



Assessment of Sagittal Jaw Dysplasia Using Correlation of Tau Angle with ANB, W, Yen Angles and Wits Appraisal - A Cephalometric Study.

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KEYWORDS

Tau angle, cephalometry, sagittal dysplasia.

ABSTRACT:

Introduction: Orthodontic discrepancies are classified into transverse, sagittal, and vertical planes, with sagittal issues being most common. Cephalometric analysis aids in diagnosing these, with the ANB angle, introduced in 1953, being widely used despite being affected by age, jaw rotation, and cranial positioning. Alternatives like the Wits appraisal, Beta, Yen, and W angles have been introduced to overcome specific limitations. The Tau angle, relying on stable craniofacial landmarks, is a newer metric resistant to growth-related changes.

Objectives: The objective of this study was to correlate Tau angle values with ANB, W, Yen angles and Wits appraisal in assessing sagittal dysplasia.

Methods: An analytical cross-sectional study was conducted at Rural Dental College, PIMS, Loni. 106 pre-treatment lateral cephalograms were categorized into Class I, II, and III malocclusions using ANB and Wits. In this study, Pearson's correlation coefficient (r) is employed to assess the strength and direction of linear relationships between variables. Cephalograms were traced manually with cephalograms taken with the Frankfort plane parallel to the floor.

Results: In Class I, Tau angle showed moderate positive correlation with ANB and moderate negative correlation with W angle; weak but significant correlation with Yen; negligible with Wits. In Class II, Tau correlated moderately with ANB, negatively with Yen and W; correlation with Wits was weak. In Class III, correlations with all parameters were insignificant.

Conclusion:

1. Tau angle shows moderate correlation with ANB, inverse with Yen and W, and no significant relation with Wits.



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- 2. Tau angle ranges: Class I (28° – 33°), Class II ($>33^{\circ}$), Class III ($<28^{\circ}$).
 3. Tau angle is a promising tool for sagittal assessment due to its stability.
 4. Further studies are needed to confirm its universal applicability.
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Introduction:

In orthodontics, discrepancies are described across three planes: transverse, sagittal, and vertical. Sagittal inconsistencies are most frequently observed. Cephalometric analysis is essential for describing and assessing orthodontic and orthopedic issues, including the sagittal denture base relationship.

The ANB angle, introduced in 1953, is widely used for assessing sagittal skeletal disparity but is influenced by factors such as age, rotation of the SN plane, and variations in vertical facial height.^{1,2} This has led to inaccuracies, prompting the development of alternative measurements. The Wits assessment reduces the impact of anatomical variations at nasion by tracing perpendiculars from points A and B to the occlusal plane.^{3,4}

In 2004, Baik and Ververidou proposed the Beta (β) angle, which uses fixed cranial points (A, B, and C) and remains unaffected by mandibular relation or dental landmarks. However, the visibility of point C can pose challenges.⁵ The Yen angle, introduced in 2009, evaluates sagittal relationships without relying on the functional occlusal plane or points A and B, making it suitable for mixed dentition.⁶

The W angle accounts for growth rotations and uses stable landmarks (points M and G) but may be affected by developmental changes.⁷ The Tau angle, defined by Gupta et al., provides stability across growth phases, jaw rotations, and dental movements by relying on fixed craniofacial landmarks.⁸

This study aims to assess the reliability and mean values of Tau, Yen, and W angles in the Central Indian population, comparing them with ANB angle and Wits appraisal across different skeletal patterns. The Tau angle offers potential as a unique sagittal metric,

ensuring consistent assessment unaffected by growth or anatomical changes.

Methods:

This cross-sectional analytical study was conducted in the Department of Orthodontics and Dentofacial Orthopedics, Rural Dental College (PIMS, Loni) over two years. The aim was to assess sagittal jaw dysplasia by correlating the Tau angle with ANB, W, YEN angles, and Wits appraisal. Ethical clearance was obtained before starting the study.

Study Design and Methodology: The study involved 106 pre-treatment lateral cephalograms of individuals aged 13-30 years with skeletal Class I, II, or III malocclusions. Participants were selected based on inclusion criteria, such as permanent dentition, absence of craniofacial anomalies or systemic diseases. Patients from archives of the department and high-quality cephalograms. Patients with prior orthodontic treatments, edentulous spaces, or oral trauma were excluded.

