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Original article

Impact of Saddle Angle on Skeletal Class II Division 1 Malocclusion in Libyan Patients: A Retrospective Cephalometric Analysis

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Abstract
Cranial base morphology plays a key role in determining maxilla-mandibular relationships. The saddle angle (N–S–Ar) reflects cranial base flexure and has been linked to sagittal discrepancies such as Class II Division 1 malocclusion. However, its role in Libyan populations remains insufficiently defined. This study was conducted to investigate the relationship between saddle angle and skeletal parameters (SNA, SNB, ANB, SN–MP) in Libyan patients with Class II Division 1 malocclusion. A retrospective cephalometric study was conducted on 116 Libyan patients. Standard angular measurements were obtained, compared to Libyan normal values, and correlations between saddle angle and skeletal variables were analyzed using Pearson correlation and simple regression analysis. The saddle angle was significantly higher than Libyan normal values. It showed a positive correlation with SNA, ANB, and SN–MP, and a negative correlation with SNB. The strongest correlation was observed with ANB. Increased saddle angle is significantly associated with the skeletal characteristics of Class II Division 1 in Libyan patients, particularly through mandibular retrusion and vertical growth tendency. Its effect on SNA is minimal, which indicates more impact on mandibular retrusion than maxillary protrusion.
Keywords. *Saddle Angle, Skeletal, Malocclusion, Libyan Patients.*

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Introduction

Class II Division 1 malocclusion is among the most prevalent skeletal discrepancies encountered in orthodontic practice, often characterized by mandibular retrusion, increased overjet, and a convex profile [1–3]. While dento-alveolar factors may contribute, the underlying skeletal pattern is typically the dominant component [4,5]. This study is the third in a row of studies aimed to evaluate the effects of some cephalometric parameters on class II division 1 skeletal malocclusion in Libyan patients, published in the Khalij Libya journal of dental and medical research [6,7], to provide a clearer understanding of the role of the cranial base in Libyan Class II Division 1 malocclusion patients.

The cranial base has long been recognized as an essential structure influencing facial growth. The saddle angle (N–S–Ar), representing the connection between the anterior and posterior cranial bases, plays a major role in determining the anteroposterior position of the mandible [8–10]. Björk first emphasized that variations in cranial base angle can alter mandibular positioning and subsequently affect sagittal jaw relationships [8]. An increased saddle angle tends to displace the mandible posteriorly, as the condylar fossa, which is a part of the posterior cranial base, will be more posteriorly placed, contributing to a Class II skeletal pattern, whereas a reduced angle is more commonly associated with Class III relationships [11–13]. Despite this well-established concept, the magnitude and clinical significance of this relationship vary among different populations [14,15].

Ethnic variability in craniofacial morphology has been widely documented. Studies in Middle Eastern populations have reported slightly increased cranial base angles compared to Caucasians, while East Asian populations often demonstrate reduced values [16–20]. African populations show greater variability, often with stronger mandibular projection despite larger cranial base angles [21]. In the Libyan population, cephalometric norms suggest subtle but clinically relevant differences in cranial base configuration and mandibular position [22]. However, the relationship between saddle angle and key skeletal parameters such as SNA, SNB, ANB, and SN–MP has not been comprehensively analyzed.

Methods:

This retrospective study included 116 lateral cephalometric radiographs of Libyan white patients diagnosed with Class II Division 1 malocclusion. The sample consists of 56 males (mean age 18.5±5.0 years) and 60 females (mean age 19.2±5.4years). The cephalographs were made by the author using a Strato X 2000 X-ray machine (Villa Medical Systems- Italy).

Inclusion criteria include: Libyan white ancestry, ANB ≥ 4, and no previous orthodontic treatment. The exclusion criteria are craniofacial anomalies, history of trauma or surgery, poor radiographic quality, and syndromic conditions.

The cephalographs were digitally analyzed using Dr.Ceph cephalometric analysis software (Fytek Corporation, USA). The following parameters were measured (Figure 1): saddle angle (N–S–Ar), angle of maxillary sagittal position relative to cranial base (SNA), angle of mandibular sagittal position relative to cranial base (SNB), sagittal discrepancy between mandible and maxilla (ANB), and mandibular rotation and vertical growth direction (SN–MP).

