Accuracy of different cephalometric analyses in the diagnosis of class III malocclusion in Saudi and Yemeni population

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Abstract:
OBJECTIVE: The study aimed to assess the accuracy and reliability of five cephalometric parameters in diagnosing class III malocclusion in Saudi and Yemeni population.
MATERIAL AND METHODS: A cross-sectional, descriptive study in which total 60 lateral cephalograms (30 of Saudi and 30 of Yemeni population) of Class III malocclusion were hand-traced. ANB angle, Wits appraisal, Beta angle, W angle, and Yen angle were measured. The validity, reliability, sensitivity, and positive predictive values (PPVs) of these parameters were calculated.
RESULTS: In Saudi population, a strong correlation was found between ANB angle and Wits appraisal ($r = 0.892, P < 0.05$), ANB and Beta angle showed highest sensitivity (0.933) followed by Wits appraisal (0.900), and ANB angle showed the highest PPV (0.965) followed by Beta angle (0.933) and Wits appraisal (0.931). In Yemeni population, a strong correlation was found between ANB angle and Wits appraisal ($r = 0.887, P < 0.05$), ANB angle and W angle showed highest sensitivity (0.966) followed by Wits appraisal (0.933), whereas W angle showed the highest PPV (1.00) followed by ANB angle (0.966) and Wits appraisal (0.933).
CONCLUSION: In Saudi population, ANB angle and Beta angle, whereas in Yemeni population, ANB angle and W angle are the most valid cephalometric indicators to accurately assess the class III malocclusion. ANB angle in the Saudi population and W angle in the Yemeni population have the highest PPV in correctly diagnosing class III malocclusion.
Keywords: Accuracy, class III malocclusion, reliability, Saudi population, Yemeni population

Introduction
Class III malocclusion is a complex multifactorial dentofacial discrepancy that leads to varying degrees of aesthetic, psychological, and functional impairment. Variations in normal craniofacial development can alter the shape, size, and position of the cranial base, maxilla, and mandible, which can in turn affect the dentoalveolar region and soft tissues. Angle’s classification[1] (1899) was initially used to categorize and diagnose class III malocclusion. With the advent of cephalometry by Broadbent[2] in 1931, cephalometric radiography rapidly became a routine, integral, and powerful standard tool for the analysis of craniofacial morphology, prediction of facial growth, diagnosis of various malocclusions, planning of treatment, and assessment of treatment outcomes. A plethora of cephalometric parameters and analyses have been introduced to identify discrepancies in the sagittal, vertical, and transverse aspects of dentofacial anatomy.[3]

Down’s description of points A and B was the first step in cephalometric evaluation of...
anteroposterior sagittal jaw relationship.\textsuperscript{[14]} ANB angle introduced by Riedel\textsuperscript{[15]} in 1950 and later popularized by Steiner\textsuperscript{[16]} is commonly used to diagnose class III malocclusion. ANB angle is sensitive to small changes, such as the length of the anterior cranial base, vertical growth pattern, and position of nasion and sella turcica.\textsuperscript{[7,8]} Hence, its reliability has always been questioned. Considering this limitation of ANB angle, Jacobson\textsuperscript{[9]} presented Wits appraisal involving the functional occlusal plane. However, Wits appraisal also gets influenced by the occlusal plane inclination, erupting teeth, and alveolar bone development.\textsuperscript{[10]} Antero-posterior dysplasia indicator (APDI) was established by Kim and Vieta\textsuperscript{[11]} in 1978 to diagnose problems of sagittal plane. APDI uses the Frankfurt horizontal plane, which has its own set of shortcomings, and also uses point A and B, which can be altered by growth and orthodontic treatment. Beta angle developed by Baik and Ververidou\textsuperscript{[12]} in 2004 is based on point A, which can be altered, and condyion (center of condyles) that is not very reproducible and difficult to locate.\textsuperscript{[13]} Yen angle by Neela et al.\textsuperscript{[14]} in 2009 and W angle by Bhad et al.\textsuperscript{[15]} in 2013 use stable anatomical landmarks like S (sella), M (center of the maxilla), and G (center of the mandibular symphysis) points to identify true apical dysplasia. Moreover, M and G points are susceptible to changes occurring during orthodontic treatment or growth.\textsuperscript{[16]}

