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Validity of Pi Angle in Comparison with Various Sagittal Discrepancy Indicators and its Correlation with Size and Position of the Mandible: A Cephalometric Study

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Abstract

Aim: To validate Pi angle with other sagittal discrepancy indicators like Beta angle, Yen angle and W angle in skeletal Class I, II and III patients, to correlate the Pi angle with the size and position of the mandible, and to evaluate the reliability of Dolphin imaging software.
Methods: One hundred fifty subjects were nominated based on the inclusion criteria and their lateral cephalograms were traced based on their ANB angle, they were placed into skeletal Class I, II and III groups. A-P discrepancy indicators and parameters of the size and position of the mandible were traced manually and digitally.
Results: Pi angle had 85% and 100% accuracy in identifying skeletal Class II and III groups, respectively. Parameters of the morphology of the mandible were found to have statistically significant correlation with Pi angle e.g., mandibular base length (-0.265), SNB (-0.408), articular angle (0.277), facial angle (-0.800), and Y axis (0.728), etc. When data was compared between manual and digital tracing, there was no difference in the mean values of Pi angle (P=0.87), Beta angle (P=0.73), and Yen angle (P=0.64) between the two techniques, suggesting good accuracy of Dolphin imaging software.
Conclusion: The Pi angle could accurately differentiate the sample into skeletal Class I, II and III groups. A statistically significant correlation was determined between Pi angle and most of the parameters of the size and position of the mandible. It was found that the imaging software Dolphin 3D is dependable to the analysis of cephalometric variables, which are not available in the software.

Keywords: Pi Angle, Sagittal Discrepancy Indicators, Cephalometry, Dolphin 3D Imaging Software, Orthodontics

Background

Facial harmony is determined by the skeleton and its overlying soft tissue (1). As the soft tissue facial drape of an individual is affected by the maxillo-mandibular discrepancy, assessment of the underlying anteroposterior jaw discrepancy together with soft tissue analysis has a vital part in orthodontics to diagnosis and design treatments (2).

Sagittal intermaxillary relationship is affected by the relative position of the mandible with the cranium and maxilla and is influenced by the variation in the degree of mandibular rotation that could be assessed by evaluating the underlying sagittal discrepancy (3). To measure this, SNA and SNB and their difference, ANB were utilized to explain the apical base connection. This was followed by the 'Beta angle' (4), which also uses points A and B, but it was developed to establish a true apical base connection autonomous of the cranial reference planes or dental occlusion. However, landmarks such as nasion, point A, point B, etc. which depict the cranium, maxilla, and mandible, respectively, changes over time due to growth. This issue of skeletal landmarks susceptible to change with growth was dealt with using the concept of centroid. The centroid is subject to the least variation about anatomical points as it has the properties of a mathematical 'mean'. Two such centroid points are points G and M, which represent the center of internal symphysis of the mandible and the center of the maxilla, respectively (5).

Recent introductions to sagittal discrepancy indicators, which utilize the points G and M, are Yen angle and W angle. Yen angle (6) was fabricated to eradicate the inconvenience in pinpointing points A and B, or the functional occlusal plane employed in Wit's appraisal, or the condyle axis employed in Beta angle. Nevertheless, in various circumstances, rotations of the jaws can conceal true sagittal dysplasia. W angle (7,8) exhibits actual sagittal dysplasia and is not impacted by growth rotations because this measurement is not contingent on variable landmarks or the functional occlusal plane. However, it employs skeletal landmarks that could be susceptible to changes with growth to some extent. Considering the shortcomings of the previously discussed parameters, Pi angle (9) was introduced, which uses point G and point M as landmarks and a true horizontal line as the reference plane, to prevail over inconsistencies due to mistakes in denoting the cranial reference planes or dental occlusion and to eliminate the reference planes that would be susceptible to growth, respectively.

Parameters such as mandibular base length, length of ascending ramus, etc. indicate size of the mandible while SNB, facial angle, angle of convexity etc. indicate position of the mandible and they play a role in the etiology of sagittal discrepancy. Various authors have studied the relationship of ANB with the parameters of size and position of the mandible in different skeletal pattern groups (6,7). However, there is a lack of literature that have established norms for parameters of the size and position of the mandible with other sagittal discrepancy indicators.