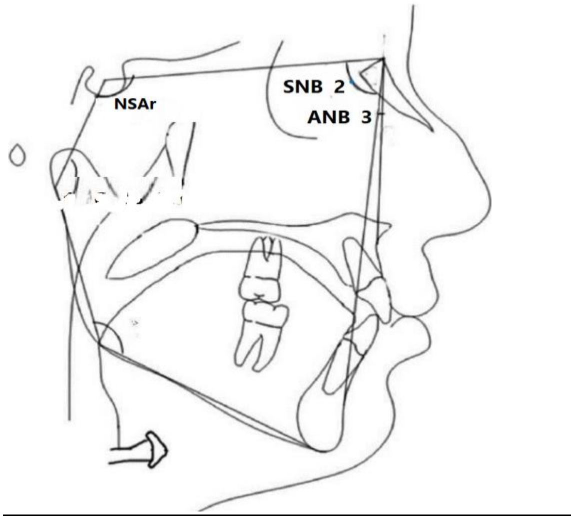

Figure 1: Cephalometric angles used

To ensure reliability, 25 radiographs were analyzed twice at two-week intervals, and the intra-examiner reliability was tested using the intra-class correlation coefficient; the difference was statistically insignificant (t =1.078, p>0.05). Libyan normative values were used as a reference (Saddle angle =126.5±5.8, SNA =82.0±1. 6, SNB =78.6±2.9 ANB =2.0±1.5, SN–MP =33±3.5) [20].
All statistical analyses were conducted using SPSS version 12.0 software (Statistical Package for the Social Sciences, Lead Technology Co.). Continuous variables were summarized as mean ± standard deviation (SD) to describe central tendency and dispersion. Associations between variables were examined using the Pearson correlation coefficient, allowing assessment of the strength and direction of linear relationships. A significance level of $p < 0.05$ was adopted to determine statistical significance across all tests. To further explore predictive relationships, regression analysis was performed, enabling evaluation of the extent to which independent variables contributed to variation in the dependent outcomes.
In addition to Pearson correlation analysis, multiple linear regression analysis was performed to evaluate the predictive effect of the saddle angle on skeletal parameters (ANB, SNB, and SN–MP). Saddle angle was considered the independent variable, while each cephalometric parameter was treated as a dependent variable in separate models. There was no difference between males and females, and the age difference was non-significant, so the data were pooled for further analysis. Regression coefficients (β), standard errors, and significance levels were calculated. A p-value < 0.05 was considered statistically significant.
The coefficient of determination (R^2) was calculated for each regression model to quantify the proportion of variance in the dependent variable explained by the saddle angle.

Results

The mean saddle angle was 130.8 ± 5.2, exceeding the Libyan normal value (126.5 ±4.8). The difference is statistically significant (P-value < 0.01), and other cephalometric parameters are shown in Table 1.

Table 1. Differences between different parameters in Class II and normal values

Measurement	Class II mean ± SD	Normal value mean±SD	P value
Saddle angle (NS-Ar)	130.8±5.2	126.5±4.8	<0.01
SNA	82.6±3.1	81.5±2.7	0.08
SNB	74.3±3.8	78.0±2.9	<0.001
ANB	6.1±1.5	2.0±1.5	<0.001
SN-MP	37.2±4.2	33.2±3.5	<0.01

SNA shows statistically a non-significant increase (P=0.08), SNB shows a significant decrease (P<0.001), ANB significantly increased (p<0.001), and SN–MP is significantly increased (p<0.01).

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Figure 2 shows the comparison between the class II and normal Libyan values.