Grouping and Sample Size: Patients were grouped into three categories based on skeletal malocclusions using the ANB angle and Wits appraisal:

- Class I (36 patients): ANB angle 1° – 4° , Wits values aligned or slightly shifted.
- Class II (65 patients): ANB angle $>4^{\circ}$, Wits with AO ahead of BO (positive).
- Class III (11 patients): ANB angle $<1^{\circ}$, Wits with BO ahead of AO (negative).

Cephalometric Analysis: Lateral cephalograms were obtained with the Frankfort horizontal plane parallel to the floor and analyzed manually using tracing tools. Nine landmarks and five parameters were studied, including ANB, Wits, YEN, W, and Tau angles. Measurements were made using acetate tracing paper, a protractor, and a millimeter ruler. (Figure no.1)



Figure no. 1: Armamentarium used for the study.

Variables Studied: Key variables included angles ANB, Wits, YEN, W, and Tau, calculated based on craniofacial landmarks (e.g., Points A, B, S, M, G, and T). The Tau

angle was highlighted for its stability across growth phases, jaw rotations, and dental movements. (Figure no. 2)

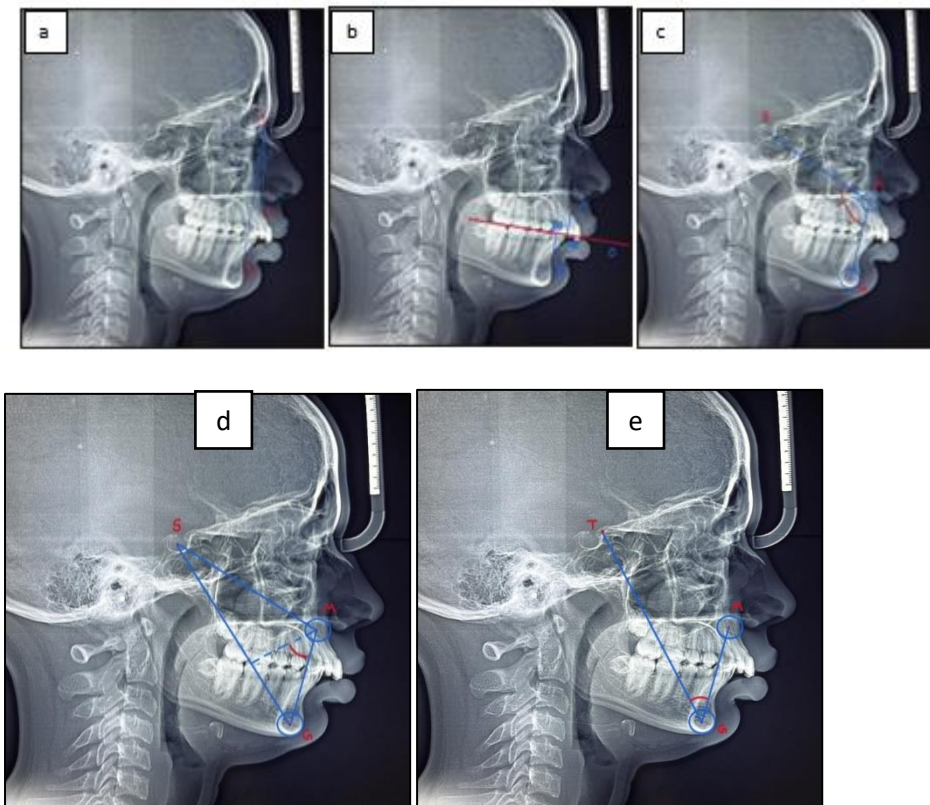


Figure no. 2: Various angles measured on lateral cephalograms. a) ANB angle. b) Wits Appraisal. c) YEN angle. d) W angle. e) Tau angle.

Statistical Analysis:



The data was entered in Microsoft Excel and analyzed using IBM SPSS version 21. For continuous data, Mean and Standard Deviation were calculated, while Frequency and Percentage were used for categorical data. Pearson's correlation was applied to determine the relationship between Tau and other angles (ANB, Wits, Yen, W) in Class I, II, and III malocclusions, with a confidence interval of 95% and statistical significance at $p < 0.05$.

