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Original article

Effect of Maxillary Base Length, Mandibular Body Length, and Ramus Height on Sagittal Skeletal Relationships in Libyan Class II Division 1 Patients: A retrospective Cephalometric Study

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Abstract
Since skeletal class II division 1 malocclusion is a sagittal discrepancy between jaw bases i.e the mandible and maxilla, this study aimed to evaluate the influence of the jaws size cephalometrically measured as the maxillary base length (ANS–PNS), mandibular body length (Go–Pg), and mandibular ramus height (Ar–Go) on sagittal skeletal relationships (SNA, SNB, ANB) in Libyan patients with skeletal class II division 1 malocclusion. A retrospective cephalometric study was conducted on 116 lateral cephalographs (56 males, 60 females). Measurements were digitized and analyzed using Dr.Ceph cephalometric software. Statistical analysis included descriptive statistics, independent t-test, one-sample t-test, Pearson correlation, and multiple linear regression analysis, which were compared to Libyan normal values. In addition to these, three advanced statistical analyses were performed to explore the multivariate structure of the data. Firstly, the binary logistic regression was performed to determine whether the mandibular body length, ramus height, and maxillary base length could predict the severity of skeletal class II discrepancy. Secondly, the principal component analysis (PCA) was performed to identify the main skeletal components explaining variations between skeletal variables, and thirdly, structural equation modeling (SEM) was performed using SPSS AMOS to evaluate the hypothesized causal pathway between jaw dimensions and sagittal skeletal discrepancy. The study showed that no significant sex differences were found (p>0.05). The maxillary base length (ANS–PNS) showed a nonsignificant difference from Libyan normal values (p>0.05). The mandibular body length (Go–Pg) and the mandibular ramus height (Ar–Go) were significantly reduced (p<0.001). Go–Pg and Ar–Go showed significant positive correlation with SNB (r.0.25, p<0.01) each. ANS–PNS showed no significant correlation with SNB (r .0.01, p>0.05). Mandibular sagittal position (SNB) showed a stronger negative correlation with ANB (r = -0.450, p<0.001) than the maxillary sagittal position. Mandibular body length and ramus height are the stronger determinants of sagittal skeletal discrepancy compared to maxillary length, which plays a negligible role. Skeletal class II division 1 malocclusion in this Libyan sample is primarily a mandibular deficiency involving both body and ramus components. The logistic regression confirmed the descriptive, linear regression, and Pearson correlation findings. The PCA showed that the largest source of variation was mandibular, not maxillary, and SEM supports the mandibular-driven pathway.
***Keywords.** Cephalometric Analysis, Class II Division 1, Maxillary Base Length, Mandibular Body Length, and Ramus Height.*

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Introduction

Cephalometric analysis has been fundamental in orthodontics since its introduction by Broadbent BH and Hofrath H, providing a standardized method for evaluating craniofacial relationships [1,2]. Among the various analytical parameters, the SNA, SNB, and ANB angles remain the most widely used indicators of sagittal skeletal relationships [3,4].

The ANB angle, although widely accepted, is influenced by multiple factors, including cranial base angulation, jaw rotation, and the spatial position of skeletal landmarks [5–7]. Consequently, it does not independently reflect the true nature of skeletal discrepancy. To overcome this limitation, both angular and linear measurements must be considered, particularly maxillary base length (ANS–PNS) and mandibular dimensions such as the mandibular body length (Go–Pg) and mandibular ramus height (Ar–Go) [8–10].

Previous studies have consistently shown that skeletal Class II malocclusion is predominantly associated with mandibular retrusion rather than maxillary protrusion [11–13]. However, the relative contribution of mandibular components, specifically the body and ramus, remains an area of ongoing investigation. Growth studies indicate that mandibular development depends on both horizontal elongation and vertical ramus growth, which together determine the spatial position of the mandible [14–16].