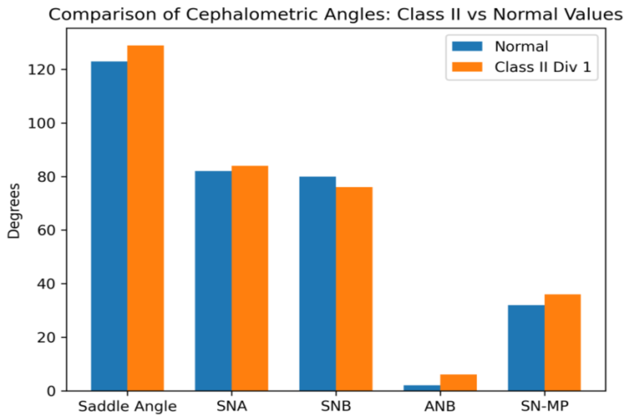

Figure 2: comparison of different cephalometric angles, Class II vs Normal valued

Correlation Findings

The correlation statistics in Table 2 show that the saddle angle vs. SNA shows a weak positive correlation (r=0.12, p=0.19), saddle angle vs. SNB indicates a moderate negative correlation (r= 0.38, p=0.001), saddle angle vs. ANB shows a moderate positive correlation (r = 0.42, p< 0.001), and the saddle angle vs. SN–MP shows a moderate positive correlation (r= 0.30, p=0.005). Figure 3 shows the distribution of saddle angle across the sample, and Figures 4, 5, and 6 show the correlation between saddle angle and other variables.

Table 2: Pearson correlation between saddle angle and other variables

Variable	r-value	p-value
Saddle angle vs. SNA	0.12	0.19
Saddle angle vs. SNB	-0.38	0.001
Saddle angle vs. ANB	0.42	<0.001
Saddle angle vs.SN-MP	0.30	0.005

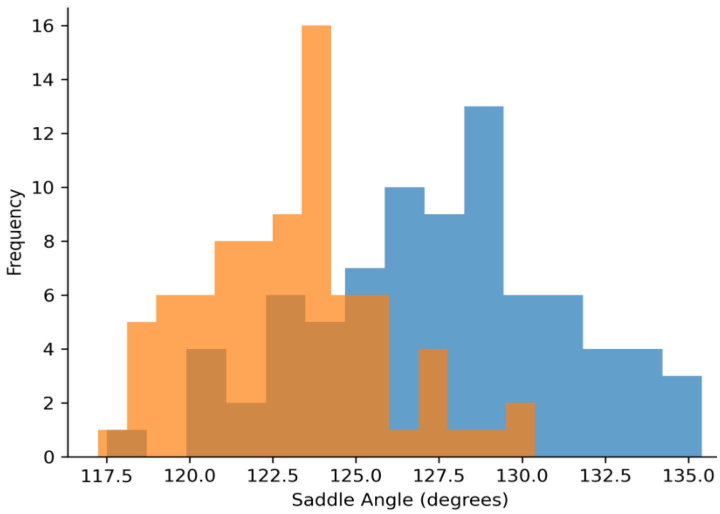

Figure 3: Distribution Histogram, right-shifted distribution indicating increased saddle angle across the sample.

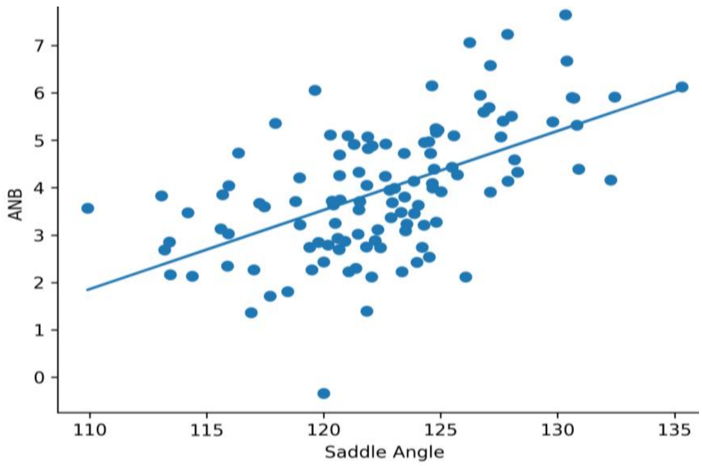

Figure 4: Scatter Plot (Saddle Angle vs. ANB), positive linear relationship confirming moderate correlation between cranial base flexure and sagittal discrepancy.