Pearson's correlation coefficient (r) was utilized to assess the strength and direction of the linear relationship between variables, focusing on whether Tau Angle increases or decreases in correlation with the other cephalometric angles.

Results:

The study analyzed the mean age and angular measurements among participants with Class I, II, and III malocclusion. The ages averaged 18.7 ± 2.57 , 18.5 ± 2.76 , and 18.6 ± 2.38 years in Groups I, II, and III, respectively. Key angular measurements showed variations across classes: ANB angle ranged from 2.91 (Class I) to -0.72 (Class III), YEN angle spanned from 115.51 (Class II) to 126.54 (Class III), and Tau angle ranged from 31.14 (Class I) to 26.27 (Class III). Tau angle exhibited significant correlations with other variables, such as ANB angle and W angle, indicating its utility in assessing skeletal discrepancies and facial proportions. (TABLE 1-4)

	MALOCCLUSION	N	Minimum	Maximum	Mean	SD
ANB ANGLE	CLASS I	35	1	4	2.914	0.981
	CLASS II	60	5	8	5.833	0.886
	CLASS III	11	-3	0	-0.727	1.009
WITS APPRAISAL	CLASS I	35	-1	3	1	1.111
	CLASS II	60	2	7	4.333	1.115
	CLASS III	11	-5	0	-1.818	1.401
YEN ANGLE	CLASS I	35	116	127	120.629	2.045
	CLASS II	60	110	130	115.517	3.357
	CLASS III	11	122	135	126.545	3.908
W ANGLE	CLASS I	35	50	60	53.057	1.846
	CLASS II	60	46	58	50.517	2.228
	CLASS III	11	55	61	57.818	1.834
TAU ANGLE	CLASS I	35	28	34	31.143	1.648
	CLASS II	60	32	38	34.917	1.533
	CLASS III	11	25	28	26.273	1.104

Table 1: Mean Distribution of the ANB Angle, Wits Appraisal, YEN Angle, W Angle and Tau Angle between Class I, II and Class III Malocclusion

The study highlights the mean distribution of various angles across Class I, II, and III malocclusions:

- **ANB Angle:** Class I (2.91 ± 0.98), Class II (5.83 ± 0.88), Class III (-0.72 ± 1.00).
- **Wits Appraisal:** Class I (1 ± 1.11), Class II (4.33 ± 1.115), Class III (-1.818 ± 1.401).
- **YEN Angle:** Class I (120.62 ± 2.04), Class II (115.51 ± 3.35), Class III (126.54 ± 3.90).



- **W Angle:** Class I (53.05 ± 1.84), Class II (50.51 ± 2.22), Class III (57.818 ± 1.834).
- **Tau Angle:** Class I (31.14 ± 1.64), Class II (34.91 ± 1.533), Class III (26.27 ± 1.10).

Correlation Matrix						
		TAU ANGLE CLASS I	ANB ANGLE CLASS I	WITS APPRAISAL CLASS I	YEN ANGLE CLASS I	W ANGLE CLASS I
TAU ANGLE CLASS I	Pearson's r	—				
	df	—				
	p-value	—				
ANB ANGLE CLASS I	Pearson's r	0.554***	—			
	df	33	—			
	p-value	<.001	—			
WITS APPRAISAL CLASS I	Pearson's r	-0.080	0.458**	—		
	df	33	33	—		
	p-value	0.647	0.006	—		
YEN ANGLE CLASS I	Pearson's r	-0.385*	-0.207	0.065	—	
	df	33	33	33	—	
	p-value	0.022	0.233	0.712	—	
W ANGLE CLASS I	Pearson's r	-0.583***	-0.549***	-0.057	0.426*	—
	df	33	33	33	33	—
	p-value	<.001	<.001	0.744	0.011	—

Note. * $p < .05$, ** $p < .01$, *** $p < .001$

Table 2: Correlation between Tau Angle and ANB, Wits Appraisal, YEN Angle and W Angle in Class I Malocclusion

