

"Evaluating the Diagnostic Reliability of MKG & Tau Angle with ANB Angle , W Angle, Yen Angle, Beta Angle, and Wits Appraisal in Mixed Solan Population – A Cephalometric Study"

Abstract:

Introduction: Precise evaluation of sagittal jaw discrepancies is crucial for orthodontic diagnosis and treatment planning. While conventional cephalometric parameters such as the ANB angle, Wits appraisal, Beta angle, Yen angle, and W angle are commonly used, they have notable limitations. Recent advancements have introduced alternative measurements like the MKG and Tau angles to improve diagnostic accuracy.

Objective: This study assesses the diagnostic reliability of the MKG and Tau angles and their correlation with established parameters in a mixed Solan population.

Materials and Methods: A total of 150 pretreatment lateral cephalograms were categorized into Class I, II, and III malocclusions based on ANB angle. Key parameters analyzed included ANB, Wits appraisal, Beta angle, Yen angle, W angle, MKG angle, and Tau angle. Statistical evaluation was conducted using ANOVA, post hoc Bonferroni tests, and Spearman's correlation to examine intergroup differences and associations.

Results: The Tau angle exhibited high sensitivity (100%) in distinguishing Class II and III malocclusions, with strong correlations to traditional measurements. The MKG angle demonstrated moderate sensitivity (76–87%) but was less consistent in Class I cases. The Beta angle and Wits appraisal showed the highest overall sensitivity (100%). Statistical significance ($*p < 0.001$) was observed across all parameters among malocclusion groups.

Conclusion: The Tau angle is a highly reliable tool for sagittal discrepancy assessment, particularly in Class II and III malocclusions, and can complement ANB and Beta angles in clinical practice. While the MKG angle provides additional diagnostic utility, its predictive accuracy is comparatively lower. Incorporating these novel angles may enhance diagnostic precision and facilitate personalized treatment strategies.

Keywords: MKG angle, Tau angle, sagittal discrepancy, cephalometric analysis.

Introduction:

The assessment of jaw alignment, particularly in the sagittal plane, plays a pivotal role in orthodontic diagnosis and treatment planning. Among the three spatial dimensions—transverse, vertical, and sagittal—the anteroposterior relationship between the maxilla and mandible is the most frequent contributor to skeletal malocclusions. Lateral cephalometric radiography remains a cornerstone diagnostic tool, offering a standardized approach to evaluating craniofacial morphology. However, due to anatomical variability and developmental differences, sagittal plane analysis remains complex, necessitating precise and reliable diagnostic criteria.

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The ANB angle, first described by *Riedel (1952)*, has traditionally served as a key metric for evaluating maxillomandibular relationships.[1] Despite its widespread adoption, this measurement has inherent limitations, including susceptibility to cranial base variations, jaw rotations, and positional changes of nasion. To address these shortcomings, *Jacobson (1975)* introduced the Wits appraisal, which relies on the functional occlusal plane.[2] However, this method is also influenced by dental factors such as tooth eruption, loss, or malpositioning, leading to potential inconsistencies.

Alternative angular measurements, including the Beta angle, Yen angle, and W angle, have been proposed to enhance the reliability of skeletal assessment. Nevertheless, these methods present their own challenges. The Beta angle, for instance, depends on the condylar axis, which can be difficult to identify accurately, while the W and Yen angles reference Sella point—a landmark that may shift during growth, affecting measurement reproducibility.[3,4,5]

To mitigate these limitations, newer cephalometric analyses such as the MKG angle (*Chachada, 2020*)[6] and Tau angle (*Gupta et al., 2020*)[7] have been developed. These approaches utilize more stable skeletal landmarks, potentially improving the assessment of sagittal discrepancies. Preliminary research suggests these angles may offer superior diagnostic consistency, particularly in diverse craniofacial morphologies.

The Solan population, characterized by genetic and environmental diversity, provides an optimal sample for evaluating these emerging techniques. This study aims to compare the diagnostic reliability of the MKG and Tau angles with conventional parameters (ANB angle, Wits appraisal, Beta angle, W angle, and Yen angle). The findings will determine whether these newer measurements can serve as robust alternatives, particularly in cases where traditional methods yield inconclusive results.

Materials And Method:
Study Design And Sample Selection

This cross-sectional investigation was carried out in the Department of Orthodontics and Dentofacial Orthopedics at Bhojia Dental College and Hospital, Baddi, Himachal Pradesh. A retrospective evaluation was performed using 150 pretreatment lateral cephalometric radiographs obtained from institutional archives.