Dolphin imaging software version 11.95 (Dolphin Imaging, CA, USA) is a powerful tool for cephalometric analysis, which is the study of the proportions and relationships of the craniofacial structures. It allows users to import digital images from various sources, such as X-rays, photographs, or 3D scans, and perform cephalometric measurements and calculations on them. Users can also create customized templates, landmarks, and analyses to suit their specific needs and preferences. It also provides features such as superimposition, tracing, simulation, and report generation, which help users visualize and communicate their findings and recommendations. However, to carry out analysis of newer cephalometric variables that are not included in the software, they must be customized within the software (10,11,12,13).

Therefore, the present study aimed to evaluate the validity of the Pi angle in comparison with the three sagittal discrepancy indicators (Beta angle, Yen angle, W angle) in skeletal Class I, Class II, and Class III patients, to establish norms for parameters of size and position of the mandible according to the Pi angle in the three skeletal pattern groups, and to demonstrate the reliability of the customization tool within the Dolphin 3D imaging software (version 11.95) in carrying out newer cephalometric analysis.

Methods

Setting and participants

Pretreatment lateral cephalograms of 600 subjects who reported to the Department of Orthodontics and Dentofacial Orthopaedics at AMC Dental College, Ahmedabad, India between 2016 to 2022 were screened. A random sampling method was used, and the cases were shortlisted based on inclusion and exclusion criteria in the skeletal Class I, II, and III groups.

Study design

- The subjects were scrutinized according to the following inclusion criteria:
- Individuals with a complete set of permanent dentitions, excluding the third molar, and aged no older than 25 years.
- Lateral cephalograms were taken in the KODAK 8000C cephalometry system (Eastman Kodak, NY, USA) in the Department of Oral Medicine and Radiology at the Institution.
- No craniofacial malformations or facial disfigurement.

Out of the 600 subjects, those subjects with mixed dentition, congenital defects, and any marked facial deformity were excluded. One hundred fifty subjects with the inclusion criteria were selected and their lateral cephalograms were taken for the study. The lateral cephalograms were traced by one examiner, both manually and digitally. Based on the ANB angle, 50, 53, and 47 subjects were delegated to skeletal Class I, II, and III groups, respectively.

- Skeletal Class I: ANB between 1°-4°
- Skeletal Class II: ANB >4°
- Skeletal Class III: ANB <1°

Lateral cephalograms of 15 subjects were randomly selected and retraced by the same examiner after 10 days to rule out tracing and measurement error.

Cephalometric analyses were done both manually and digitally. The parameters included in the study were measured separately with each method and tabulated. For digital tracing, a soft copy of each lateral cephalogram was captured in the Dolphin 3D imaging software version 11.95 (Dolphin Imaging, CA, USA) under the name of the individual subjects. The lateral cephalograms were then traced using the 'digitize' option in the software. Once all the required cephalometric landmarks were registered in the software, the measurements of the parameters of size and position of the mandible were obtained and tabulated (Fig. 2). In the Dolphin 3D imaging software version 11.95 (Dolphin Imaging, CA, USA), Pi angle, Beta angle, W angle, and Yen angle are not included in the list of built-in analysis as these are relatively new cephalometric variables, hence, these angles were drawn in the software using the customization option present in the 'annotations' section of the software. Once these angles were drawn in the software individually for each lateral cephalogram, they were measured one by one for each subject (Fig. 1)

Approval for the study was obtained from the institutional review board and the study was cleared by the ethical committee (AMC/IRB/ORTHO/PG48/21) at AMC Dental College, Ahmedabad, India.

Measurements and data collections

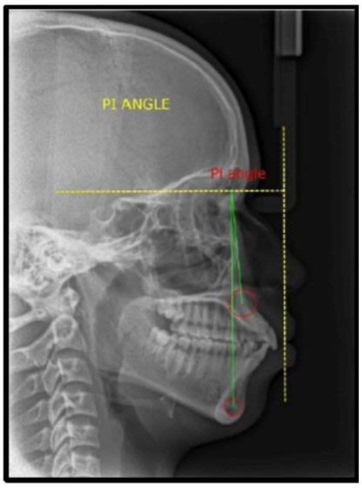
The data were collected and tabulated in Microsoft Excel spreadsheets, and statistically analyzed using Statistical Package for Social Sciences (SPSS version 20.0, IBM Corporation, USA). Statistical significance was assessed for $P<0.05$.