Correlation Matrix						
		TAU CLASS II	ANB CLASS II	WITS APPRAISAL CLASS II	YEN CLASS II	W CLASS II
TAU CLASS II	Pearson's r	—				
	df	—				
	p-value	—				
ANB CLASS II	Pearson's r	0.439***	—			
	df	58	—			



	p-value	< .001	—			
WITS APPRAISAL CLASS II	Pearson's r	0.066	0.606***	—		
	df	58	58	—		
	p-value	0.616	< .001	—		
YEN CLASS II	Pearson's r	-0.443***	-0.369**	-0.160	—	
	df	58	58	58	—	
	p-value	< .001	0.004	0.222	—	
W CLASS II	Pearson's r	-0.404**	-0.359**	-0.166	0.729***	—
	df	58	58	58	58	—
	p-value	0.001	0.005	0.205	< .001	—

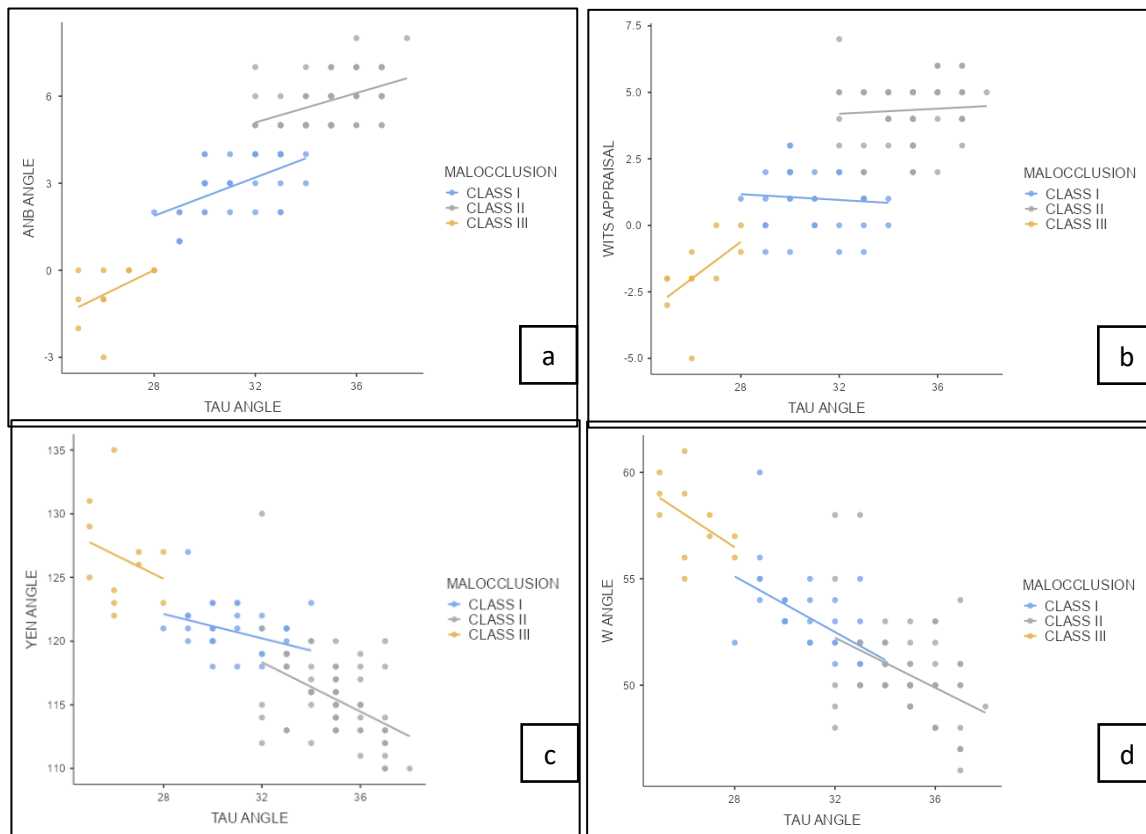
Note. * $p < .05$, ** $p < .01$, *** $p < .001$

Table 3: Correlation between Tau Angle and ANB, Wits Appraisal, YEN Angle and W Angle in Class II Malocclusion