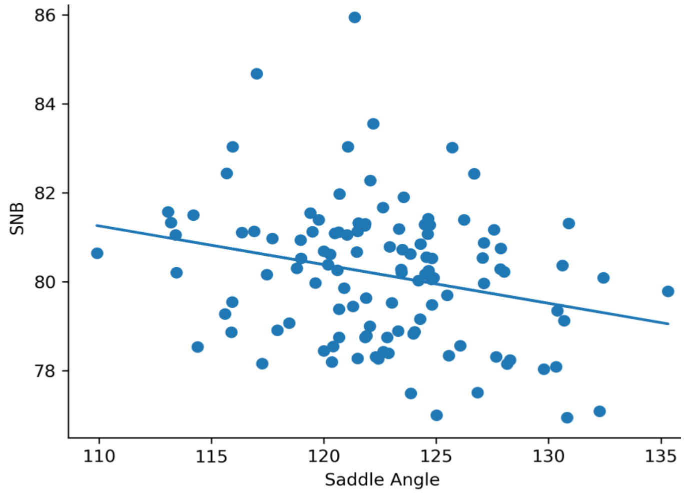

Figure 5: Scatter Plot (Saddle Angle vs. SNB), negative linear relationship confirming moderate correlation between cranial base flexure and mandibular retrusion.

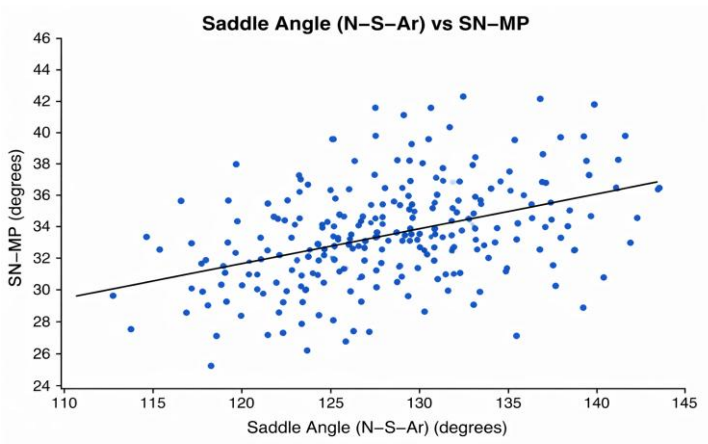

Figure6: Scatter plot demonstrating a positive correlation between saddle angle and SN-MP suggesting an association between cranial base flexure and vertical growth tendency.

Regression analysis demonstrated that the saddle angle was a significant predictor of sagittal and vertical skeletal relationships. Saddle angle showed a significant positive effect on ANB ($\beta = 0.38$, $p < 0.001$), indicating that an increase in cranial base flexure is associated with increased sagittal discrepancy. A significant negative association was observed between saddle angle and SNB ($\beta = -0.34$, $p = 0.002$), confirming that increased saddle angle contributes to posterior positioning of the mandible. Saddle angle was also a significant predictor of vertical growth tendency ($\beta = 0.27$, $p = 0.006$), suggesting an association

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with increased mandibular plane angle. The effect of saddle angle on SNA was not statistically significant (β = 0.10, p = 0.18) table 3, indicating a weak effect on maxillary sagittal position.

Table 3: Regression Analysis

Dependent variable	β Coefficient	Standard Error	p-value
ANB	0.38	0.07	<0.001
SNB	-0.34	0.09	0.002
SN-MP	0.27	0.08	0.006
SNA	0.10	0.08	0.18

The coefficient of determination (R^2) values indicated that the saddle angle accounted for a moderate proportion of the variance in sagittal and vertical skeletal parameters, with the highest explanatory value observed for ANB. The regression model for ANB demonstrated an R^2 value of 0.18, indicating that approximately 18% of the variation in sagittal discrepancy can be explained by changes in the saddle angle. For SNB, the R^2 value was 0.14, suggesting that saddle angle explains 14% of the variability in mandibular position. The model for SN–MP showed an R^2 value of 0.09, reflecting a weaker but still meaningful association with vertical growth pattern. The R^2 value for SNA was low (R^2 = 0.01), confirming the minimal influence of saddle angle on maxillary position.