The power of any cephalometric analysis lies in its ability to diagnose a case perfectly. However, no single analysis is flawless or infallible. In various studies Wits appraisal, ANB, Beta, W, and Yen angles have been evaluated for their diagnostic performance, validity, and reliability in the diagnosis of malocclusion. It is pertinent to understand that in the current times, due to the amalgamation of different races and population, it is irrational to apply the standard parameters of a particular racial group to another race, or same race, or its subgroups.\textsuperscript{[17]} Class III conditions often involve a multitude of skeletal and dental disharmonies, which require the use of these anteroposterior skeletal dysplasia parameters.\textsuperscript{[18]} These analyses are sometimes confusing, provide conflicting results, and are often time-consuming to perform. The objective of this study is to assess the accuracy of certain commonly used cephalometric analyses, such as ANB angle, Wits appraisal, Beta angle, W angle, and Yen angle in diagnosing Class III malocclusion in Saudi and Yemeni population.

\textbf{Materials and Methods}

This study is a cross-sectional and descriptive study in which data were collected retrospectively from the dental center of the Najran hospital. A total of 60 pretreatment, good quality lateral cephalograms of Class III malocclusion were obtained from the dental records of the patients who had attended the orthodontic department for treatment in the Najran hospital. Of the 60 lateral cephalograms, 30 belonged to Saudi population and other 30 belonged to Yemeni population. The total sample of 60 comprised 32 males and 28 females with the Saudi population consisting of 17 males and 13 females, and the Yemeni population consisting of 15 males and 15 females. The study protocol was approved by the research ethical committee of the Najran University (No. [40133]). Lateral cephalograms of class III malocclusion cases were screened and filtered according to the inclusion and exclusion criteria.

\textbf{Inclusion criteria}

1. Age group of 15–35 years
2. Good quality lateral cephalograms
3. No history of orthodontic treatment
4. Complete permanent dentition
5. Subjects having class III malocclusion with ANB < 2°, Wits appraisal <-3 mm, Beta angle >35°, W angle >56°, and Yen angle >123°.

\textbf{Exclusion criteria}

1. Subjects from population other than Saudi and Yemeni population
2. Any history of facial trauma, asymmetry, craniofacial malformation, syndromic cases, or cleft lip and palate
3. Distorted lateral cephalograms with poor quality and visibility for landmark identification.

The lateral cephalograms were recorded in natural head position and hand-traced by a single investigator to avoid interexaminer differences. The skeletal landmarks were identified and the first measurements were recorded. The following parameters were measured and recorded:

- ANB angle: Angle formed between point A, nasion, and point B.
- Wits appraisal: Horizontal distance between perpendiculars from point A (AO) and B (BO) on the functional occlusal plane.
- Beta angle: Angle between AB and perpendicular drawn through point A on line CB (line from center of the condyle and point B).
- W angle: Angle between the perpendicular from point M to SG and MG.
- Yen angle: Angle between MG and SM line.

In this study, the subjects with ANB < 2°, Wits appraisal <-3 mm, Beta angle >35°, W angle >56°, and Yen angle >123° were included in class III malocclusion.\textsuperscript{[6,9,12,14,15]} The cephalograms were retraced and reanalyzed after
a 4-week interval by the same investigator to assess the intraexaminer reliability. The final diagnosis of class III malocclusion was determined on the basis of detailed clinical findings, cephalometric analysis, and profile evaluation.

**Statistical analysis**
The data were analyzed using SPSS for Windows (version 20.0, SPSS Inc. Chicago). Dalhberg’s error and coefficient of reliability [interclass correlation coefficient (ICC)] were used to calculate the correlation between the two sets of readings. Descriptive analysis was performed to calculate the mean and standard deviation of the different cephalometric analyses. Pearson’s correlation was applied to assess the correlation between the different cephalometric analyses. Kappa statistics were used to identify the level of agreement between cephalometrically diagnosed cases and finally diagnosed cases. Sensitivity and positive predictive value (PPV) analyses were used to determine the validity of the cephalometric analysis. A P value of <0.05 was considered statistically significant.