Correlation Matrix						
		TAU CLASS III	ANB CLASS III	WITS CLASS III	YEN CLASS III	W CLASS III
TAU CLASS III	Pearson's r	—				
	df	—				
	p-value	—				
ANB CLASS III	Pearson's r	0.465	—			
	df	9	—			
	p-value	0.149	—			
WITS CLASS III	Pearson's r	0.547	0.810**	—		
	df	9	9	—		
	p-value	0.082	0.003	—		
YEN CLASS III	Pearson's r	-0.270	-0.549	-0.623*	—	
	df	9	9	9	—	
	p-value	0.422	0.080	0.041	—	
W CLASS III	Pearson's r	-0.467	-0.619*	-0.725*	0.713*	—
	df	9	9	9	9	—
	p-value	0.148	0.042	0.012	0.014	—

Note. * $p < .05$, ** $p < .01$, *** $p < .001$

Table 4: Correlation between Tau Angle and ANB, Wits Appraisal, YEN Angle and W Angle in Class III Malocclusion



Graph 1: Scatter plot for overall correlation between the Tau angle and other angles for different malocclusions. a) Correlation between Tau and ANB angle. b) Correlation between Tau and Wits Appraisal. c) Correlation between Tau and YEN angle. d) Correlation between Tau and W angle

Discussion:

Class II malocclusion is prevalent among Indian populations, with rates ranging from 10% to 25%.^{9,10} Factors such as geography, ethnicity, age, and diagnostic criteria impact these variations. Diagnostic methods include clinical examinations, cephalometric analysis, and advanced tools like CBCT for detailed 3D evaluations. While cephalometric analysis remains widely used, advancements like CBCT provide better accuracy in assessing sagittal discrepancies.

Pioneers like Broadbent¹¹ laid the foundation for cephalometric evaluations. Techniques like ANB angle, Wits appraisal, Beta angle, and Tau angle are used to measure sagittal jaw relationships, but each has limitations. For instance, the ANB angle is simple but influenced by growth factors. The Wits evaluation addresses some issues but is reliant on the occlusal plane, which changes with treatment. The Beta angle eliminates

reliance on the occlusal plane but requires precise landmark identification.

More recently, the Tau angle, which uses stable landmarks like T, G, and M points, is gaining attention for accurately diagnosing sagittal jaw relationships. Unlike traditional methods, the Tau angle is unaffected by jaw rotation, making it reliable for assessing malocclusions.⁸ Studies on the Central Indian population confirmed its efficacy, showing consistent results across Class I, II, and III malocclusions.¹²

The YEN and W angles are also evaluated, with results aligning with prior studies.^{6,7} Both parameters provide additional insight into sagittal discrepancies. Overall, precise diagnostic tools like the Tau angle are essential for treatment planning, ensuring effective outcomes through orthodontic, surgical, or growth-modification interventions. Future studies are needed to validate these methods across diverse populations.



In Class I malocclusion, Tau angle shows a positive correlation with the ANB angle ($r = 0.554$, $p < 0.001$) but demonstrates negative correlations with the YEN angle ($r = -0.385$, $p = 0.022$) and the W angle ($r = -0.583$, $p < 0.001$) which is opposite of what is given by **Kaushik et al.**¹² A weak negative correlation exists with Wits appraisal ($r = -0.080$, $p = 0.647$) which is in accordance with **Kaushik et al.** These findings suggest that Tau angle is significantly associated with ANB, YEN, and W angles, making it useful for sagittal jaw assessment, though its link to Wits appraisal is limited. (Graph 1)

The YEN angle shows no significant correlation with the ANB angle ($r = -0.207$, $p = 0.233$) or Wits appraisal ($r = 0.065$, $p = 0.712$). However, it has a moderate positive correlation with the W angle ($r = 0.426$, $p = 0.011$). This relationship indicates that as YEN increases, W also rises, aligning with previous research. This is in accordance with study by **Kapadia et al.**¹³, **Mittal et al.**¹⁴

For the W angle, a moderate negative correlation with ANB angle ($r = -0.549$, $p < 0.001$) is observed, indicating that W decreases as ANB increases. Additionally, a moderate positive correlation exists with Wits appraisal ($r = 0.426$, $p = 0.011$), while ANB and Wits appraisal are positively linked ($r = 0.458$, $p = 0.006$).

