Anterior cranial base features in skeletal Class III patients with maxillary recession: A cephalometric study

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Aim: The relationship of anterior cranial base to midface dimensions in skeletal Class III malocclusions is said to be unclear. The purpose of this retrospective study was to investigate and correlate various cephalometric parameters depicting anterior cranial base and cranial base flexure to maxillary dimensions in skeletal Class III malocclusions. Methods: Lateral cephalometric radiographs of 60 skeletal Class III subjects aged 16 to 29 years comprising 30 cases with maxillary retrusion (group A) and 30 cases with normal maxillae (group B) were analyzed for 14 variables, along with 60 skeletal Class I controls (group C) matched for both age and sex. Results: The Bonferroni multiple comparison and ANOVA tests revealed a statistically significant decrease of maxillary (Co-A, Ptm-A, ANS-PNS) and anterior cranial base (S-N, S-Ca) linear dimensions (P < .001) as well as a decrease in N-S-Co (P < .001) and N-S-Ar (P < .05) in group A subjects. Comparison of ratios of the skeletal dimensions to each of the maxillary dimensions showed statistically significant increased values for group A (P < .001). The Pearson correlation coefficient showed a positive correlation between each cranial base parameter and the maxillary parameters (P < .001). Conclusion: The anterior cranial base dimensions were found to be decreased in only skeletal Class III cases with maxillary deficiencies. Significant decrease of angle N-S-Co may prove diagnostically reliable in maxillary retrusion. Significant positive correlations were found to exist between each cranial base parameter and the maxillary parameters. The strongest correlation was observed between S-N and Co-A, and the weakest with respect to S-Ca and ANS-PNS. ORTHODONTICS (CHIC) 2012;13:e105–e115.

Key words: anterior cranial base, maxillary recession, skeletal Class III

The cranial base area of the craniofacial complex has long been an area of keen interest to orthodontists since it has a very important role in determining anteroposterior jaw relationships. It can be described as a pivotal structure divided by the sella into an anterior leg extending up to the frontonasal suture (nasion) and a posterior leg extending to the anterior border of the foramen magnum (basion). These two legs form a flexure with the anterior leg articulating with the maxilla and posterior leg with the mandible. Changes in proportions of the cranial base would thus be definitely manifested in that part of the face to which it is attached.¹,²

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A challenging factor in the diagnosis and treatment of skeletal Class III malocclusion is its etiologic diversity. Numerous studies have been conducted to determine the morphologic variability of the craniofacial complex in patients with Class III malocclusions. Sanborn reported a prevalence of 45.2% mandibular protrusion and 33% maxillary retrusion in his sample of skeletal Class III patients, whereas 9.5% had a combination of both skeletal deviations. The prevalence reported by Ellis and McNamara is much lower at 19.5% and 19.2% for maxillary retraction and mandibular protrusion, respectively. Guyer et al. also confirms various combinations of maxillary deficiency (25%) and mandibular excess (20%) in skeletal Class III malocclusions.

Development of the maxilla, both in terms of size and position, has been shown to be an important etiologic factor in skeletal Class III malocclusions as evidenced by linear analysis. In fact, most of the characteristic aberrations associated with adult Class III malocclusions are said to be evident at an early age. It can be concluded that Class III malocclusions can exist with any number of combinations of skeletal and dentoalveolar components within the facial skeleton. There are abundant studies in the literature confirming a correlation between the dimensions of the posterior leg of the cranial base and cranial flexure angle to mandibular position. A reduced length of anterior cranial base in Class III subjects has also been reported. But this is not supported by Proff et al., whose study failed to show a significant reduction in anterior cranial base length in skeletal Class III patients in spite of an overall shortening of the total cranial base, which was attributed to various minor alterations. The role of the maxilla in skeletal Class III malocclusions is controversial. Some authors have described the maxilla to be small and some retrognathic, while others have found it to be similar to a normal Class I occlusion. All the above studies have focused on cranial base and maxillary and mandibular parameters of skeletal Class III malocclusions on the whole. However, the etiologic diversity of skeletal Class III malocclusions necessitates a skeletal differentiation of different combinations of Class III while correlating cranial base parameters to individual maxillomandibular dimensions.

Until about the age of 7, secondary displacement due to cranial base growth is a major contributor to the downward and forward growth of the maxilla and midfacial regions. As age advances, growth of the cranial base decreases, obviously diminishing its contribution to this secondary displacement. Primary displacement and sutural growth take over as the mechanisms for bringing the maxilla further forward. Thus, any deficiencies in growth of the cranial base would obviously affect the midface.