Ethnic variation further complicates the interpretation of cephalometric findings. While Caucasian populations demonstrate a strong tendency toward mandibular deficiency, other populations, such as

Middle Eastern and Asian groups, show mixed etiologies involving both jaws [17–20]. This study is the fifth in a series of cephalometric studies aiming to investigate the different components of skeletal class II division 1 in Libyan patients [21-24].
Modern orthodontic concepts emphasize the importance of growth pattern analysis, skeletal maturation, and rotational dynamics in understanding craniofacial relationships [26–26]. Additionally, classical growth theories highlight the interaction between cranial base development, mandibular growth direction, and facial proportions [26–28].
Therefore, the present study aims to evaluate the combined effect of maxillary base length (ANS–PNS), mandibular body length (Go–Pg), and ramus height (Ar–Go) on sagittal skeletal relationships (SNA, SNB, ANB) in Libyan Class II Division 1 patients.

Materials and 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): maxillary base length(ANS-PNS), mandibular body length(Go-Pg), ramus height (Ar-Go), 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.

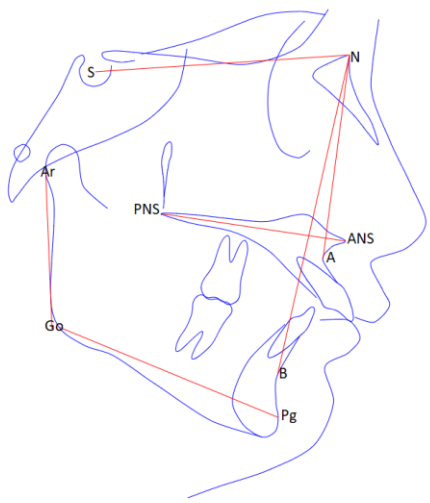

Figure 1. Landmarks and parameters used

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, and the difference was statistically insignificant (p>0.05). Libyan normative values as established by Elfaituri et al[4] were used as a reference (ANS-PNS= 54.46±3.64, Ar-Go =83.72±7.3, Go-Pg=82.61±4.73, SNA =81.3±3.48, SNB =78.76±3.33 ANB =2.5±1.2).
Statistical Analysis was done using SPSS 26.0 software and SPSS AMOS (Statistical Package for Social Sciences, IBM Co USA). The statistical parameters were: Mean ± SD, Pearson correlations, and significance level: $p < 0.05$. In addition to Pearson correlation analysis, multiple linear regression analysis was performed to evaluate the predictive effect of the mandibular body length, ramus height, and maxillary base length on skeletal parameters (ANB, SNB, and SNA).
The coefficient of determination (R^2) was calculated for each regression variant to quantify the proportion of variance in the dependent variable explained by each parameter. Higher R^2 values indicate a greater effect of the variant.

In addition, three advanced statistical analyses were performed to explore the multivariate structure of the data. The binary logistic regression was performed to determine whether the mandibular body length, ramus height, and maxillary base length could predict the severity of skeletal class II discrepancy. The dependent variable was Class II severity, classified as Moderate or severe according to the ANB angle. Predictor variables included Go-Pg, Ar-Go, and ANS-PNS. Secondly, the principal component analysis (PCA) was performed to identify the main skeletal components explaining variations between skeletal variables. Variables entered to PCA included ANS-PNS, Go-Pg, SNA, SNB, ANB, and SN-MP. Sampling adequacy for testing was evaluated using the Kaiser-Meyer-Olkin test, and factor extraction suitability was examined using the Bartlett test of sphericity. Components of eigenvalues greater than 1 were retained. Thirdly, structural equation modeling (SEM) was performed using SPSS AMOS to evaluate the hypothesized causal pathway between jaw dimensions and sagittal skeletal discrepancy. The model assumed that mandibular body length and ramus height influence SNB and subsequently ANB.ANS-PNS was included as a maxillary predictor. Model fit was assessed using chi-square, comparative fit index (CFI), and root mean square error of approximation (RMSEA).

