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Research Article

A Novel Approach for the Assessment of True Maxillomandibular Sagittal Relationship in Maharashtrian Population Using a Zeta Angle: Cross-Sectional Study

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Abstract

Introduction: Accurate diagnosis and treatment planning for sagittal skeletal dysplasia require a thorough assessment. A novel cephalometric parameter, the Zeta angle, is proposed to evaluate maxillomandibular relationships in the sagittal plane.

Materials and Methods: This observational study used 294 pre-treatment lateral cephalograms of 15- to 25-year-olds, categorized into skeletal Classes I, II, and III based on Wits appraisal, ANB angle, and Beta angle. "Patients were recruited from the Maharashtrian population between February 2020 and November 2024. The Zeta angle, constructed using points Pt, M, and Pm, was measured to assess maxillomandibular discrepancy in the sagittal plane. Statistical tests were used to calculate the mean Zeta angle values. "ANOVA, followed by Bonferroni post-hoc tests, was used to assess skeletal differences between groups. ROC curve analysis was used to evaluate the sensitivity and specificity of the Zeta angle.

Results: The results indicated that a mean of Zeta angle for Class I skeletal jaw pattern is 62.85, mean Zeta angle for Class II skeletal jaw pattern is 55.72, mean Zeta angle for Class III skeletal jaw pattern is 67.86, a Zeta angle less than 57.5° indicated a Class II skeletal jaw pattern, and a Zeta angle greater than 64.5° indicated a Class III skeletal jaw pattern. According to ROC curves showed that a Zeta angle less than 57.5° had 57% sensitivity and 52% specificity in distinguishing Class II from the Class I subset. A Zeta angle greater than 64.5° has a sensitivity of 89% and specificity of 82% in distinguishing Class III from the Class I subset.

Conclusion: The Zeta angle offers a reliable diagnostic tool for assessing sagittal jaw relationships, as it is based on stable anatomical landmarks. This ensures that its measurement remains unaffected by jaw rotations or orthodontic treatments, enhancing its utility in clinical evaluations.

Keywords: True Maxillomandibular Sagittal Relationship; Zeta angle*; Maharashtrian Population*

Introduction

Accurate assessment of dentofacial discrepancies is crucial for optimal orthodontic treatment outcomes. Cephalometric analysis plays a key role in diagnosing and planning treatment, particularly for anteroposterior (A-P) dysplasia.

Various linear and angular measurements are used to evaluate A-P discrepancies between the maxilla and mandible, enabling customized treatment plans. The ANB angle is frequently utilized as a criterion, despite the presence of discrepancies in nasion movement and jaw rotations that can be influenced by growth or orthodontic interventions, consequently impacting points A (deepest point on the concavity of maxilla) and B (deepest point on the concavity of mandible).

To address these limitations, Jacobson introduced the Wits appraisal [4]. However, it's influenced by tooth eruption and orthodontic treatment, making it less reliable for diagnosis pure sagittal discrepancies [5,6]. Additionally, gender and ethnicity can affect its accuracy [5]. Researchers often rely on the palate as a stable reference point [7], but changes in palatal plane inclination due to growth and treatment can compromise its reliability. "Therefore, a parameter unaffected by occlusion or cranial reference planes is needed to assess apical base dysplasia. While the Beta angle is less influenced by cranial landmarks, it can still be affected by changes at points A and B due to growth and orthodontic treatment. Additionally, identifying the center of the condyle can be challenging.

The Yen [11] and W angles [12] were proposed to address these limitations. However, the Yen angle can be affected by jaw rotations due to growth or orthodontic treatment. While the W angle is less affected by jaw rotations, it relies on the sella turcica, which can be unreliable.

This study introduces the Zeta angle, a new cephalometric parameter to assess sagittal maxillomandibular discrepancy. The Zeta angle is based on three stable skeletal landmarks: Pt, M, and Pm. The study aims to determine the mean values and standard deviation of the Zeta angle in Class I, II, and III skeletal patterns.

Study design

This observational, retrospective, cross-sectional study analyzed 296 pre-treatment cephalograms from patients Maharashtrian population between February 2020 and November 2024. All participants were from Maharashtra and provided informed consent. The study was approved by the Institutional Ethic Board.