Inclusion Criteria:

1. Patients with **skeletal Class I malocclusion** (ANB angle: 1°–4°).

2. Patients with **skeletal Class II malocclusion** (ANB angle: >4°).
3. Patients with **skeletal Class III malocclusion** (ANB angle: ≤0°).
4. Full permanent dentition with no missing teeth.
5. No history of craniofacial anomalies or significant facial asymmetry.
6. High-quality, standardized pretreatment lateral cephalograms with clear landmarks.

Exclusion Criteria:

1. Individuals who had undergone prior orthodontic or orthognathic treatment.
2. Patients with congenital craniofacial syndromes.
3. Medically compromised patients.

Group Allocation:

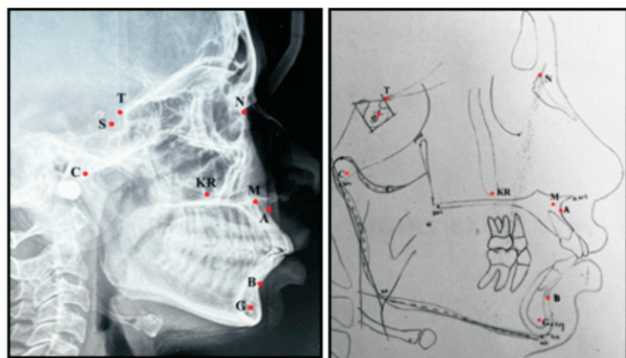
The sample size of 150 pretreatment lateral cephalogram was **selected retrospectively from the institutional archives** and was based on **stratification into three equal groups** (n = 50 each) according to **ANB angle–defined skeletal classification:**

- **Group I:** Skeletal Class I malocclusion (n = 50)
- **Group II:** Skeletal Class II malocclusion (n = 50)
- **Group III:** Skeletal Class III malocclusion (n = 50)

Table 1: Landmarks And Planes Used In The Study

LANDMARK / PLANE	DEFINITION
NASION (N) ⁸	The most anterior point of the frontonasal suture in the midsagittal plane
POINT A ^{8,14}	(Subspinale) most posterior midline point in concavity between the anterior nasal spine and prosthion (most inferior point on alveolar bone overlying maxillary incisors)
POINT B ^{8,14}	(Supramentale) most posterior midline point in concavity of the mandible between most superior point on alveolar bone overlying lower incisors and pogonion
SELLA (S) ⁸	The midpoint of the pituitary fossa, determined by visual approximation
KEY RIDGE (KR) ⁸	Lower most point on the contour of the anterior wall of the infra-temporal fossa
POINT C ³	The geometric center of the mandibular condyle, identified by tracing its outline
POINT T ⁷	Uppermost point at the junction of the frontal wall of pituitary fossa and tuberculum sellae
POINT M ⁷	The constructed midpoint of the premaxillary region
POINT G ⁷	Focal point of the biggest circle that is tangent to the inner frontal, posterior, and lower edge of the mandibular symphysis
POINT MtoPOINT KR ⁶	A linear measurement connecting the premaxillary midpoint (M) to the key ridge (KR)
POINT KRtoPOINT G ⁶	A linear measurement extending from the key ridge (KR) to the symphysis center (G)
POINT TtoPOINT G ⁷	A reference line joining the tuberculum sellae (T) to the symphysis center (G)
POINT MtoPOINT G ⁷	Line connecting the midpoint of the premaxilla (M) and the center of the largest circle tangent to the internal inferior, anterior, and posterior surfaces of the mandibular symphysis (G)
NA PLANE ¹	A line connecting Nasion (N) to Point A (the most concave point on the anterior maxilla)
NB PLANE ¹	A line connecting Nasion (N) to Point B (the most concave point on the anterior mandible)

CB LINE ³	A line drawn from Point C (the center of the sella turcica) to Point B (the most concave point on the anterior mandible)
AB LINE ³	A line connecting Point A (the most concave point on the anterior maxilla) to Point B (the most concave point on the anterior mandible)
PERPENDICULAR from POINT A to CB LINE ³	A perpendicular is drawn from Point A to the CB Line
SM PLANE ⁴	A cranial base-maxillary reference plane
MG PLANE ⁴	A maxillary-mandibular relationship plane.
SG PLANE ^{4,5}	A cranial base-mandibular symphysis reference plane
PERPENDICULAR from POINT M to SG PLANE ⁵	A perpendicular line is drawn from Point M to the SG Line