Sample size

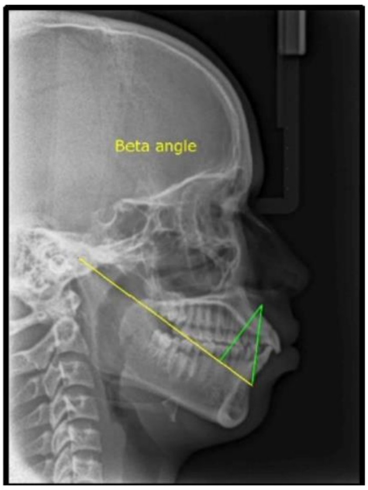
The formula used for the determination of sample size was

n=2×sigma2 × (Z1-α/2+ Z1-β/2)2/(m1-m2)2

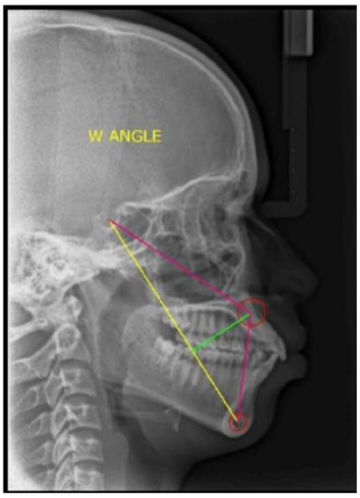
The confidence interval was 95%.



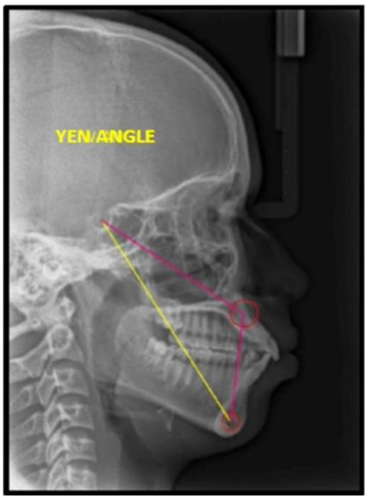
a. Pi angle.



b. Beta angle.



c. W angle.



d. Yen angle.