Sample size calculation

The sample size was calculated using an expected sensitivity and specificity of 90% and 85%, respectively, a 25% prevalence rate of sagittal dysplasia, an alpha error of 5%, and a 95% confidence interval. Statistical analysis was performed using Statistical package for social sciences (SPSS) software (IBM Corp) (v.21.0). Descriptive and inferential statistics was performed for different parameters assessed in the study and the sample size was 98 samples in each group. As the present study was conducted in three groups, the total sample size was 294.

Methodology

Inclusion Criteria

Age Range- 15-25 years

Race- Indo-Aryan (Maratha Population)

Growth Pattern- Average (SN-GoGn angle of 27-36)

Lateral Cephalograms could be easily and clearly visualized.

Exclusion Criteria

Age limit

Growth Pattern- Horizontal **and vertical**

H/O of Previous Orthodontic Treatment History

Craniofacial Anomalies

Presence of third molar

All lateral cephalograms were obtained using a KODAC 8000 C Digital Panoramic and Cephalometric system in the voltage range of 70 kV and a current range of 10 mA. The patients were positioned within the cephalostat, such that the sagittal plane intersected at a perpendicular angle to the trajectory of the X-rays.

The primary beam was oriented toward the left aspect of the face with a standardized level of magnification set at 10mA, while ensuring that the Frankfort horizontal (FH) plane remained parallel to the horizontal plane.

All participants were directed to occlude centric occlusion while ensuring that their lips were gently sealed. Each cephalogram was captured by an oral and maxillofacial radiologist with a decade of expertise. A total of 294 pre-treatment lateral cephalograms were traced manually on a 0.003" thick acetate matte tracing paper (0.3 mm, 3H mechanical lead pencil). The ANB angle [1], Wits appraisal [4], Beta angle [9], and SNGoGn angle [14] were measured and compared by two examiners separately, and the mean values were evaluated. The ANB angle, Wits appraisal, and Beta angle were used to determine the antero-posterior discrepancy, whereas the SN-GoGn angle indicated the skeletal pattern in the vertical dimension. The details of the angles with the landmarks are provided in Table 1 Of the total 602 pre-treatment cephalograms screened, 294 lateral cephalograms were selected and subcategorized into three groups, that is, Class I, II, and III skeletal jaw base, each consisting of 98 lateral cephalograms, based on pre-set inclusion and exclusion criteria. They were further segregated according to gender, with 49 males (50%) and 49 females (50%) in each group.

The criteria for segregation into skeletal Class I were the presence of an ANB angle of 2°-4°, Wits appraisal of 0 to 3 mm, Beta angle of 27-35°, and a pleasant profile. The criteria for skeletal Class II were ANB angle ≥4°, Wits appraisal ≥3 mm, Beta angle<27°, and convex profile. The criteria for skeletal Class III were an ANB angle ≤2°, Wits appraisal ≤0 mm, Beta angle >35°, and a concave profile.

Zeta angle

The Zeta angle serves as an innovative diagnostic parameter for evaluating the anteroposterior (sagittal) relationship between the maxillary and mandibular apical bases. This angle is derived using three anatomical landmarks:

Figure 1. *Landmarks of Zeta angle.*

Point Pt: Defined as the junction of the pterygomaxillary fissure and the foramen rotundum. The foramen rotundum's position can be identified using a specialized template, such as the Jacobson-Sadowsky lip contour template by Unitek Corp, or approximated at the 10:30 position along the circular contour of the superior border of the pterygomaxillary fissure.

Point M: Located at the midpoint of the premaxilla. This point is identified using a concentric circle template with 0.5" diameter increments, centering the template to locate the midpoint.

Point Pm: Represents the point where the shape of the chin transitions from convex to concave.

Once these points are identified, the Zeta angle is determined by constructing three lines:

- The **Pt-Pm line**, connecting Point Pt and Point Pm.
- The **M-Pm line**, connecting Point M and Point Pm.
- A line extending from Point M perpendicular to the Pt-Pm line.

The Zeta angle is measured between the perpendicular line from Point M and the M-Pm line. This angle quantifies the sagittal discrepancy and offers insight into the positional relationship of the maxillary and mandibular apical bases.