In Class II malocclusion, a moderate positive correlation was observed between the Tau angle and the ANB angle ($r = 0.439$, $p < 0.001$), suggesting interdependency. However, no significant correlation exists between the Tau angle and Wits appraisal ($r = 0.066$, $p = 0.616$). The Tau angle negatively correlates with the YEN angle ($r = -0.443$, $p < 0.001$) and W angle ($r = -0.404$, $p = 0.001$), indicating an inverse relationship. (Graph 1)

The YEN angle shows a moderate negative correlation with the ANB angle ($r = -0.369$, $p = 0.004$), highlighting an inverse relationship, while no significant correlation was found between YEN and Wits appraisal ($r = -0.160$, $p = 0.222$). A strong positive correlation exists between the YEN and W angles ($r = 0.729$, $p < 0.001$), emphasizing a significant link. **Trivedi et al.**¹⁵ and **Maharjan et al.**¹⁶ found a significant positive correlation between YEN and W angles in Class II malocclusion.

Similarly, the W angle does not significantly correlate with Wits appraisal ($r = -0.166$, $p = 0.205$), but

demonstrates a moderate negative correlation with the ANB angle ($r = -0.359$, $p = 0.005$). A strong positive correlation exists between ANB angle and Wits appraisal ($r = 0.606$, $p < 0.001$). **Kaushik et al.**¹² reported no significant association of Tau angle with ANB, YEN, W angles, and Wits appraisal in Class I and II malocclusion which differs from the current study.

In Class III malocclusion, the Tau angle showed a moderate positive but statistically insignificant correlation with ANB angle ($r = 0.465$, $p = 0.149$) and Wits appraisal ($r = 0.547$, $p = 0.082$). A weak negative correlation was found with the YEN angle ($r = -0.270$, $p = 0.748$) and the W angle ($r = -0.467$, $p = 0.148$). While previous studies suggested stronger correlations, our findings lacked statistical significance. (Graph 1)

The YEN angle exhibited a moderate negative correlation with ANB ($r = -0.549$, $p = 0.080$) and a significant negative correlation with Wits appraisal ($r = -0.623$, $p = 0.041$). A strong positive correlation was noted with the W angle ($r = 0.713$, $p = 0.014$), indicating alignment in describing skeletal Class III patterns. **Kumari et al.**¹⁷ found a strong positive correlation between YEN and W angles across different malocclusions.

For the W angle, a moderate negative correlation with ANB angle ($r = -0.619$, $p = 0.042$) and a strong negative correlation with Wits appraisal ($r = -0.725$, $p = 0.012$) were observed, both statistically significant. Additionally, ANB and Wits showed a strong positive correlation ($r = 0.810$, $p = 0.003$), consistent with prior studies.

Ahmed et al.¹⁸ reported a strong negative correlation between ANB and W angles, aligning with the current findings. **Mittal et al.**¹⁴ found strong correlations in Class II and Class III malocclusions, including negative associations between ANB and YEN angles.

These findings reveal complex interrelations among these parameters, aiding in accurate diagnosis and treatment planning. However, Wits appraisal remains less strongly associated with Tau and YEN angles.

Conclusion:

Based on the results of the present study, it was concluded that: -



- 1) There is a moderate positive correlation with the ANB angle, a moderate negative correlation with the YEN and W angles and no significant correlation with Wits appraisal.
- 2) For Tau angle, we reported that the mean value for Class I was 31.143 ± 1.648 for Class II was 34.917 ± 1.533 and for Class III was 26.27 ± 1.10 . To conclude,
 - a) The Skeletal **Class I** cases, would have a Tau angle between **28 to 33** degrees
 - b) The Skeletal **Class II** cases would have a Tau angle greater than **33** degrees
 - c) The Skeletal **Class III** cases would possess Tau angle values lesser than **28** degrees.
- 3) The Tau angle offers a promising approach to evaluating sagittal discrepancies, as it is independent of unstable cranial landmarks and occlusal plane instability. Therefore, Tau angle would be one of the novel parameters for assessing the sagittal skeletal relationship.
- 4) However, further research is necessary across different populations to validate its universal applicability and reliability.
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