The Enlow counterpart theory stresses the importance of harmony in growth patterns of the various parts and counterparts of the face. According to the Enlow counterpart principles, the cranial base sets structural limits for the spatial and thus morphologic development of facial elements. Enlow assumes that the morphology of the basicranium is molded by the development and evolution of the brain lobes. A developmental sequence of morphologic maturation implies that once the brain and basicranium have ceased growth, a structural (ie, spatial) basis is set up on which facial structures are suspended during their remaining development. He further suggested a spatial correspondence between the anterior cranial base and the nasomaxillary complex. Also, it is reported in the literature that failure of the cranial base to lengthen normally, as in achondroplasia and several congenital syndromes, creates a characteristic midface deficiency.
A linear ratio was established\(^1\) between the anterior cranial base (SN) and mandibular length (20:21). However, no study exists in the literature correlating cranial base features to maxillary anteroposterior parameters in skeletal Class III cases, and there is no proposed ratio between the cranial base length and the maxillary length in spite of documented evidence showing that skeletal Class III cases show a maxillary retrusive component in 42.5\(^8\), 47.5\(^1\), and 49.5\(^5\) of the population.

The etiology and expression of a malocclusion must be understood before it can be clinically corrected. This is because the modality of intervention in growth modification will vary depending upon the location of the anomalous growth pattern in interceptive orthodontic procedures. The available literature on skeletal Class III anomalies shows that the number of studies on clinical management and therapeutic outcomes clearly outweigh those focusing on morphologic and developmental aspects of these malocclusions. This is particularly true with regard to the maxilla and its relationship to the anterior cranial base. In fact, the basicranial maxillary relationship in skeletal Class III has been reported to be unclear.\(^2\) Therefore, this controlled study aims to investigate the relationships of various cephalometric parameters of the anterior cranial base to maxillary dimensions in skeletal Class III patients with and without maxillary retrusion.

A significant decrease in cranial base flexure angle has been reported in skeletal Class III malocclusions with mandibular prognathism. The relationship of this angle to maxillary position or dimension has not been reported so far. The effect of the saddle angle (N-S-Ar) and N-S-Co on midfacial dimensions is also not known. It is possible that changes in these cranial base angles could also reflect alterations in midfacial dimensions.

This investigation tested several null hypotheses: (a) the anterior cranial base has no effect on the maxillary and midfacial dimensions; (b) the cranial base angles N-S-Ba, N-S-Ar, and N-S-Co have no influence on maxillary anteroposterior dimensions; and (c) there is no correlation between anterior cranial base and maxillary length.

**METHODS**

This retrospective study was based on pretreatment lateral cephalometric radiographs of 120 patients obtained from the Department of Orthodontics, Government Dental College, Calicut, Kerala, India. Only radiographs with Frankfurt horizontal plane parallel to the floor, lips in a relaxed position, and teeth in maximum intercuspation were included. The study was approved by the institutional ethics committee.

The initial sample consisted of pretreatment lateral cephalometric radiographs of 84 patients with skeletal Class III malocclusions retrieved from the records of the Department of Orthodontics based on the following inclusion criteria: growth largely completed (16 to 26 years of age in females, 17 to 29 years of age in males); ANB < –1 degree; Wits appraisal < –3 mm; and presence of a mesial occlusion.

Lateral cephalograms were hand-traced onto 0.003-inch matte acetate paper with a sharpened 2H lead drafting pencil by the same investigator. Landmark identification was verified. Bilateral images were bisected and treated as midline structures. Linear measurements were recorded with a digital vernier caliper (6-inch, 0.01-mm accuracy; 500-196-20 Absolute Digimatic Digital Caliper, Mitutoyo). Angular measurements were made with a semicircular protractor to the nearest 0.5 degree. Any disparities were addressed by retracing the structure. Based on maxillary effective length (Co-A), two subgroups were
identified—a maxillary retrusion group (group A, 15 males and 15 females) and a nonmaxillary retrusion group (group B, 14 males and 16 females).