Statistical Analysis

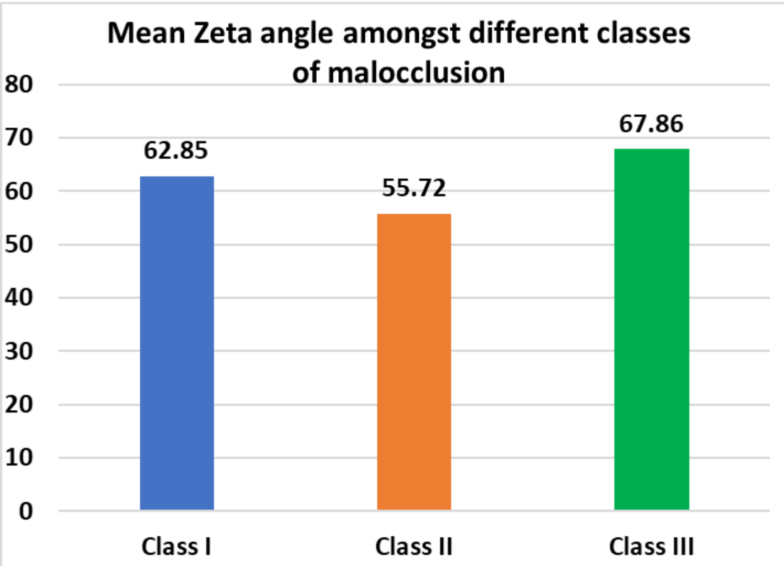
Statistical analysis was performed using Statistical package for social sciences (SPSS) software (IBM Corp) (v.21.0). Descriptive and inferential statistics was performed for different parameters assessed in the study. Comparison of Zeta angle between different classes of malocclusion was performed using One-way ANOVA for continuous variables. Comparison between gender was performed using independent samples/unpaired t-test to assess significant differences between 2 groups for continuous variables. All statistical tests were performed at 95% confidence intervals. A p value of less than 0.05 was considered as statistically significant in the study.

Results

The mean Zeta angle for the Class I skeletal base group was recorded at 62.85° . Conversely, the mean Zeta angle for the Class II skeletal base group was 55.72°. Similarly, the mean Zeta angle for the Class III skeletal base group was measured at 67.86°. An analysis using one-way ANOVA revealed a statistically significant variance among the three subgroup categories, further confirmed by the Bonferroni post-hoc test, which also highlighted significant differences when comparing all groups. Moreover, an independent t-test showed no significant differences in the Zeta angle mean values between sexes.

Table 1. Descriptive statistics of Zeta angle amongst different classes of malocclusion

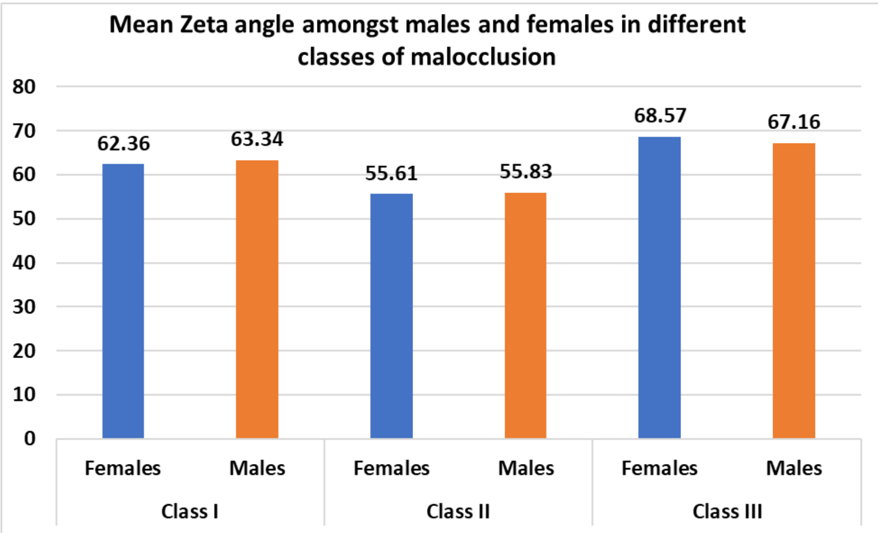
Class	N	Minimum	Maximum	Mean	Std. Deviation
Class I	98	55.00	70.00	62.85	3.05
Class II	98	50.00	70.00	55.72	2.78
Class III	98	62.00	77.00	67.86	3.05



Graph. 1

Table 2. Descriptive statistics of Zeta angle amongst males and females in different classes of malocclusion.