Discussion

The findings of this study highlight the significant role of the saddle angle in shaping the skeletal characteristics of Class II Division 1 malocclusion in Libyan patients. The observed increase in saddle angle beyond Libyan normative values [22] suggests a structural predisposition toward posterior mandibular positioning. This is strongly supported by the negative correlation between saddle angle and SNB, indicating that as cranial base flexure increases, the mandible tends to be positioned more posteriorly. Similar findings have been reported in earlier studies, reinforcing the importance of cranial base morphology in sagittal discrepancies [8,11,24]. Interestingly, the relationship between saddle angle and SNA was relatively weak. This suggests that maxillary position is less influenced by cranial base flexure compared to mandibular position. Clinically, this supports the view that Class II Division 1 malocclusion in Libyan patients is predominantly a mandibular problem rather than a maxillary one, which aligns with findings in Middle Eastern populations [16,17].

The strong positive correlation with ANB confirms that saddle angle plays a direct role in determining the severity of sagittal discrepancy. As the saddle angle increases, the relative position between the maxilla and mandible becomes more divergent, resulting in a higher ANB value. This relationship has also been emphasized in classical cephalometric analyses [9,12]. Another important finding is the association between saddle angle and vertical growth pattern (SN–MP). The positive correlation indicates that increased cranial base flexure is linked to a more vertical facial pattern. This may be explained by rotational changes in mandibular growth direction, which have been previously described in growth studies [24,25]. When compared to other populations, Libyan patients show the greatest similarity to Middle Eastern groups, where increased saddle angles and mandibular retrusion are commonly observed [16–18]. In contrast, East Asian populations often exhibit smaller saddle angles and a greater contribution of maxillary protrusion to Class II malocclusion [19,20]. African populations, while sometimes presenting with larger cranial base angles, tend to maintain stronger mandibular projection, resulting in a different skeletal balance [21].

The regression analysis further strengthens the findings of this study by demonstrating that the saddle angle is not only correlated with skeletal parameters but also serves as a significant predictor of sagittal discrepancy and mandibular position. The strongest predictive effect was observed for ANB, indicating that cranial base flexure plays a substantial role in determining the severity of Class II skeletal relationships. The negative regression coefficient for SNB confirms that mandibular retrusion is the primary mechanism through which saddle angle influences malocclusion, rather than maxillary protrusion. These findings enhance the clinical value of saddle angle assessment as a diagnostic and predictive parameter. These differences underline the importance of using population-specific norms rather than relying on universal standards.

The R^2 values obtained in this study suggest that, although the saddle angle is a statistically significant predictor of skeletal relationships, it explains only a moderate proportion of the observed variability. This indicates that additional anatomical and functional factors contribute to the development of Class II malocclusion. While statistically significant, the R^2 values indicate that the saddle angle alone cannot fully account for the complexity of sagittal and vertical discrepancies, reinforcing the multifactorial nature of craniofacial growth.

Saddle angle cannot be altered by orthodontic treatment nor orthognathic surgery, so from a clinical standpoint, evaluating the saddle angle provides valuable insight into the underlying skeletal pattern. In cases with increased saddle angle, treatment approaches should focus more on mandibular advancement or growth modification rather than solely addressing maxillary position. Libyan orthodontists and maxillofacial surgeons need to understand these variations and the limitations of treatment in order to plan a good strategy based on local standards.

Conclusion

This study highlights the saddle angle as a critical structural determinant of craniofacial relationships in Libyan patients with Class II Division 1 malocclusion. An increased saddle angle was consistently linked to posterior mandibular positioning (reduced SNB), greater sagittal discrepancy (elevated ANB), and a vertical growth tendency (higher SN–MP values). These associations underscore the importance of cranial base morphology in both sagittal and vertical dimensions of malocclusion. The predictive strength of the saddle angle, demonstrated through regression analysis, confirms its role as a contributing factor rather than a sole determinant of skeletal Class II malocclusion. Moreover, the craniofacial characteristics observed in this Libyan cohort appear to align with Middle Eastern populations, suggesting shared genetic and developmental influences. This finding emphasizes the need for ethnic-specific diagnostic standards in orthodontics. Future research employing longitudinal designs and three-dimensional imaging is recommended to further elucidate the dynamic role of cranial base morphology in facial growth and orthodontic treatment outcomes.

Conflict of interest. Nil

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