Figure1. Cephalometric analysis by manual tracing

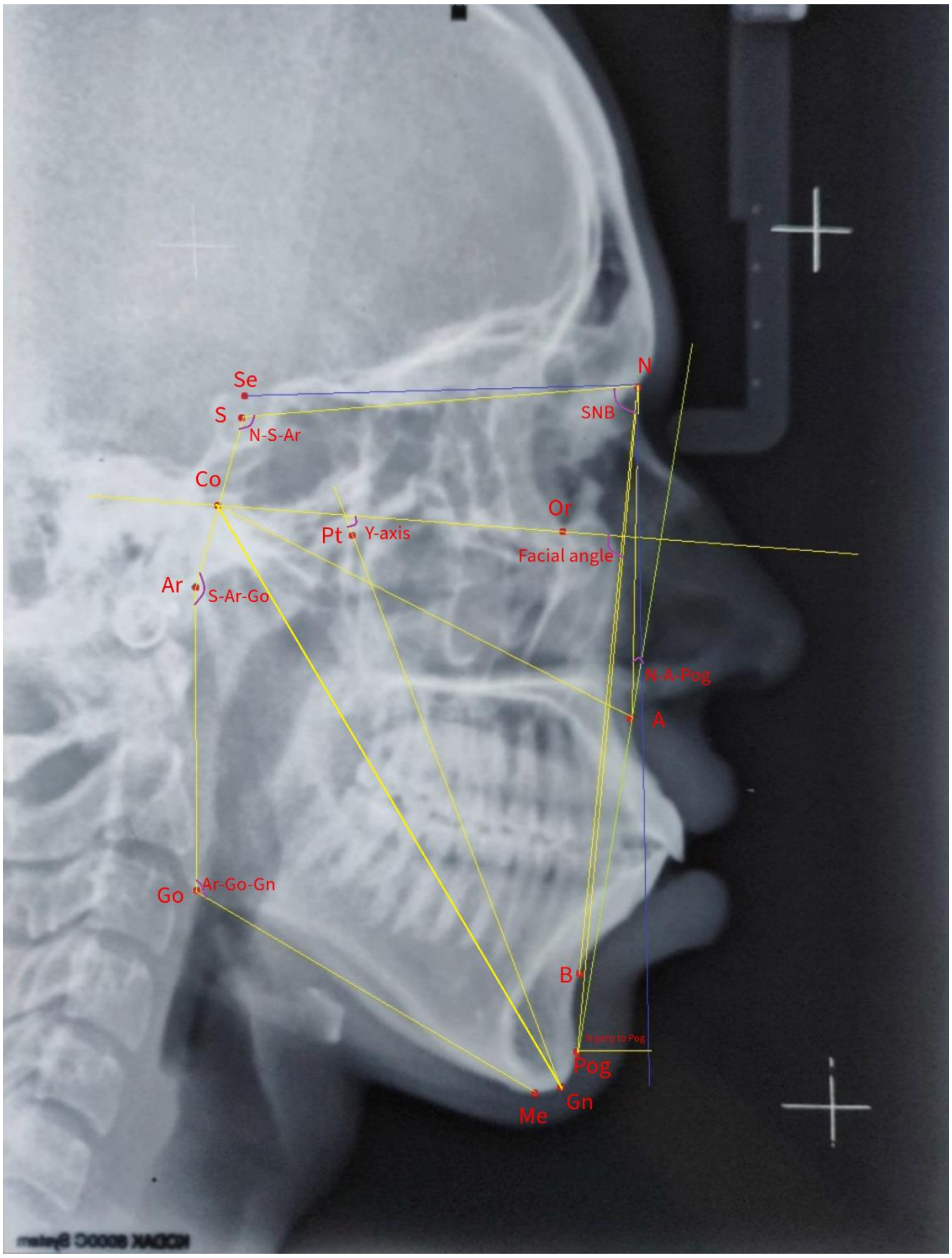


Figure 2. Capturing of digital copy of lateral cephalogram in the software

Statistical analysis

Statistical analyses were carried out to interpret the results. One-way Analysis of Variance (ANOVA) test was done to obtain mean and standard deviation values of sagittal discrepancy indicators for the three skeletal pattern groups and to determine whether these values were statistically significant. Tukey HSD post hoc test was performed to test whether the mean values of anteroposterior (A-P) discrepancy indicators in each skeletal pattern group were significantly different from one another. A Chi-square test was done to assess the accuracy with which the A-P indicators could discriminate between Class I, Class II, and Class III skeletal pattern groups from each other. Pearson's correlation analysis was performed to check whether there was any significant correlation among the four sagittal discrepancy indicators. Regression analysis was done to predict the values of the parameters of the size and position of the mandible from the values of Pi angle. Unpaired t-test was performed to determine the reliability of the software to check if any statistically significant difference existed between the mean values of sagittal discrepancy indicators obtained by manual tracing and by Dolphin 3D imaging software.

Results

In the current study, the mean value of Pi angle in the Class I skeletal pattern group is 4.52° (±3.39°), in the Class II skeletal pattern group it is 9.92° (±3.89°), and in the Class III skeletal pattern group it is -2.78° (±2.86°) (Table 2).

The mean values for Beta angle are 29.97° (±3.66°), 23.81° (±4.29°), and 38.95° (±4.24°) in the Class I, Class II, and Class III skeletal pattern groups, respectively (Table 2).

The mean values for W angle for the Class I, II, and III skeletal pattern group are 53.75° (±3.85°), 49.95° (±3.55°), and 59.71° (±2.84°), respectively (Table 2).

The mean value for Yen angle in the Class I skeletal pattern group is 121.21° (±4.70°), in the Class II skeletal pattern group it is 115.19° (±4.89°), and in the Class III skeletal pattern group it is 129.07° (±5.10°) (Table 2).

Pi angle, Beta angle, Yen angle, and W angle could differentiate between different skeletal patterns in the following order: Class III > Class I > Class II. The statistically significant highest mean difference among the skeletal Class I, Class II, and Class III groups are depicted by Beta angle, signifying it is a very good determinant to distinguish between the three groups among the four angular measurements (Table 3).

Table 1. Parameters of size and position of mandible

Parameters	Description
Size of mandible	
Mandibular base length	The distance between Gonion and Gnathion
Length of ascending ramus	The distance between Articulare and Gonion
Effective mandibular length	The distance between Condylion and Gnathion.
Position of mandible	
SNB	It depicts the relative position of mandible about cranium
Saddle angle	A large angle indicates a posterior position of the mandibular fossa and a small angle indicates anterior position of the fossa.
Articular angle	A large angle imposes retrognathic changes on the profile; A small angle imposes prognathic changes on the profile.
Gonial angle	A large angle indicates a tendency to posterior rotation of the mandible, with condylar growth directed posteriorly; A small angle indicates a tendency to anterior rotation with vertical growth of the condyles.
Facial angle	It measures the degree of retrusion or protrusion of the mandible in relation to the upper face.
Angle of convexity	A positive angle suggests prominence of the maxillary dental base relative to the mandible; A negative angle is associated with a prognathic profile
Nasion perpendicular to Pog	It measures the degree of retrusion or protrusion of the mandible in relation to the upper face.
Go-Gn to SN	It shows the horizontal or vertical growth pattern of mandible.
Y-axis	It indicates the degree of the downward, backward or forward position of the chin in relation to the upper face