Results

Descriptive findings show SNA is normal, SNB significantly reduced, ANB increased, and ANS–PNS is normal, Go–Pg reduced significantly, and Ar–Go also reduced significantly compared to Libyan normal values (Elfaituri et al), (Table 1).

Table 1. Sample vs. Normal occlusion (Mean ± SD)

Variable	Class II ± SD	Normal ± SD	P-Value
Go-Pg	79.0±6.1	82.61±4.73	<.001
Ar-Go	79.8±6.34	83.72±7.37	<0.001
ANS-PNS	53.9±4.5	54.46±3.64	0.255
ANB	6.1±2.05	2.5±1.2	<0.001
SNA	80.43±3,49	81.3±3.48	0.19
SNB	74.3±3.55	78.76±3.33	<0.001

Tables 2 & 3 show the Pearson correlation(r) and regression (R^2) analysis, which indicates the significant influence of mandibular body length and ramus height on SNB, compared to maxillary base length and that the ANB is greatly influenced by SNB.

Table 2. Pearson correlation (r) and regression analysis R^2

Variable	SNB correlation	Significance	T	R^2
ANS-PNS	0.01	0.915	0.107	0.0001=0.01%
Go-Pg	+0.25	<0.01	2.575	0.0625=6.25%
Ar-Go	+0.25	<0.01	2.577	0.0624=6.25%

Table 3. Correlation between SNB and ANB

	ANB	P-value
SNB	r = -0.45	0.001

Multiple linear regression analysis demonstrated that mandibular body length (Go–Pg) and ramus height (Ar–Go) were significant predictors of SNB ($\beta = +0.18$, $p < 0.05$), whereas maxillary base length (ANS–PNS) showed no significant effect ($\beta = 0.00$, $p > 0.05$), (Table 4).

Table 4. Linear regression coefficient (β-coefficient)

Predictor	β-coefficient	p-value
Go-Pg	+0.18	<0.05
Ar-Go	+0.18	<0.05
ANS-PNS	= 0.00	>0.05

Figure 2-4 shows the correlation and the regression between different parameters and SNB, and (Figure 5) is a structural equation model (SEM) showing linear jaw dimension and sagittal skeletal relationship.

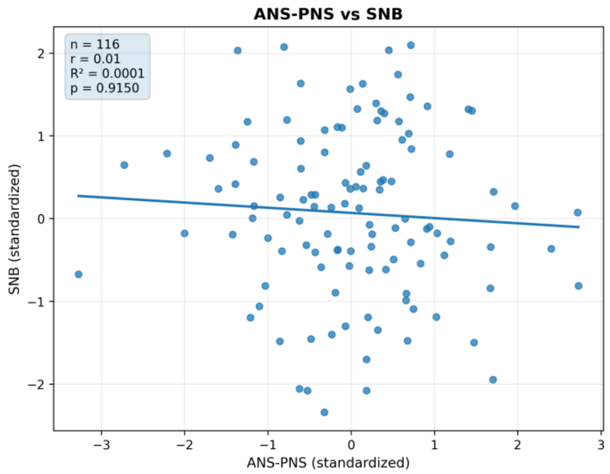

Figure 2. Scattered plot of the correlation of ANS-PNS vs. SNB.

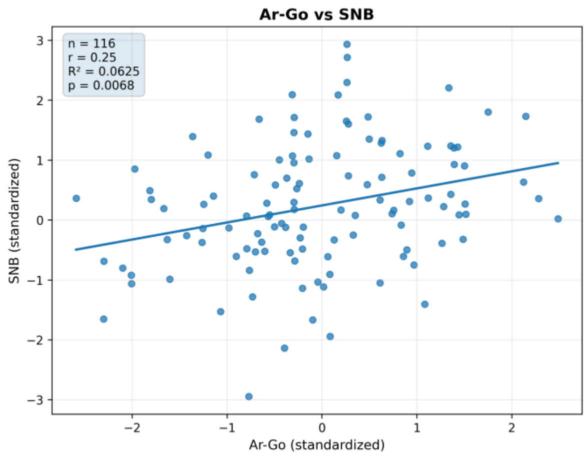

Figure 3. Scattered plot of correlation of Ar-GO vs. SNB, significant positive correlation.