Class	Groups	N	Mean	Std. Deviation	Std. Error Mean
Class I	Females	49	62.36	3.08	.44002
	Males	49	63.34	2.97	.42514
Class II	Females	49	55.61	2.58	.36980
	Males	49	55.83	2.99	.42792
Class III	Females	49	68.57	3.25	.46566
	Males	49	67.16	2.67	.38282

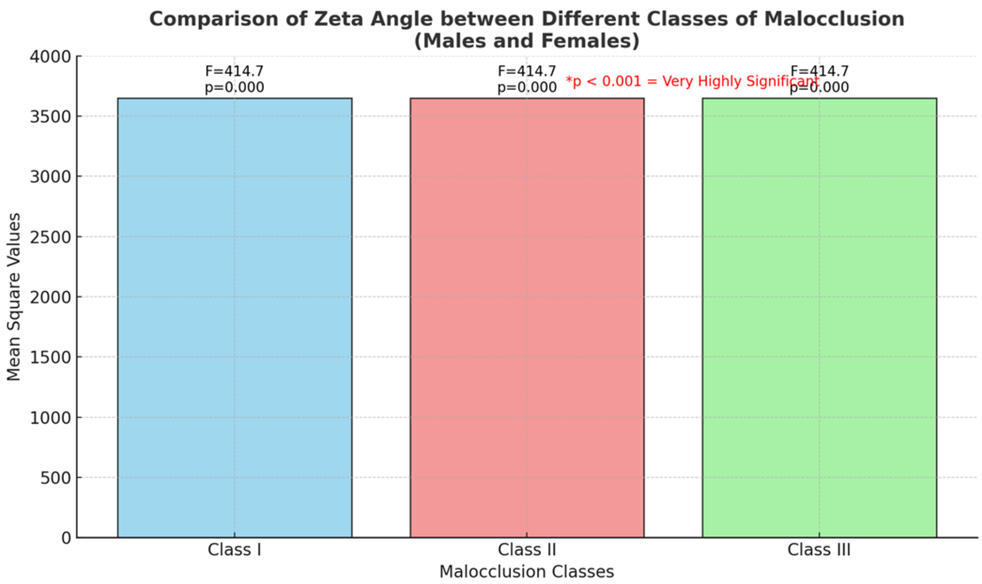


Graph. 2

Table 3. Comparison of Zeta angle between different classes of malocclusion in males and females.

Comparison groups	Sum of Squares	df	Mean Square	F	p value
Class I vs Class II vs Class III vs	7298.578	2	3649.289	414.686	0.000*

*p value <0.05 statistically significant, <0.01 highly significant, <0.001 very highly significant



Graph. 3

Table 4. Multiple pairwise comparison of Zeta angle between different classes of malocclusion in males and females.

Bonferroni Post Hoc Tests						
(I) Groups	(J) Groups	Mean Difference (I-J)	Std. Error	p value	95% Confidence Interval	
					Lower Bound	Upper Bound
Class I	Class II	7.13265*	.42379	.001*	6.1122	8.1531
	Class III	-5.01020*	.42379	.000*	-6.0306	-3.9898
Class II	Class I	-7.13265*	.42379	.001*	-8.1531	-6.1122
	Class III	-12.14286*	.42379	.000*	-13.1633	-11.1224
Class III	Class I	5.01020*	.42379	.000*	3.9898	6.0306
	Class II	12.14286*	.42379	.000*	11.1224	13.1633