Table 2. Mean values of sagittal discrepancy indicators

		Pi angle		**Beta angle**		**Yen angle**		**W angle**	
Skeletal group	N	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Class I	50	4.52	3.39	29.97	3.66	121.21	4.70	53.75	3.85
Class II	53	9.92	3.89	23.81	4.29	115.19	4.89	49.95	3.55
Class III	47	-2.78	2.86	38.95	4.24	129.07	5.10	57.71	2.84

Table 3. Tukey HSD post hoc test for intergroup comparison

Variable	Group (I)	Group (J)	Mean difference (I-J)	P value
Pi angle	Class I	Class II	-5.40	<0.001
		Class III	7.30	<0.001
Beta angle	Class I	Class II	5.89	<0.001
		Class III	-8.98	<0.001
W angle	Class I	Class II	3.78	<0.001
		Class III	-5.98	<0.001
Yen angle	Class I	Class II	6.02	<0.001
		Class III	-7.86	<0.001

P >0.05: Not Significant (NS),
P <0.05: Significant (S),
P <0.001: Highly Significant (HS)

Among the Class I skeletal group, the Beta angle could identify 70% of subjects as Class I, which was highest among the four angular measurements while Pi angle showed least predictability as it could segregate only 32% of subjects into the Class I category. Among the Class II skeletal group, the Pi angle was determined to be most predictable with an accuracy of 85%. The least predictability was seen with the W angle as it could categorize 62% of the subjects into the skeletal Class II group; and among the Class III skeletal group, the Pi angle showed the strongest association with the ANB angle and highest accuracy (100%) in discerning skeletal Class III subjects (Table 4.1, 4.2, 4.3, and 4.4).

Table 4.1. Chi-Square test for Pi angle

Pi angle	**Class I**	**Class II**	**Class III**
< Normal count	n=8 16%	n=1 2.2%	n=47 100%
Normal count (1.3°-5°)	n=16 32%	n=7 13%	n=0 0%
> Normal count	n=26 52%	n=45 85%	n=0 0%
Total sample (N)	50	53	47

X2=128.076

Table 4.2. Chi-Square test for Beta angle

Beta angle	**Class I**	**Class II**	**Class III**
< Normal count	n=10 20%	n=44 83%	n=0 0%
Normal count (27°-35°)	n=35 70%	n=9 17%	n=9 19%
> Normal count	n=5 10%	n=0 0%	n=38 81%
Total sample (N)	50	53	47

X2=144.484

Table 4.3. Chi-Square test for W angle

W angle	**Class I**	**Class II**	**Class III**
< Normal count	n=7 14%	n=33 62%	n=1 2%
Normal count (51°-56°)	n=30 60%	n=15 28%	n=0 0%
> Normal count	n=13 26%	n=5 9.4%	n=46 98%
Total sample (N)	50	53	47

X2=117.881

Table 4.4. Chi-Square test for Yen angle

Yen angle	Class I	Class II	Class III
< Normal count	n=7 14%	n=37 70%	n=0 0%
Normal count (117°-123°)	n=30 60%	n=13 24%	n=10 21.2%
> Normal count	n=13 26%	n=3 5.7%	n=37 79%
Total sample (N)	50	53	47

X2=99.871

A statistically significant highest positive correlation was found between the W angle and Yen angle and the highest negative correlation was found between the Pi angle and Yen angle in the skeletal Class I, II, and III group. A statistically significant correlation was found between the Pi angle and W angle, between the Beta angle and W angle, between the Beta angle and Yen angle, and between Pi angle and Beta angle in all three skeletal groups (Table 5.1, 5.2, and 5.3).

Mandibular base length showed a weak negative correlation with the Pi angle, suggesting that it is inversely proportional to the Pi angle (-0.265). The Pi angle and length of ascending ramus showed a weak negative correlation with each other (-0.298) and the effective mandibular length showed a weak negative correlation with Pi angle (-0.396) (Table 6).

