001	.396**	.002	.559**	.0001*	.308*	.001	.568**	.001	.917**	0.0001

		Average angle cases						**High angle cases**					
		RAW VALUE		**Calibrated to ACB**		**Calibrated to PCB**		**RAW VALUE**		**Calibrated to ACB**		**Calibrated to PCB**	
Vertical molar heights	**Vertical linear measurement**	**r value**	**P value**	**r value**	**P value**	**r value**	**P value**	**r value**	**P value**	**r value**	**P value**	**r value**	**P value**
U6-PP	UAFH	.661	0.08	.745**	**.001**	.457**	**.0001***	.169	.195	.621**	**.001**	.823**	**0.0001***
	LAFH	.428**	**.001***	.278*	**.031**	.656**	**.0001***	.314*	**.015**	.554**	**.001**	.829**	**0.0001***
	TAFH	.050	**.001**	.705**	**.001**	.909**	**.0001***	.831**	**.001**	.299*	**.020**	.843**	**0.0001***
	PFH	-.281*	**.001**	-.153	.244	-.720**	**.0001***	-.305*	**.018**	-.394**	0.32	-.759**	**0.0001***
	Facial height index	-.153	0.92	-.402	**.001**	-.638**	**.0001***	-.024	.857	-.490**	**.001**	-.817**	**0.0001***
	Po-PP	.904**	**.001**	.880**	**.001**	.410**	**.0001***	.408**	**.001**	.693**	**.001**	.744**	**0.0001***
	Ar-PP	.927**	**.001**	.917**	**.001**	.641**	**.0001***	.435**	**.001**	.634**	**.001**	.429**	**0.0001***
	S-PP	.744**	**.001**	.801**	**.001**	.226	**.0001***	.287*	**.026**	.521**	**.001**	.739**	**0.0001***
	Ptm-PP	.927**	**.001**	.923**	**.001**	.718**	**.0001***	.605**	**.001**	.670**	**.001**	.397**	**0.001***
	Or-PP	.932**	**.001**	.909**	**.001**	.482**	**.0001***	.884	**.001**	.483**	**.001**	.612**	**0.0001***
	N-PP	.659**	**.001**	.738**	**.001**	.455**	**.0001***	.576**	**.001**	.604**	**.001**	.817**	**0.0001***

Table VI: Linear Regression analysis of U6-SN in Average angle cases

Dependent Variable	**Independent T variable**	**P value(significance)**	**R^2 change**
	Sex	**0.752**	**0.692**
	Nasion - PP distance	**0.01***	

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Raw linear distance of U6-SN	**Sella-PP distance**	**0.001***	
U6-SN Calibrated to ACB length	**Sex**	**0.158**	**0.748**
	Nasion - PP distance	**0.001***	
	Sella-PP distance	**0.01***	
U6-SN Calibrated to PCB length	**Sex**	**0.479**	**0.796**
	Nasion - PP distance	**0.001***	
	Sella-PP distance	**0.0001***	

Table VII : Linear Regression analysis of U6-SN in high-angle cases

Dependent Variable	Independent T variable	P value(significance)	R^2 change
Raw linear distance of U6-SN	**Sex**	**0.620**	**0.638**
	Nasion - PP distance	**0.01***	
	Sella-PP distance	**0.001***	
U6-SN Calibrated to ACB length	**Sex**	**0.32**	**0.720**
	Nasion - PP distance	**0.001***	
	Sella-PP distance	**0.01***	
U6-SN Calibrated to PCB length	**Sex**	**0.76**	**0.774**
	Nasion - PP distance	**0.001***	
	Sella-PP distance	**0.0001***	

TABLE VIII: Comparison of vertical molar height, angular measurements, and vertical linear measurements between males and females

Parameters	Average angle		P value	High angle		P value
Vertical molar height	**Male**	**Female**		**Male**	**Female**	
U6-SN	69.61±2.54	63.62±3.42	**0.006***	74.46±2.28	68.20±2.24	0.04*
U6-PP	22.52±2.56	18.79±3.63	**0.05***	25.80±1.43	23.29±2.22	0.03*
Angular measurements						
Gonial angle	126.80±4.49	122.30±2.94	**0.27**	129.15±23.21	132.25±23.79	0.61
UGA	52.16±3.98	50.52±9.28	**0.37**	49.68±9.45	51.90±10.00	0.04*
LGA	74.96±1.88	72.03±5.93	**0.22**	79.51±14.26	77.46±13.91	0.57

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Bjork's sum	382.86±27.70	382.81±39.38	**0.99**	388.16±40.12	391.89±38.86	0.83
RFA	89.90±3.02	87.49±5.70	**0.41**	81.75±14.66	81.48±14.62	0.94
SN to Go-Me	35.26±8.39	32.05±6.01	**0.09**	40.76±7.23	38.23±6.91	0.4
SN to Y axis	65.40±2.82	62.48±3.21	**0.17**	74.97±12.56	68.17±12.24	0.57
ODI	77.06±2.70	74.31±3.33	**0.27**	70.17±12.05	68.66±12.35	0.63
Vertical linear measurements						
UAFH	50.93±5.53	46.82±8.45	**0.02***	52.73±9.47	50.72±9.11	0.4
LAFH	68.38±2.45	59.47±2.02	**0.0001***	70.35±12.63	67.29±12.08	0.34
TAFH	115.72±7.87	105.91±19.01	**0.01***	117.45±21.09	109.60±19.68	0.14
PFH	78.98±1.15	67.37±5.11	**0.0001***	65.65±11.78	63.57±11.54	0.49
FHI	73.64±3.28	76.93±14.03	**0.21**	78.16±12.96	73.10±13.12	0.78
Po-PP	22.73±9.95	20.67±4.77	**0.13**	27.09±4.23	24.97±3.95	0.29
Ar-PP	11.45±11.56	9.86±3.30	**0.47**	17.43±3.20	15.44±2.37	0.008*
S-PP	37.18±6.31	35.86±7.39	**0.004***	46.01±6.69	40.20±6.53	0.04*
Ptm-PP	7.51±12.13	8.52±3.02	**0.38**	14.96±1.78	12.23±1.84	0.56
Or-PP	24.97±10.21	20.39±3.96	**0.02***	31.10±5.75	26.76±4.87	0.002*
N-PP	50.90±5.55	46.83±8.45	0.03*	54.61±9.45	52.72±9.11	0.43

$P<0.05$ is statistically significant. $P<0.01$ is statistically very significant.