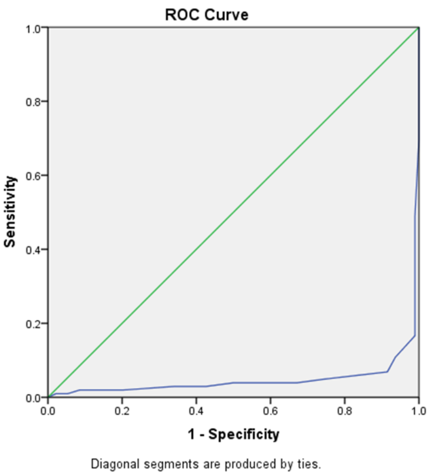
*p value <0.05 statistically significant, <0.01 highly significant, <0.001 very highly significant

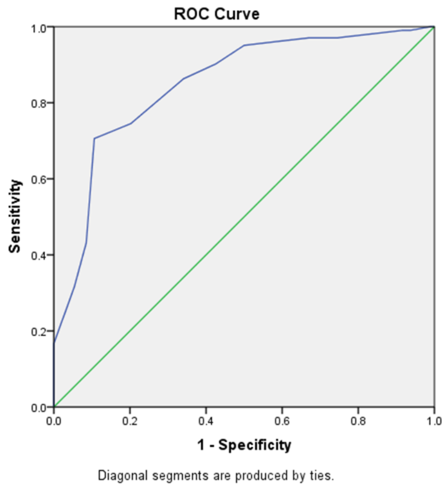
Table 5. Comparison of Zeta angle between males and females in different classes of malocclusion.

Class	Comparison Groups	N	Mean	Mean difference	t value	p value
Class I	**Females**	49	62.3673	-.97959	-1.601	.113
	Males	49	63.3469			
Class II	**Females**	49	55.6122	-.22449	-.397	0.692
	Males	49	55.8367			
Class III	**Females**	49	68.5714	1.40816	2.336	0.022*
	Males	49	67.1633			

*p value <0.05 statistically significant, <0.01 highly significant

ROC Curve and other analysis





Differentiation of Class II from Class I : Sensitivity – 57%

Specificity – 52%

AUC – 0.047

Differentiation of Class III from Class I: Sensitivity – 89%

Specificity –82%

AUC – 0.849

In our study, according to the ROC curves, a Zeta angle cut-off value of around 57.5° was identified between Class I and Class II groups, while a cut-off value of approximately 64.5° was observed between Class I and Class III groups. These thresholds align closely with the mean values from the Class I group (62.85), underscoring the high level of reliability. Conversely, mean values from the Class II group (55.72). Similarly, they mean values from the Class III group (67.86). This implies that individuals with a Zeta angle between 57.5° and 64.5° truly exhibit a Class I skeletal pattern. The findings further suggested that a Zeta angle less than 57.5° indicates a class II sagittal relation, whereas a Zeta angle greater than 64.5° indicates a Class III sagittal relation (Table 1).

Comparison of Zeta angle between different classes of malocclusion in males and females was performed using One-way ANOVA. This comparison showed statistically very high significant differences (p value <0.05) between the 3 classes (Table 3). In Multiple pairwise comparison of Zeta angle between different Classes of malocclusion in males and females was performed using Bonferroni post hoc test. This comparison showed statistically high significant differences (p value <0.01) between the all the Classes (Table 4). Comparison of Zeta angle between males and females in different Classes of malocclusion was performed using independent samples t-test/Unpaired t-test. This comparison showed statistically significant differences (p value <0.05) between males and females in Class III; whereas no significant differences were noted in Class I and Class II (Table 5).

Discussion

Since its introduction in 1931, cephalometrics has become a crucial diagnostic tool for evaluating transverse, sagittal, and vertical jaw relationships. In cases of skeletal base dysplasia, the sagittal relationship plays a pivotal role in diagnosis and treatment planning, making its careful evaluation essential. Several angular and linear parameters, including the ANB angle [1], Wits appraisal [4], Beta angle [9], Yen angle [11], and W angle [12], have been suggested to assess anteroposterior dysplasia, each with its own strengths and limitations.