PARAMETER	DEFINITION
MKG ANGLE ⁶	Formed by three anatomical landmarks: M point (premaxilla midpoint), G point (symphysis center), and KR point (key ridge). The angle is created by drawing lines from M to KR and from KR to G
TAU ANGLE (τ) ⁷	Constructed using points M (premaxilla midpoint), G (symphysis center), and T (tuberculum sellae). The angle is formed between lines connecting T to G and M to G
ANB ANGLE ^{1,14}	The angle formed by the intersection of lines joining nasion to point A and nasion to point B. It denotes the relative position of the maxilla and mandible to each other
BETA ANGLE (β) ³	Determined by first drawing a perpendicular from point A to the CB line (condylin to point B), then measuring the angle between this perpendicular and the AB line (point A to point B)
YEN ANGLE ⁴	The angle formed between the S, G and M points and the angle measured at M is the Yen angle
W ANGLE ⁵	A perpendicular line is drawn from point M to the SG line and the angle formed by the SG and MG lines is the W angle
WITS APPRAISAL ²	Evaluates sagittal jaw relationship by measuring the linear distance between perpendicular projections of points A and B onto the functional occlusal plane

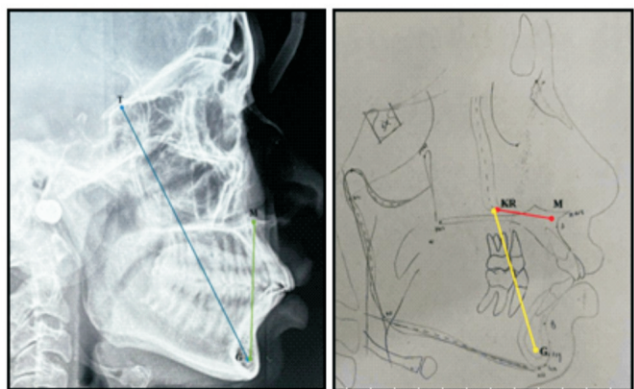


Fig 2. MKG angle formed by three anatomical landmarks: point M (premaxilla midpoint), point G (symphysis center), and point KR (key ridge).

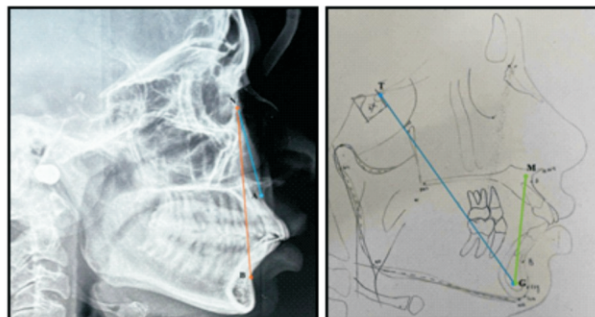


Fig 3. Tau angle constructed using points M (premaxilla midpoint), G (symphysis center), and T (tuberculum sellae).

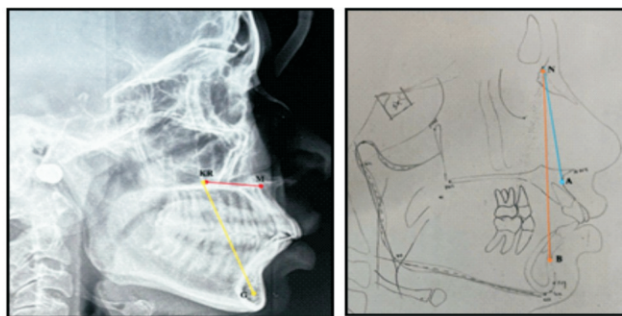


Fig 4. ANB angle, formed by lines NA and NB, denotes the relative anteroposterior position of the maxilla (point A) and mandible (point B) with respect to the cranial base (Nasion).

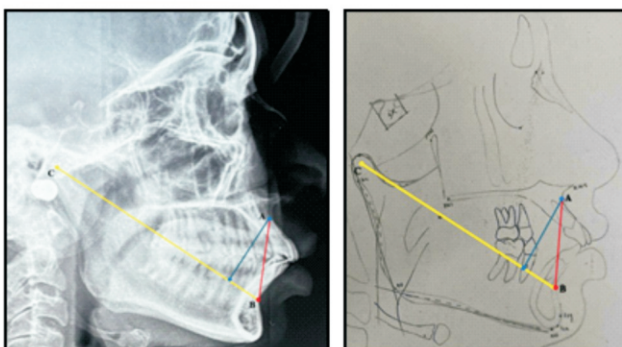


Fig 5. Beta (β) Angle measured by dropping a perpendicular from point A to the CB line (Condylin to point B), and recording the angle between this perpendicular and the AB line.