Table 5.1. Correlation among sagittal discrepancy indicators in skeletal Class I group

Parameter	Pi angle	Beta angle	W angle	Yen angle
Pi angle	-	-0.360* (S)	-0.295* (S)	-0.392** (HS)
Beta angle		-	0.566** (HS)	0.501** (HS)
W angle			-	0.706** (HS)
Yen angle				-

**: Correlation is significant at the 0.01 level (HS)
*: Correlation is significant at the 0.05 level (S)

Table 5.2. Correlation among sagittal discrepancy indicators in skeletal Class II group

Parameter	Pi angle	Beta angle	W angle	Yen angle
Pi angle	-	-0.404** (HS)	-0.356* (S)	-0.667** (HS)
Beta angle		-	0.487** (HS)	0.323* (S)
W angle			-	0.768** (HS)
Yen angle				-

**: Correlation is significant at the 0.01 level (HS)
*: Correlation is significant at the 0.05 level (S)

Table 5.3. Correlation among sagittal discrepancy indicators in skeletal Class III group

Parameter	Pi angle	Beta angle	W angle	Yen angle
Pi angle	-	0.216$ (NS)	-0.741** (HS)	-0.877** (HS)
Beta angle		-	0.388** (HS)	0.394** (HS)
W angle			-	0.786** (HS)
Yen angle				-

**: Correlation is significant at the 0.01 level (HS)
$: Correlation is not significant at the 0.05 level (NS)

The highly positive correlation was found between Pi angle and angle of convexity (0.852). The facial angle showed a highly negative correlation with Pi angle (-0.800). The Pi angle and Y-axis showed a moderately positive correlation with each other (0.728). Pi angle and N perpendicular – pogonion (-0.649) showed a moderately negative correlation with each other. There was a weak negative correlation found between SNB and Pi angle (-0.408). Both GoGn-SN (0.379) and articular angle (0.277) showed weak positive correlation with Pi angle (Table 6). Statistically significant correlations were not discovered between the Pi angle and Saddle angle (0.054) and between the Pi angle and Gonial angle (-0.002) as seen in (Table 6).

Table 6. Range of size and position of mandible based on Pi angle

	Correlation Coefficient (r)	CLASS I (1.3°-5°) (n=23)	CLASS II (>5°) (n=71)	CLASS III (<1.3°) (n=56)
		SIZE OF MANDIBLE		
Mandibular base length	-0.265	69.59-70.80 mm	<69.59 mm	>70.80 mm
Length of ascending ramus	-0.298	44.88-45.96 mm	<44.88 mm	>45.96 mm
Effective mandibular length	-0.396	101.91-103.52 mm	<101.91 mm	>103.52 mm
		POSITION OF MANDIBLE		
SNB	-0.408	78.87°-80.43°	<78.87°	>80.43°
Saddle angle	0.054$	122.09°-122.26°	>122.26°	<122.09°
Articular angle	0.277	143.15°-144.43°	>144.43°	<143.15°
Gonial angle	-0.002$	123.550°-123.536°	<123.536°	>123.550°
Facial angle	-0.800	86.97°-88.79°	<86.97°	>88.79°
Angle of convexity	0.852	1.41°-5.70°	>5.70°	<1.41°
N perp TO POG	-0.649	-0.2 mm- -3.6 mm	>-3.6 mm	<-0.2 mm
GoGn-SN	0.379	27.20°-28.52°	>28.52°	<27.20°
Y-axis	0.728	57.74°-59.40°	>59.40°	<57.74°

$: Nonsignificant

Table 7. Range of size and position of mandible based on ANB angle

	CLASS I (1°-4°) (n=50)	CLASS II (≥5°) (n=53)	CLASS III (≤0°) (n=47)
	SIZE OF MANDIBLE		

Mandibular base length	69.07-71.02 mm	<69.07 mm	>71.02 mm
Length of ascending ramus	44.28-46.36 mm	<44.28 mm	>46.36 mm
Table 7 continue			
Effective mandibular length	100.74-104.50 mm	<100.74 mm	>104.50 mm
POSITION OF MANDIBLE			
SNB	77.69°-81.44°	<77.69°	>81.44°
Saddle angle	122.59°-122.42°	>122.59°	<122.42°
Articular angle	142.21°-145.48°	>145.48°	<142.21°
Gonial angle	123.01°-124.27°	<123.01°	>124.27°
Facial angle	85.94°-89.49°	<85.94°	>89.49°
Angle of convexity	-1.45°-9.01°	>9.01°	<-1.45°
N perp TO POG	-5.61-1.17 mm	>-5.61 mm	<1.17 mm
GoGn-SN	26.94°-29.08°	>29.08°	<26.94°
Y-axis	57.15°-60.31°	>60.31°	<57.15°