The ANB angle, initially introduced by Reidel and later popularized by Steiner, is widely used to assess the anteroposterior relationship of the jaws [1]. However, it is crucial to recognize that this angle is influenced by several factors. Research has shown that nasion movement during growth or jaw rotation can significantly affect the ANB angle. Specifically, a 2.5° reduction occurs for every 5 mm anterior displacement of the nasion, a 0.5° decrease for a 5 mm upward displacement, and a 1° increase for a 5 mm downward displacement. Additionally, the cranial base length, cranial base inclination, and anterior facial height are key factors in determining the ANB angle [2]

Jacobson's Wits appraisal is a widely used alternative for evaluating anteroposterior (AP) severity [4]. Unlike methods that rely on cranial landmarks, the Wits appraisal uses perpendiculars drawn from points A and B on the functional occlusal plane (FOP). Although the Wits appraisal remains fairly consistent across age groups and accounts for jaw rotation, it depends on the FOP to detect discrepancies in AP alignment. Factors such as dental development, tooth eruption, and orthodontic treatment can significantly influence the occlusal plane. However, accurately identifying and replicating the FOP can be challenging, and any changes to the FOP during orthodontic procedures may affect the Wits appraisal, potentially leading to an inaccurate representation of sagittal dysplasia in the jaws [6, 8].

The challenges associated with traditional parameters for assessing anteroposterior dysplasia, emphasizing their susceptibility to factors like age, growth, rotational changes, and inconsistencies in landmark identification. To address these limitations, the Zeta angle was developed. This approach relies on three stable skeletal landmarks—point Pt, point M, and point Pm—eliminating the reliance on unstable landmarks or reference planes such as the cranial or occlusal plane.

To overcome the limitations of using the occlusal plane as a reference, Chang introduced the AF-BF concept, where the AF-BF distance is determined by projecting perpendiculars from points A and B onto the FH plane [16]. However, this evaluation can be influenced by the inclination of the FH plane. Additionally, a study indicated that Porion and Orbitale, commonly used to construct the FH plane, are among the least reliable reference points [17]. The Beta angle, developed by Baik and Ververidou, is another widely used parameter that involves three key skeletal landmarks: points A, B, and condylion (C) [9]. This angle is formed by the intersection of a line perpendicular to the CB line at point A and the AB line. While the Beta angle remains unaffected by jaw rotations, changes in the positions of points A and B due to growth and orthodontic treatment may influence the measurement [2]. Furthermore, accurately identifying the center of the condyle poses challenges, as does ensuring the precision, consistency, and estimation of this parameter [10].

To overcome the limitations of the Beta angle, Neela introduced the Yen angle, which is determined by points S, M, and G (the midpoint of the largest circle tangent to the internal surfaces of the mandibular symphysis) [11]. While it uses reliable landmarks, the Yen angle can be influenced by jaw rotation, potentially leading to inaccuracies [2]. In contrast, the W angle utilizes the same points as the Yen angle, but the measurement is taken between a perpendicular line dropped from point M to the SG and MG lines [12]. The W angle is not affected by jaw rotations; however, it relies on point S, which has been considered unstable in several studies [13]. Li et al. (2022) introduced the G triangle analysis for evaluating sagittal relationships [18]. Unlike the ANB angle, this method does not include the nasion point in the triangle but uses points A and B to assess the relationship between the maxilla and mandible. It is important to recognize that points A and B are prone to changes due to growth, rotations, and orthodontic treatments, as noted earlier [2].

Most of the parameters used to assess anteroposterior dysplasia are influenced by factors such as the patient's age, growth, rotation of the apical bases, inaccuracies in landmark identification, and the mechanics of orthodontic treatment. To address these limitations, the Zeta angle was developed. The Zeta angle relies on three stable skeletal landmarks—point Pt, point M, and point Pm—thereby eliminating the need for unstable landmarks, cranial reference planes, or the occlusal plane.

The Zeta angle employs anatomical skeletal landmarks, points M and Pm, to represent the maxilla and mandible, respectively. Point M, first introduced by Nanda and Merrill [7] and later refined by Braun, is defined as the midpoint of the premaxilla, corresponding to the center of the largest circle that contacts the anterior, superior, and palatal surfaces of the premaxilla. Unlike points A and B, point M remains unaffected by local remodeling caused by dental shifts or orthodontic interventions, making it a reliable marker for analyzing maxillary growth, particularly during active growth periods [19]. On the other hand, the supererogation (point Pm) is situated at a critical stress point marked by a reversal line. Implant research confirms its stability as an unchanging bony landmark in the chin, establishing it as a consistent reference point for the mandible. Together, these stable landmarks enhance the Zeta angle's precision and reliability in assessing skeletal relationships.