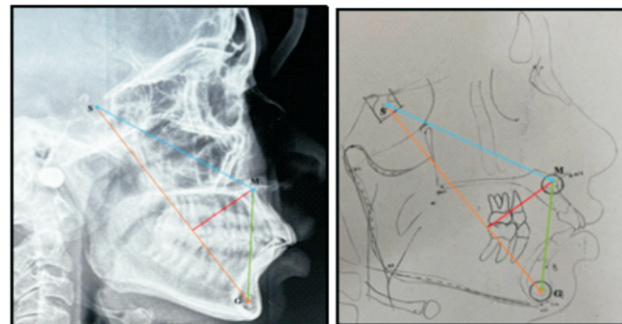


Fig 6. Yen angle (formed at point M by lines SM and MG) and W angle (formed by the intersection of MG and SG lines with

a perpendicular from M).

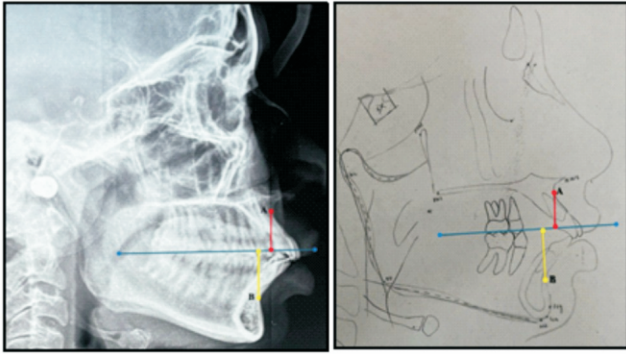


Fig 7. WITS appraisal, showing perpendicular projections of points A and B onto the functional occlusal plane

Statistical Analysis:

The statistical analysis was conducted using **SPSS version 21.0 software**. Descriptive statistics were computed for all cephalometric variables across Class I, II, and III malocclusions. The **Kolmogorov-Smirnov test** confirmed non-normal data distribution (*p* < 0.05), prompting the use of non-parametric tests. Inter-group comparisons were performed using the **Kruskal-Wallis test**, revealing significant differences (*p* = 0.000) for all variables followed by **Post hoc Bonferroni tests** was used to identify pairwise distinction. **Spearman's correlation (Rho)** assessed correlation of MKG and Tau angles with other parameters. Sensitivity analysis highlighted the diagnostic validated of newer angular measurements alongside conventional methods.

Method of Error Assessment:

To minimize measurement error, all cephalograms were traced and analyzed by a single examiner under standardized conditions.

Results;

Table 3. Descriptive statistics for Class I, II and III malocclusions

Variable	Group I Class I (Mean ± SD)	Group II Class II (Mean ± SD)	Group III Class III (Mean ± SD)
ANB Angle	2.48 ± 1.27	7.08 ± 1.66	-2.32 ± 1.46
Beta Angle	32.56 ± 4.56	26.98 ± 4.80	39.00 ± 4.94
Yen Angle	119.76 ± 5.26	112.12 ± 4.47	127.44 ± 6.01
W Angle	53.98 ± 3.43	49.28 ± 3.16	59.00 ± 3.53
Tau Angle	31.92 ± 3.43	35.94 ± 3.68	26.48 ± 3.66
MKG Angle	59.54 ± 7.85	64.40 ± 7.20	53.18 ± 7.51
Wits Appraisal	1.90 ± 1.23	5.04 ± 2.37	2.98 ± 1.74

In **Table 3** the descriptive analysis of cephalometric parameters across malocclusion classes revealed significant variations in all measured values. The ANB angle showed the highest mean value in Class II malocclusion (7.08° ± 1.66), followed by Class I (2.48° ± 1.27), with Class III demonstrating a negative mean value (-2.32° ± 1.46).