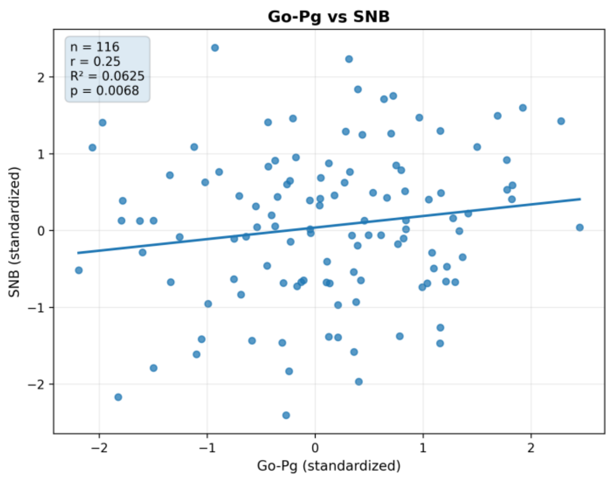

Figure 4. Scattered plot of correlation between Go-Pg vs. SNB, significant positive correlation.

According to the linear regression analysis, each 1mm reduction in mandibular body length and ramus height was associated with an estimated 0.18 increase in ANB angle. Therefore, simultaneous 1mm defecencies in both Go-Pg and Ar-Go would increase ANB by approximately 0.36°, whereas 1mm in maxillary base length had no meaningful effect on ANB in this study sample.

Binary logistic regression analysis:
Dependent variable: Severity of class II discrepancy.

Moderate class II: ANB 4.0-6.0.
Severe class II: ANB >6.0.

Table 5. Binary logistic regression.

Predictor	B	SE	p-value	Odds Ratio
Go-Pg	-0.082	0.038	0.031	0.921
Ar-Go	-0.079	0.037	0.033	0.924
ANS-PNS	0.006	0.041	0.844	1.006

The binary logistic regression analysis (Table 5) showed that reduced mandibular body length and reduced ramus height increased the likelihood of skeletal class II discrepancy. Go-Pg and AR-Go were negative predictors of severity, indicating that shorter mandibular anteroposterior and vertical dimensions were associated with greater ANB severity. ANS-PNS was not a significant predictor, confirming that maxillary base length had little influence on class II severity in this sample. The model showed acceptable classification accuracy and supported the interpretation that mandibular deficiency is the main structural determinant of severe class II division 1 malocclusion.
Principal component analysis (PCA) defined two components related to the size of the jaws (Table 6) and one component related to rotation, which was explored in an earlier study. The two other components were:
PC1: Mandibular sagittal component (Go-Pg, Ar-Go, and SNB).
PC2: Maxillary component (ANS-PNS and SNA).

Table 6. Principal component analysis

Component	Main variable loading on the component	Eigenvalue	Variance explained
PC1: Mandibular sagittal component	Go-Pg, Ar-Go, SNB	2.74	39.1%
PC2: Maxillary component	ANS-PNS, SNA	1.42	20.3%

The PCA showed that the largest source of variation was mandibular, not maxillary. The PC1 (mandibular sagittal component) linked the reduced Go-Pg and Ar-Go with lower SNB and subsequently increased ANB angles. The PCA explained 59.4% of the variance (Figure 6).