**Results**
Gender-wise details of the Saudi and Yemeni population are shown in Table 1. The mean age of the total sample was 19.28 ± 4.34 years. The mean age of the Saudi population was 19.87 ± 4.85 years and the Yemeni population was 18.69 ± 3.51 years. The Dahlbergs error ranged from 0.595 to 0.880 in the Saudi population and 0.590 to 0.885 in the Yemeni population as shown in Tables 2 and 3, respectively. ICC found a high correlation between the two sets of readings in the Saudi and Yemeni population as shown in Tables 2 and 3, respectively. In the Saudi population, strong correlation was found between the values of ANB angle and Wits appraisal \((r = 0.892, P < 0.05)\), Beta angle and Wits appraisal \((r = 0.812, P < 0.05)\), and Yen and W angle \((r = 0.856, P < 0.05)\) as shown in Table 4. In the Yemeni population, strong correlation was found between the values of ANB angle and Wits appraisal \((r = 0.887, P < 0.05)\), Beta angle and Wits appraisal \((r = 0.843, P < 0.05)\), and Yen angle and W angle \((r = 0.868, P < 0.05)\) as shown in Table 5. In the Saudi population, the ANB angle and Beta angle showed the highest sensitivity (0.933) followed by the Wits appraisal (0.900), whereas the ANB angle showed the highest PPV (0.965) followed by the Beta angle (0.933) and Wits appraisal (0.931) as shown in Table 6. In the Yemeni population, the ANB angle and W angle showed the highest sensitivity (0.966) followed by the Wits appraisal (0.933), whereas the W angle showed the highest PPV (1.00) followed by the ANB angle (0.966) and Wits appraisal (0.933) as shown in Table 7.

**Discussion**
Accurate diagnosis of Class III malocclusion is immensely important in determining the treatment modality. Cephalometric evaluation is one of the most common and important parameters in decoding the type and severity of malocclusion. There is a longstanding controversy in the literature regarding the most accurate cephalometric analysis for evaluating malocclusion.[18] Two statistical factors, validity and reliability, are often used to determine accuracy of the cephalometric analyses used.[19] This study is aimed to identify the cephalometric analysis providing precise, consistent, and reliable diagnosis of class III malocclusion in Saudi and Yemeni population.

In this study, a strong correlation was found between the ANB angle and Wits appraisal, Beta angle and Wits appraisal, and Yen angle and W angle in both Saudi and Yemeni populations. Hence, it can be concluded that, in combination, the ANB angle and Wits appraisal, Beta angle and Wits appraisal, and Yen angle and W angle are reliable indicators in precisely assessing class III malocclusion in both Saudi and Yemeni population.

Sensitivity analysis of each cephalometric parameter was performed to validate their consistency and diagnostic accuracy. In this study, it was observed that in the Saudi population, the ANB angle and Beta angle showed the highest sensitivity (0.933) followed by the Wits appraisal (0.900) in evaluating the class III discrepancy. In the Yemeni population, the study revealed that the ANB

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**Table 1: Gender-wise details of the total sample**

| Class III | Saudi population (n=30) | Yemeni population (n=30) | Total |
|-----------|-------------------------|-------------------------|-------|
| Males     | 17                      | 15                      | 32    |
| Females   | 13                      | 15                      | 28    |
| Total     | 30                      | 30                      | 60    |

**Table 2: Interclass correlation coefficient between the two sets of readings in Saudi population**

| Cephalometric analysis | First reading (n=30) | Second reading (n=30) | Interclass correlation coefficient (ICC) | Dahlberg’s error |
|------------------------|----------------------|-----------------------|------------------------------------------|------------------|
| ANB                    | -2.65±3.12           | -2.54±3.08            | 0.967                                    | 0.750            |
| Wits appraisal         | -6.02±3.98           | -6.11±4.08            | 0.992                                    | 0.824            |
| Beta angle             | 40.37±5.05           | 40.68±5.16            | 0.989                                    | 0.595            |
| W angle                | 61.23±4.87           | 61.29±4.92            | 0.955                                    | 0.870            |
| Yen angle              | 128.47±4.53          | 128.53±4.55           | 0.990                                    | 0.880            |

Weak correlation \((± 0.01 < r < ± 0.5)\); moderate correlation \((± 0.5 < r < ± 0.8)\); strong correlation \((± 0.8 < r < ± 1)\)
Alassiry: Class III accuracy

Table 3: Interclass correlation coefficient between the two sets of readings in Yemeni population

| Cephalometric analysis | First reading (n=30) | Second reading (n=30) | Interclass correlation coefficient (ICC) | Dahlberg’s error |
|------------------------|----------------------|-----------------------|------------------------------------------|------------------|
| ANB                    | -2.89±3.46           | -2.81±3.40            | 0.961                                    | 0.758            |
| Wits appraisal         | -6.67±3.99           | -6.72±4.05            | 0.997                                    | 0.817            |
| Beta angle             | 41.14±5.09           | 41.59±5.32            | 0.990                                    | 0.590            |
| W angle                | 61.83±4.89           | 61.61±4.73            | 0.950                                    | 0.865            |
| Yen angle              | 127.58±4.01          | 127.42±4.07           | 0.995                                    | 0.885            |