Conversely, the Beta angle exhibited an opposite trend, peaking in Class III (39.00° ± 4.94), followed by Class I (32.56° ± 4.56), and reaching its lowest value in Class II (26.98° ± 4.80). Similar progressive patterns were observed for the Yen angle, with Class III showing the highest measurements (127.44° ± 6.01), followed by Class I (119.76° ± 5.26) and Class II (112.12° ± 4.47). The W angle followed this same gradation, being greatest in Class III (59.00° ± 3.53), intermediate in Class I (53.98° ± 3.43), and smallest in Class II (49.28° ± 3.16). The Tau angle displayed a distinct pattern, with Class II demonstrating the highest values (35.94° ± 3.68), followed by Class I (31.92° ± 3.43) and Class III (26.48° ± 3.66). Similarly, the MKG angle was maximal in Class II (64.40° ± 7.20), intermediate in Class I (59.54° ± 7.85), and minimal in Class III (53.18° ± 7.51). Finally, the Wits appraisal measurements revealed Class II had the greatest values (5.04 ± 2.37 mm), followed by Class III (2.98 ± 1.74 mm), with Class I showing the smallest measurements (1.90 ± 1.23 mm). These findings demonstrate clear differentiation among malocclusion classes across all evaluated parameters.

Table 4: Comparative Evaluation of the Parameters between Three Groups Using One Way Anova.

Variable	(Mean ±SD)	Sum of Squares Between Groups	Df	Mean Square Between Groups	Mean Square Within Group	F Value	P Value	
ANB Angle	2.41 (±1.42)	2209.333	2	1104.667	2.177	507.393	.000*	
		Sum of Squares Within Groups	147					
		Total	320.040					149
Beta Angle	32.84 (±6.83)	1809.087	2	904.544	22.784	79.400	.000*	
		Sum of Squares Within Groups	147					
		Total	3349.300					149
Yen Angle	119.77 (±5.26)	2933.787	2	1466.894	27.950	104.694	.000*	
		Sum of Squares Within Groups	147					
		Total	4108.720					149
W Angle	119.77 (±5.26)	1181.407	2	590.704	11.463	103.063	.000*	
		Sum of Squares Within Groups	147					
		Total	2362.813					149
Tau Angle	31.44 (±5.23)	1127.047	2	563.524	12.483	90.288	.000*	
		Sum of Squares Within Groups	147					
		Total	1685.060					149
MK Angle	Total (±SD)	1582.980	2	791.490	56.679	27.929	.000*	
		Mean	3165.960					147
		Sum of Squares Within Groups	8331.880					149
Wits Appraisal	Total (±SD)	127.247	2	63.624	3.397	37.455	.000*	
		Mean	254.493					147
		Sum of Squares Within Groups	499.400					149

The one-way ANOVA analysis revealed highly significant differences across all cephalometric parameters when comparing the three malocclusion groups (Table 4). All measured variables demonstrated statistically significant intergroup variations at the $P < 0.001$ level. The ANB angle emerged as showing the most robust statistical discrimination ($P = 0.000$), closely followed by the Yen angle ($P = 0.000$), W angle ($P = 0.000$), Tau angle ($P = 0.000$), and Beta angle ($P = 0.000$), each exhibiting extremely significant differences between malocclusion classes. While maintaining statistical significance at the $P < 0.001$ level, the MK angle ($P = 0.000$) and Wits appraisal ($P = 0.000$) showed comparatively less pronounced between-group differences than the angular measurements. These results collectively confirm that each cephalometric parameter evaluated in this study serves as a statistically valid discriminator among Class I, II, and III malocclusion groups, though with varying degrees of discriminatory power.

Table 5: Comparison of variable between malocclusions using Post Hoc Bonferroni test

Variable	Class I Vs Class II	Class I Vs Class III	Class II Vs Class III	Standard Error
ANB Angle	.000*	.000*	.000*	29510
Beta Angle	.000*	.000*	.000*	.95466
Yen Angle	.000*	.000*	.000*	1.05736
W Angle	.000*	.000*	.000*	.67714
Tau Angle	.000*	.000*	.000*	.70662
MKG Angle	.007	.000*	.007	1.50571
Wits Appraisal	.000*	.015	.000*	.36863

The post hoc Bonferroni test results demonstrated statistically significant differences in all cephalometric parameters when comparing the three malocclusion groups (Table 5). For the ANB angle, Beta angle, Yen angle, W angle, and Tau angle, extremely significant variations ($p = 0.000^*$) were observed across all pairwise comparisons (Class I vs II, Class I vs III, and Class II vs III). The MKG angle exhibited highly significant differences between Class I and III ($p = 0.000^*$) and Class II and III ($p = 0.007$), with a slightly less pronounced but still significant difference between Class I and II ($p = 0.007$). Similarly, Wits appraisal measurements showed significant distinctions in all group comparisons, with particularly strong significance for Class I vs II and Class II vs III (both $p = 0.000^*$), and a slightly less pronounced but still statistically significant difference between Class I and III ($p = 0.015$). These findings confirm that all evaluated parameters effectively discriminate between different malocclusion classes, though with varying degrees of statistical significance depending on the specific comparison.