According to Nikita Mohelay and Nisha Dua Individuals exhibiting a Zeta angle ranging from 57° to 64° typically present with a class I skeletal jaw pattern, while a Zeta angle below 57° suggests a class II skeletal jaw pattern and a Zeta angle exceeding 64° indicates a class III skeletal jaw pattern. ROC curves showed that a Zeta angle less than 57.5° had 80% sensitivity and 82.5% specificity in distinguishing class II from the class I subset. A Zeta angle greater than 64.5° has a sensitivity and specificity of 92.5% in distinguishing class III from the class I subset [23].

The pterygoid point, referred to as Pt, is a key anatomical landmark characterized by its role as a locus of energy due to the innervation by the maxillary nerve [21]. Pt is situated closest to the center of minimal growth, which enhances its utility in facilitating sequential comparisons. When used in superimposing tracings on a polar grid, Pt, as emphasized by Ricketts, represents a critical growth point owing to its strategic placement. This notion is further reinforced by Brodie, who highlighted the enduring stability of the pterygopalatine fossa, underscoring Pt's reliability as a stable reference landmark.

The Zeta angle maintains stability during jaw rotations due to its inherent geometric properties. This stability arises from the consistent alignment of the perpendicular line originating from point M with the Pt-Pm line, even during rotational jaw movements. Additionally, as the M-Pm line rotates in the same direction, the Zeta angle remains unchanged. This makes the Zeta angle particularly advantageous for evaluating sagittal dysplasia associated with upward or backward jaw movements and during the transitional phases of vertical facial development. Moreover, its utility extends to monitoring treatment progress, as it accurately reflects genuine changes in sagittal alignment resulting from natural growth or orthodontic interventions.

Accurate delineation of the premaxilla and identification of its midpoint can be challenging, making it essential to obtain a high-quality cephalogram to effectively trace the premaxillary outline and locate its center. However, the Zeta angle alone is insufficient for determining the prognathic or retrognathic nature of the jaw in cases involving Class II and Class III apical bases. Clinicians must, therefore, complement the Zeta angle with additional cephalometric data to ensure a comprehensive assessment.

The literature offers a wide array of parameters designed to assess sagittal dysplasia through cephalometrics, yet many of these parameters exhibit notable limitations. As a result, clinicians must approach their application with prudence and critical judgment. The Zeta angle complements existing cephalometric parameters, providing additional support in evaluating sagittal dysplasia and improving the accuracy of diagnosis and treatment planning for orthodontic patients.

The clinical significance of the Zeta angle is associated with upward or backward jaw movements and during the transitional phases of vertical facial development. The Zeta angle maintains stability during jaw rotations due to its inherent geometric properties. This stability arises from the consistent alignment of the perpendicular line originating from point M with the Pt-Pm line, even during rotational jaw movements. Additionally, as the M-Pm line rotates in the same direction, the Zeta angle remains unchanged. This makes the Zeta angle particularly advantageous for evaluating sagittal dysplasia.

Conclusions

Formerly acknowledged cephalometric measurements for evaluating sagittal dysplasia may lead to inaccuracies; therefore, a novel angle known as the Zeta angle was introduced as an additional tool for consistent identification of sagittal jaw relationships. The results indicated that a mean of Zeta angle for Class I skeletal jaw pattern is 62.85, mean Zeta angle for Class II skeletal jaw pattern is 55.72, mean Zeta angle for Class III skeletal jaw pattern is 67.86, a Zeta angle less than 57.5° indicated a Class II skeletal jaw pattern, and a Zeta angle greater than 64.5° indicated a Class III skeletal jaw pattern. ROC curves showed that a Zeta angle less than 57.5° had 57% sensitivity and 52% specificity in distinguishing Class II from the Class I subset. A Zeta angle greater than 64.5° has a sensitivity of 89% and specificity of 82% in distinguishing Class III from the Class I subset.

Conflict of Interest

None declared.

Acknowledgment

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