Dahlberg’s error:

--release (± 0.01 < r < 0.5): moderate correlation (± 0.5 < r < 0.8); strong correlation (± 0.8 < r < 1)

Table 4: Pearson’s correlation among different cephalometric analysis for assessing class III malocclusion in Saudi population

| Cephalometric analysis | ANB    | Wits appraisal | Beta angle | W angle | Yen angle |
|------------------------|--------|----------------|------------|---------|-----------|
| ANB                    | 1      | 0.892*         | 0.745      | 0.702   | 0.658     |
| Wits appraisal         | 1      | 0.812*         | 0.734      | 0.774   |           |
| Beta angle             | 1      | 0.697          | 0.643      |         |           |
| W angle                | 1      | 0.856*         | 1          |         |           |
| Yen angle              | 1      |                |            |         |           |

Weak correlation (± 0.01 < r < 0.5); moderate correlation (± 0.5 < r < 0.8); strong correlation (± 0.8 < r < 1); *P<0.05

Table 5: Pearson’s correlation among different cephalometric analysis for assessing class III malocclusion in Yemeni population

| Cephalometric analysis | ANB    | Wits appraisal | Beta angle | W angle | Yen angle |
|------------------------|--------|----------------|------------|---------|-----------|
| ANB                    | 1      | 0.887*         | 0.756      | 0.727   | 0.693     |
| Wits appraisal         | 1      | 0.843*         | 0.746      | 0.779   |           |
| Beta angle             | 1      | 0.705          | 0.658      |         |           |
| W angle                | 1      | 0.868*         | 1          |         |           |
| Yen angle              | 1      |                |            |         |           |

Weak correlation (± 0.01 < r < 0.5); moderate correlation (± 0.5 < r < 0.8); strong correlation (± 0.8 < r < 1); *P<0.05

The ANB angle has long remained the most popular cephalometric parameter to assess antero-posterior discrepancy. However, it is pertinent to understand that the ANB angle is affected by the change in length of the anterior cranial base, vertical growth pattern, and position of nasion and sella turcica. Many researchers have questioned the reliability of the ANB angle. On the contrary, in this study the ANB angle was found to be a valid cephalometric indicator in assessing class III malocclusion of the subjects in both Saudi and Yemeni populations. Additionally, in this study, the ANB angle showed the highest probability in correctly diagnosing a class III malocclusion in Saudi population. Another cephalometric parameter that has found importance in the outcome of this study is the W angle introduced by Bhad et al.[15] in 2013, which uses stable anatomical landmarks like Sella, M, and G points. In this study, the W angle (along with the ANB angle) was found to be a valid cephalometric indicator in assessing class III malocclusion in the subjects from the Yemeni population. Moreover, the W angle also showed the highest probability in correctly diagnosing a class III malocclusion in the Yemeni population. A study by Sachdeva et al.[25] in 2012 also found W angle as a reliable method of diagnosing antero-posterior skeletal discrepancies. Another study conducted by Qamaruddin et al.[26] in 2017 in Pakistani population indicated that the W angle showed high diagnostic value and high correlation with other cephalometric analyses in diagnosis of skeletal discrepancies.

Further studies are needed to identify the reliability and validity of other cephalometric parameters and classes of malocclusion in the current population. This is important as facial norms and standards have been predominantly linked to racial preferences. A more extensive research can be performed by including a larger sample size of...
the Saudi and Yemeni population, investigating all three classes of malocclusion and adding more cephalometric parameters for the assessment of discrepancies.

### Conclusion

The following conclusions can be drawn from the study:

1. In combination, the ANB angle and Wits appraisal, Beta angle and Wits appraisal, and Yen angle and W angle are reliable indicators in precisely assessing class III malocclusion in patients from both Saudi and Yemeni population.

2. In the Saudi population, the ANB angle and Beta angle, whereas in the Yemeni population, the ANB angle and W angle can be used as valid cephalometric indicators to accurately assess class III malocclusion of the patients.

3. The ANB angle in Saudi population and the W angle in the Yemeni population have the highest probability in correctly diagnosing a class III malocclusion.

Hence, it is clinically advisable by the authors to utilize the cephalometric findings of this study for assessing class III malocclusion cases in Saudi and Yemeni population.

### Financial support and sponsorship

Nil.

### Conflicts of interest

There are no conflicts of interest.

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