Table 6: Correlation of MKG and Tau Angle with other variables in all the 3 Groups

Groups	Variables	Variables	Spearman's Correlation (Rho)	Rank	P Value		
Group I Class I	MKG Angle	ANB Angle	.225		0.059		
		Beta Angle	-.165		0.126		
		Yen Angle	-.534		0.000*		
		W Angle	-.412		0.001*		
		Wits Appraisal	.130		0.184		
		Tau Angle	1.000		0.419		
	Tau Angle	ANB Angle	.227		0.056		
		Beta Angle	-.037		0.040		
		Yen Angle	-.097		0.251		
		W Angle	-.310		0.014		
		Wits Appraisal	-.120		0.204		
		MKG Angle	.030		0.419		
		Group II Class II	MKG Angle	ANB Angle	.142		0.163
				Beta Angle	-.089		0.270
Yen Angle	-.506				0.000*		
W Angle	-.219				0.064		
Wits Appraisal	.350				0.006*		
Tau Angle	.160				0.133		
Tau Angle	ANB Angle		.480		0.000*		
	Beta Angle		-.621		0.000*		
	Yen Angle		-.743		0.000*		
	W Angle		-.890		0.000*		
	Wits Appraisal		.397		0.002*		
	MKG Angle		.160		0.133		
	Group III Class III		MKG Angle	ANB Angle	.141		0.165
				Beta Angle	-.239		0.047
Yen Angle		-.576			0.000*		
W Angle		-.437			0.001*		
Wits Appraisal		-.089			0.270		
Tau Angle		.437			0.000*		
Tau Angle		ANB Angle	.548		0.000*		
		Beta Angle	-.615		0.000*		
		Yen Angle	-.888		0.000*		
		W Angle	-.906		0.000*		
		Wits Appraisal	-.136		0.173		
		MKG Angle	.473		0.000*		

Spearman's correlation analysis revealed distinct patterns of association between the MKG angle, Tau angle, and other cephalometric parameters across malocclusion groups (Table 6). In Class I subjects, the MKG angle demonstrated strong inverse relationships with both the Yen angle ($\rho = -0.534$) and W angle ($\rho = -0.412$), while Tau angle showed only a modest negative correlation with the W angle ($\rho = -0.310$). Class II malocclusions presented more pronounced correlations, particularly for the Tau angle, which showed very strong negative associations with Beta angle ($\rho = -0.621$), Yen angle ($\rho = -0.743$), and W angle ($\rho = -0.890$) and moderate positive correlations with both ANB angle ($\rho = 0.480$) and Wits appraisal ($\rho = 0.397$). The MKG angle in Class II maintained its strong negative correlation with Yen angle ($\rho = -0.506$) while developing a new moderate positive association with Wits appraisal ($\rho = 0.350$). The most robust correlations emerged in Class III malocclusions, where the Tau angle showed extremely strong negative correlations with Beta angle ($\rho = -0.615$), Yen angle ($\rho = -0.888$), and W angle ($\rho = -0.906$) and strong positive relationships with both ANB angle ($\rho = 0.548$) and MKG angle ($\rho = 0.473$). The MKG angle in this group replicated its pattern of strong negative correlations with Yen angle ($\rho = -0.576$) and W angle ($\rho = -0.437$).

Table 7. Predictivity of different variables in patients with Class I, II, III Malocclusion.

Variable		Class I	Class II	Class III
MKG Angle	Sensitivity	76%	85%	87%
Tau Angle	Sensitivity	71%	100%	100%
ANB Angle	Sensitivity	70%	97%	100%
Beta Angle	Sensitivity	100%	100%	100%
Yen Angle	Sensitivity	74%	100%	76%
W Angle	Sensitivity	52%	100%	100%
Wits Angle	Sensitivity	100%	100%	99%

Table 7 showed the sensitivity of various cephalometric variables in predicting different groups of malocclusion. The Beta angle and Wits appraisal demonstrated the highest sensitivity across all classes, showing 100% predictivity in Class I, II, and III malocclusions, with Wits appraisal slightly lower (99%) in Class III. Tau angle also exhibited excellent predictive power, with a sensitivity of 100% in both Class II and III, and 71% in Class I. The MKG angle showed high sensitivity in Class II (85%) and Class III (87%), but was slightly lower in Class I (76%). Similarly, ANB angle demonstrated high sensitivity in Class II (97%) and Class III (100%), but only 70% in Class I. Yen angle was more consistent, with 74% sensitivity in Class I, 100% in Class II, and 76% in Class III. In contrast, W angle had the lowest sensitivity for Class I (52%), although it achieved 100% sensitivity in Class II and III.