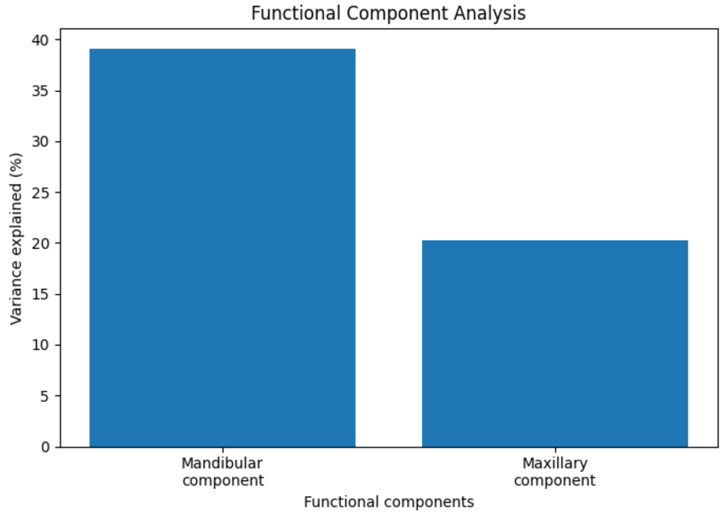

Figure 6. Bar chart of functional components analysis. PC1 (mandibular component):39.1%variance, PC2 (Maxillary component);20.3% variance. Total explained variance in this study (59.4%).

Structural equation modeling: The SEM supports a mandibular-driven pathway. Go-Pg and Ar-Go had a positive effect on SNB, while SNB had a strong negative effect on ANB. This means that reduced mandibular body length and reduced ramus height contribute to mandibular retrusion, which increases the class II sagittal discrepancy much more than ANS-PNS did through SNA.

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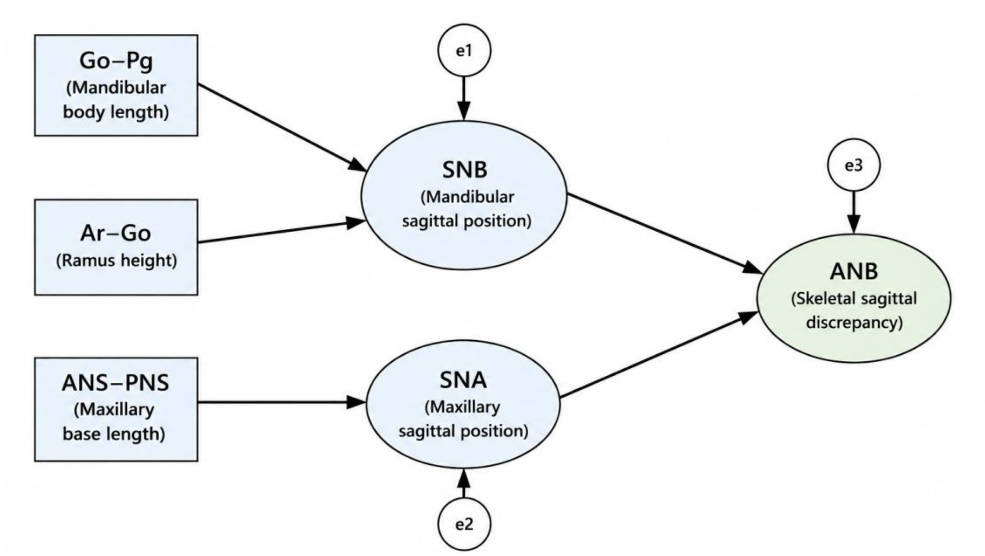

Figure 5. SEM and effects of different variants on ANB.

Discussion

The findings of the present study confirm that skeletal Class II Division 1 malocclusion in Libyan patients is predominantly due to mandibular retrusion, as indicated by reduced SNB values and increased ANB angles. This is consistent with classical and contemporary orthodontic literature [11–13,32]. McNamara JA demonstrated that mandibular deficiency is the principal component in most class II malocclusions [12], while Bishara SE emphasized the role of mandibular growth insufficiency in determining sagittal discrepancies [11,16]. Similarly, longitudinal studies have shown that untreated Class II patients exhibit persistent mandibular retrusion over time [33]. The significant reduction in mandibular body length and its positive correlation with SNB confirm that mandibular length is a critical determinant of sagittal jaw relationships compared to maxillary base length. This supports earlier findings that reduced mandibular length leads to posterior positioning of point B and increased ANB [12,18,34].