Table 8. Comparison between manual tracing and Dolphin software

Variables	Manual measurements mean (M)	S. D	Dolphin measurements mean (D)	S. D	Mean difference (M-D)	p-value
PI ANGLE	3.87°	5.91°	3.99°	5.95°	-0.11°	0.87 (n.s)
BETA ANGLE	30.70°	7.07°	30.39°	7.16°	0.30°	0.73 (n.s)
YEN ANGLE	118.04°	19.96°	119.18°	18.14°	-1.14°	0.64 (n.s)
W ANGLE	56.91°	1.11°	54.49°	0.43°	2.40°	0.043*(S)

P>0.05**
S=Significant
n.s.= non-significant

Discussion

New cephalometric parameters like Pi angle, Yen angle, and W angle were developed using these G and M points as landmarks because these points are least impacted by the local remodeling secondary to the dental movements, unlike points A and B. These angular measurements do not depend on the cranial reference plane or the dental occlusion. Also, they abolish the complexity in pinpointing point A, point B, functional occlusal plane, or condyle axis (3-5).

Pi angle is independent of cranial reference planes and dental occlusion, and it can appraise true anteroposterior skeletal patterns even when clockwise or counterclockwise rotation of the jaws would veer to disguise them. It was introduced as a cephalometric diagnostic aid with a vision to establish a sagittal discrepancy indicator that could assess the anteroposterior jaw relationship with more consistency and with a greater degree of accuracy. However, as Pi angle may be affected by the upward and forward movement of nasion with growth, to overcome this issue, Pi linear can be used as an adjunct to Pi angle for proper determination of sagittal discrepancy.

The present study was carried out in the Department of Orthodontics and Dentofacial Orthopaedics at A.M.C. Dental College and Hospital, Ahmedabad. Totally, 150 sets of pre-treatment lateral cephalograms of patients with a full set of permanent dentition excluding third molars and not beyond the age of 25 years were obtained from the departmental records based on inclusion and exclusion criteria. The obtained lateral cephalograms were traced manually as well as digitally (Dolphin software, version 11.95), and measurement of all the angular and linear parameters included in this study were carried out. The anteroposterior discrepancy indicators used were Pi angle, Beta angle, W angle, and Yen angle.

Primary objective

The Pi angle measurements in our study closely match those from Kumar et al. (9,14) across skeletal Classes I, II, and III. Similarly, our Beta angle values for these skeletal Classes align with Baik and Ververidou's (4) findings, and our study's W angle measurements for these Classes correspond with Bhad et al's (7) observations. Additionally, Neela et al.'s3 study results for the Yen angle in Class I, Class II, and Class III groups resemble our findings. These consistent measurements bolster the reliability of our study's outcomes.

Bohra et al. (15) showed that mean values of Pi angle, Beta angle, W angle, and Yen angle could differentiate more between Class I and Class III groups than between Class I and Class II group. This was in accordance with those found in our study. Mehta et al. (16) established similar findings in their study showing the subsequent order of Beta, Yen, and W angle values was detected in different

Classes (i.e. Class III > Class I > Class II). Kumar et al. (9) also observed similar results in their study, showing that the Pi angle could better differentiate between Class I and Class III groups than between Class I and Class II groups.

This study shows that the Pi angle is the most predictable for identifying skeletal Class II and Class III cases and least predictable for identifying skeletal Class I cases from the given sample while the Beta angle was most predictable for identifying skeletal Class I cases from the sample. Similar results were obtained in a study conducted by Bohra et al. (15).

The present study shows that a negative correlation exists between the Pi angle with other sagittal discrepancy indicators (i.e., they rise and fall in the opposite direction). In the skeletal Class I group, the Pi angle showed a strong relationship with the Yen angle and the weakest correlation with the W angle. Among the four angular parameters, the W angle and Yen angle showed the highest correlation with each other, which was similar to the findings reported by Garima Soni et al. (17).

In the Class II group, the Pi angle showed a strong relationship with the Yen angle and a weak relationship with the W angle. Among the four angular parameters, the W angle and Yen angle showed the strongest correlation with each other. Garima Soni et al. (17) observed similar findings in their study.