Discussion:

The evaluation of sagittal jaw relationships represents a fundamental aspect of orthodontic diagnosis and therapeutic planning. Conventional cephalometric measurements including the ANB angle, WITS appraisal, Beta angle, Yen angle, and W angle have traditionally served as diagnostic tools, yet each possesses distinct methodological constraints. Contemporary innovations such as the MKG and Tau angles were developed to overcome these limitations by offering enhanced reliability and consistency in skeletal assessment. Our investigation examined the diagnostic validity of these angular measurements within the District Solan population, while exploring their relationships with established sagittal parameters across various malocclusion classifications.

These observations are further substantiated by *Taliyakula et al. (2024)[9]*, who confirmed the reliability of newer measurements like Yen and Tau angles across different malocclusion groups in the Konaseema population. Conversely, *Kotula et al. (2023)[10]* cautioned against over-reliance on Tau angle due to its lower repeatability compared to ANB in interobserver assessments.

The descriptive statistics highlight distinct cephalometric patterns among the three malocclusion groups. Class II

malocclusion exhibited the highest ANB angle, indicating a pronounced skeletal discrepancy, while Class III showed a negative ANB angle, reflecting a reverse jaw relationship. Beta, Yen, and W angles were consistently highest in Class III, suggesting a more forward mandibular position, whereas Class II displayed the lowest values, aligning with its retrusive mandibular tendency. The Tau angle was greatest in Class II, reinforcing its skeletal divergence, while the MKG angle followed a similar trend, being highest in Class II and lowest in Class III. Wits appraisal further supported these findings, with Class II presenting the most significant maxillomandibular discrepancy. These baseline measurements confirm established skeletal differences among malocclusion classifications.

These trends are in agreement with *Gupta et al. (2020)⁷*, who emphasized the Tau angle's ability to distinguish among malocclusion types, particularly due to its stability across skeletal patterns. Similarly, *Chachada et al. (2020)⁶* observed comparable MKG angle trends, especially noting its higher values in Class II cases. However, *Jacobson (1975)²* critiqued the reliability of the Wits appraisal due to its susceptibility to changes in the occlusal plane, highlighting the need for caution in its interpretation. This view is echoed by *Kotula et al. (2023)[10]*, who reiterated the challenges with Wits analysis owing to the instability of occlusal references during growth and treatment progression.

The ANOVA results demonstrated statistically significant differences across all cephalometric variables, reinforcing the distinct skeletal characteristics of each malocclusion class. The ANB angle exhibited the most pronounced intergroup variation, validating its diagnostic importance in differentiating skeletal patterns. Similarly, Beta, Yen, W, and Tau angles showed highly significant differences, indicating their reliability in assessing sagittal jaw relationships. The MKG angle and Wits appraisal, though significant, had comparatively lower F-values, suggesting that while they contribute to classification, their discriminatory power may be secondary to other angular measurements.

These findings align with *Baik & Ververidou (2004)³*, who confirmed the Beta angle's robustness in evaluating sagittal discrepancies. Furthermore, *Kaushik et al. (2023)¹¹* demonstrated the Tau angle's high discriminatory power, particularly in Class II malocclusions. On the other hand, the W angle's dependency on unstable landmarks, such as the S-point, has been criticized by *Bhad et al. (2013)[5]*, who noted its potential for reduced reproducibility in clinical practice. Additionally, the 2022 systematic review by *Kotula et al. [12]* raised concerns over landmark instability for W and Beta angles due to growth-related positional changes, particularly when used in adolescents.

The Bonferroni test revealed significant differences in nearly all pairwise comparisons, further validating the distinctiveness of each malocclusion group. ANB, Beta, Yen, W, and Tau angles showed highly significant differences across all groups, emphasizing their diagnostic utility. The MKG angle displayed significant but less extreme differences, particularly between Class I and II, suggesting some overlap in these groups. Wits appraisal was significant in all comparisons, though the difference between Class I and III was less pronounced than in other contrasts.