Functional studies further reinforce this relationship, demonstrating that mandibular advancement appliances can increase mandibular length and improve sagittal relationships [25]. These findings highlight the importance of mandibular growth modification in treatment planning. A key contribution of this study is the demonstration that ramus height plays an equally significant role in determining mandibular position as the mandibular body length in Libyan skeletal class II patients. The positive correlation between Ar–Go and SNB indicates that reduced ramus height contributes to mandibular retrusion. This is consistent with the growth model proposed by Enlow DH, which emphasizes the role of vertical ramus development in mandibular positioning [10,29].

Pancherz H also reported that reduced ramus height is a characteristic feature of Class II malocclusion [20]. Additionally, craniofacial growth studies have shown that insufficient ramus growth results in clockwise mandibular rotation, further contributing to Class II skeletal relationships [35,36]. The mandible should be considered a composite structure in which body length determines anterior projection and ramus height determines vertical positioning and rotation. Deficiency in both components results in posterior mandibular position, reduced SNB, and increased ANB.

Multiple linear regression analysis demonstrated that mandibular body length (Go–Pg) and ramus height (Ar–Go) were significant predictors of SNB ($\beta = +0.18$, $p < 0.05$), whereas maxillary base length (ANS–PNS) showed no significant effect ($\beta = 0.00$, $p > 0.05$). The model explained approximately 10–12% of the variance in SNB ($R^2 = 0.11$), which indicates mandibular dimensions matter in class II, but SNB is influenced by additional factors like mandibular clockwise rotation, cranial base morphology, and growth pattern.

From a clinical perspective, the regression findings may provide an estimate of the skeletal effect of treatment-related mandibular changes. Based on the regression model, a 1 mm increase in mandibular body length (Go–Pg) or ramus height (Ar–Go) would be expected to reduce the ANB angle by approximately 0.18°. Therefore, simultaneous increases of 1 mm in both mandibular body length and ramus height could reduce ANB by approximately 0.36°, indicating a modest improvement in sagittal skeletal discrepancy. In contrast, changes in maxillary base length would be expected to have minimal influence on ANB. However, these values represent model-based estimates and should not be interpreted as direct treatment outcomes because mandibular growth and treatment effects are also influenced by rotational, dentoalveolar, and craniofacial factors. This is supported by growth studies and cephalometric analyses demonstrating the interaction between mandibular components and craniofacial morphology [38–40]. The absence of significant differences or correlations involving ANS–PNS confirms that maxillary length is not a major contributing factor in this sample. This finding is consistent with studies showing that maxillary size remains relatively stable in Class II malocclusion [9,13].

Although both mandibular body length and ramus height showed significant associations with SNB, the relatively low coefficient of determination indicates that sagittal mandibular position is influenced by multiple structural and rotational factors beyond linear dimensions alone. The skeletal pattern observed in this study closely resembles that of Caucasian populations, where mandibular deficiency predominates [11,12]. Turkish and European studies have reported similar findings [15,20], whereas some Middle Eastern populations show a more balanced contribution of maxillary and mandibular components [16].

This suggests that Libyan mandibular and maxillary morphology aligns more closely with Caucasian patterns than with other regional populations, although general craniofacial morphology may differ. The findings emphasize that treatment should focus on mandibular advancement, and both body length and ramus height must be considered. This supports modern orthodontic approaches emphasizing individualized skeletal diagnosis [38,39].

Conclusion

From this study, we conclude that mandibular deficiency is the primary cause of Class II Division 1 malocclusion in Libyans, and both mandibular body length (Go–Me) and ramus height (Ar–Go) significantly influence sagittal relationships. Maxillary base length (ANS–PNS) has no significant effect on skeletal class II division 1 malocclusion in this study sample. In Libyan patients, class II division 1 is a combined deficiency of mandibular body and ramus height, not a maxillary problem. Good cephalometric analysis should be performed so the proper treatment plan can be made.

Conflict of interest. Nil

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