Pi angle showed a strong relationship with the Yen angle and a good relationship with the W angle in skeletal the Class III group. Among the four angular parameters, in the Class III skeletal group, Pi angle and Yen angle showed the strongest correlation, which was in accordance with Bohra et al. (15).

We can infer that among the parameters of the size of the mandible, the mandibular base length shows a weak negative correlation with the Pi angle suggesting that it is inversely proportional to the Pi angle. It showed a trend opposite to that of the Pi angle, for example as the Pi angle increases such as in skeletal Class II cases, the mandibular base length decreases and likewise, for skeletal Class III cases the mandibular base length also increases. The pi angle and length of ascending ramus showed a weak negative correlation with each other. It showed a trend similar to that of the mandibular base length in relation to Pi angle. Effective mandibular length showed a weak negative correlation with Pi angle. This meant that its value showed changes in the opposite direction as that of the Pi angle.

Among the parameters of the position of the mandible, the angle of convexity, Y-axis, GoGn-SN, and articular angle showed a positive correlation with the Pi angle such that they show a change in the same direction as that of the Pi angle. Parameters such as facial angle, N perpendicular – pogonion, and SNB showed negative correlation with Pi angle, i.e., as their value becomes larger, Pi angle becomes smaller and vice versa.

Regression analysis was used to establish the values of the size and position of the mandible based on Pi angle. This was compared with the values that were obtained based on the ANB angle, and it was found that there were significant similarities between the two values. However, significant differences were observed in the values of only two parameters, i.e., angle of convexity as well as N perpendicular to Pog. This can be attributed to significant differences in the construction of points G and Pogonion.

Secondary objective

Comparison between the values of sagittal discrepancy indicators obtained by manual tracing and digital tracing utilizing the imaging software Dolphin version 11.95 (Dolphin Imaging, CA, USA) showed that the mean and standard deviation were similar in both methods, reflecting a statistically nonsignificant P value for all the measurements. This result was in line with Paixao et al. (18) and Khan et al. (19). The results of this study further supplemented the fact that Dolphin software works as a reliable tool even when customization is done for the cephalometric variables. which are not built into the software. Therefore, it can be said that it is a reliable tool for cephalometric analysis even for specially customized cephalometric parameters as well, and could be utilized regularly for clinical orthodontic diagnosis and treatment planning.

As the Pi angle is a promising anteroposterior dysplasia indicator for the diagnosis of sagittal discrepancy, the present study was conducted with the purpose to establish the Pi angle as the determinant of mandibular morphology rather than establishing it as a replacement of previously introduced sagittal discrepancy indicators. Also, the present study utilized the scope of customization of cephalometric variables of the Dolphin Imaging software version 11.95 (Dolphin Imaging, CA, USA) to evaluate the reliability of the software in addition to the primary objective of the study. Hence, the results of this study will be valuable in determining of spatial position of the mandible just by obtaining the value of the Pi angle.

As for the shortcomings, the present study did not consider the effect sex has on the cephalometric variables and the sample included a mixed population. The furtherance of this study with a bigger sample size consisting of a wider spectrum of sagittal malocclusion will give a more valid value of the Pi angle. Future studies can include comparative analysis between the sexes.

Conclusion

Pi angle could obtain statistically significant mean and standard deviation values for each skeletal pattern group. Thus, the Pi angle could accurately differentiate the sample into skeletal Class I, II, and III groups.

Pi angle was found to be the most accurate sagittal discrepancy indicator in identifying skeletal Class II and Class III cases from the sample while Beta angle was better able to identify the skeletal Class I cases from the sample.

Pi angle was found to have statistically significant correlation with Beta angle, Yen angle, and W angle in skeletal Class I, Class II, and Class III pattern groups. It showed highest negative correlation with Yen angle in the three skeletal pattern groups.

A statistically significant correlation was found between Pi angle and all the parameters of size and position of the mandible. All the parameters of the size of the mandible (i.e., mandibular base length, length of ascending ramus, and effective midface length), and Pi angle were found to be inversely proportional to each other.

On comparing the data obtained by manual and digital tracing using Dolphin 3D imaging software version 11.95 it was found that the customization for the analysis of newer cephalometric variables that are not available as a built-in feature in the software can be utilized reliably to diagnose, plan, monitor, and evaluate orthodontic treatments in clinical and research settings.

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