This outcome is consistent with *Gupta et al. (2020)*[7], who identified Tau angle cutoff ranges with high sensitivity, underscoring its clinical usefulness. Additionally, *Neela et al. (2009)*[4] emphasized the reliability of the Yen angle in differentiating skeletal classes. However, *Chachada et al. (2020)*⁶ highlighted MKG angle's limited sensitivity in Class I cases (74%), questioning its ability to consistently distinguish this group from others. *Taliyakula et al. (2024)*[9] similarly reported MKG's diagnostic limitation in borderline cases, further supporting this criticism.

The correlation analysis revealed varying associations between MKG/Tau angles and other cephalometric measurements across malocclusion groups. In Class I, the MKG angle correlated strongly with Yen and W angles, whereas the Tau angle showed weaker associations. In Class II, Tau angle demonstrated particularly strong negative correlations with Beta, Yen, and W angles, suggesting a key role in assessing skeletal discrepancies. Class III exhibited the strongest correlations overall, with Tau angle showing near-perfect negative associations with Yen and W angles.

*Gupta et al. (2020)*⁷ attributed Tau angle's consistent correlations to its stability during jaw rotations, enhancing its diagnostic value across varying skeletal patterns. Additionally, *Baik & Ververidou (2004)*[3] supported the strong inverse relationship between Beta and Tau angles in Class III cases. In contrast, *Kaushik et al. (2023)*[11] noted MKG angle's weaker correlations in Class I subjects, suggesting its diagnostic limitations in borderline skeletal profiles. This limitation is supported by recent findings from *Kotula et al. (2023)*[10], who reported significant observer variability in locating the T and G points required for accurate Tau angle measurement.

The sensitivity analysis demonstrated that Beta angle and Wits appraisal were the most consistent predictors across all malocclusion types, achieving near-perfect sensitivity. Tau and ANB angles also performed exceptionally well, particularly in Class II and III malocclusions. MKG and Yen angles showed high but slightly variable sensitivity, while the W angle had the lowest predictive power in Class I.

These results reinforce the findings of *Baik & Ververidou (2004)*[3], who confirmed Beta angle's 100% sensitivity in Class II and III diagnoses. *Gupta et al. (2020)*[7] similarly reported high specificity (94–100%) for Tau angle, highlighting its potential as a reliable diagnostic tool. However, the limited performance of W angle—especially its low sensitivity in Class I (52%)—mirrors the concerns raised by *Bhad et al. (2013)*[5] regarding landmark inconsistency and reduced accuracy. *Kotula et al. (2023)*[10] added that Tau angle's measurement error was three times higher than ANB, and its ICC was 3.5 times lower, indicating significantly less reliability in routine practice.

Conclusion:

The findings of this study strongly support the diagnostic reliability of the MKG and Tau angles as valuable tools for assessing sagittal jaw relationships, particularly in comparison to conventional cephalometric parameters such as the ANB angle, Wits appraisal, Beta angle, Yen angle, and W angle. The results demonstrate that

1. The Tau angle exhibits superior sensitivity (100%) in Class II and III malocclusions, outperforming traditional measurements like the ANB angle in certain cases. Its strong negative correlations with Yen and W angles further validate its consistency in evaluating skeletal discrepancies.
2. The MKG angle shows promising diagnostic potential, particularly in Class II and III malocclusions, with high sensitivity (85% and 87%, respectively). While it is less predictable in Class I cases, its integration with other measurements enhances overall diagnostic accuracy.
3. Both MKG and Tau angles provide distinct advantages over conventional methods, as they rely on more stable skeletal landmarks, reducing susceptibility to cranial base variations and occlusal plane changes—common limitations of ANB and Wits appraisal.
4. A combined approach using MKG, Tau, and traditional angles (ANB, Beta) is recommended for a comprehensive assessment of sagittal jaw relationships. This multi-parametric strategy minimizes diagnostic errors and improves treatment planning precision.
5. Future studies should explore larger, diverse populations and 3D cephalometric applications to further validate these findings and refine landmark identification techniques.

To summarize, this study highlights the clinical significance of MKG and Tau angles as reliable alternatives to conventional cephalometric analyses. Their incorporation into orthodontic practice can enhance diagnostic consistency, particularly in complex malocclusion cases, paving the way for more accurate and individualized treatment strategies.

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