Thus, a total of 60 skeletal Class III cases were selected (Fig 1). Sample size was determined after a power calculation was made based on a previous study showing dimensional variation of anterior cranial base in Class III subjects. Following this, lateral cephalometric radiographs of 60 Class I subjects matched for both age and sex were retrieved from the departmental records to be used as a control group (group C, 29 males and 31 females). The inclusion criteria for the control group were ANB, 1 to 4 degrees; Wits appraisal, −1 to 3 mm; and the presence of a neutral occlusion.

To test reliability, 20 randomly selected cephalograms were retraced after 2 weeks by the same investigator. The level of agreement was evaluated using the Cronbach alpha. All the scores exhibited high agreement (Table 1).
Patients with the presence of craniofacial disorders (eg, cleft anomalies and craniosynostosis) and facial asymmetries, missing or extracted teeth, and history of previous orthodontic or orthopedic treatment before the cephalogram was taken were excluded from the study. The records of patients with indications of systemic disease of orthodontic relevance or poor-quality radiographs were also excluded. The final sample consisted of 30 skeletal Class III cases with maxillary retrusion (group A), 30 skeletal Class III cases without maxillary retrusion (group B), and 60 skeletal Class I cases (group C).

Figure 2 displays the cephalometric landmarks used in this study. The linear and angular cranial base parameters suggested in the literature\(^2\) determined from these points are S-N, S-Ca, Co-A, Ptm-A, ANS-PNS, N-S-Co, N-S-Ar, and N-S-Ba. The ratios of each cranial base parameter to maxillary parameter were then calculated. They include S-N/Ptm-A, S-N/Co-A, S-N/ANS-PNS, S-Ca/Ptm-A, S-Ca/Co-A, and S-Ca/ANS-PNS.

**Statistical analysis**

All statistical analyses were performed using SPSS 13 for Windows (IBM). Descriptive statistics, including means and standard deviations (SDs), of the cephalometric parameters and their ratios were calculated for all groups. One-way analysis of variance (ANOVA) was used to identify overall differences in mean values of cranial base and maxillary retrusion parameters, their ratios, and the angles among the three groups. The level of significance was set at \( P < .05 \). When differences between groups were found to be significant, the Bonferroni test for multiple comparisons was applied. Pearson correlation coefficients and \( P \) values were used to compute the strength of association between each of the anterior cranial base measurements with the maxillary variables. Significance was determined only when the confidence level was \( P < .05 \). The association between the anterior cranial base length and maxillary length was analyzed with the aid of multiple linear regression analysis, which assesses a linear relationship between independent variables and a dependent variable and thus tests which anterior cranial base parameter is most predictive of maxillary length.
RESULTS

The means and SDs for the cephalometric measurements of all groups are presented in Table 2. The results of the Bonferroni multiple comparisons and ANOVA of the maxillary and anterior cranial base dimensions are given in Table 3 and Fig 3.

The maxillary dimensions of group A are less than groups B and C. The effective maxillary length Co-A in group A subjects shows a mean value of 80.55 ± 4.58 mm, a decrease of more than 9 mm when compared with groups B and C, which showed mean values of 90.43 ± 5.63 mm and 89.28 ± 5.53 mm, respectively. The mean values of Ptm-A and ANS-PNS also showed similar trends. Group A showed a mean value of 47.22 ± 4.61 mm for Ptm-A dimensions, whereas in groups B and C, this sagittal dimension was higher at 53.82 ± 4.95 mm and 53.72 ± 4.76 mm, respectively. The mean value of ANS-PNS dimensions in group A was 49.02 ± 2.95 mm, whereas group B showed 54.81 ± 4.89 mm and group C 55.76 ± 3.98 mm. None of these parameters showed much variation between groups B and C. Multiple comparisons using the Bonferroni test proved that the decrease observed in the mean values of Ptm-A, Co-A, and ANS-PNS in group A was statistically significant (P < .001).

The differences between groups B and C were insignificant.

The mean values of the anterior cranial base dimensions S-N (69.07 ± 4.51 mm) and S-Ca (62.91 ± 4.96 mm) were also found to be significantly decreased in group A (P < .001) compared with groups B and C. Again, there were no significant differences in anterior cranial base dimensions between group B nonmaxillary retrusion skeletal Class III subjects and group C Class I control subjects.

Among the angular measurements, the mean N-S-Ba value of 127.27 ± 5.99 degrees in group A was less than groups B and C, but the decrease was statistically insignificant. The mean value of the saddle angle, N-S-Ar (120.43 ± 7.42 degrees), however, showed a significant decrease in group A subjects as compared with the mean value of group C (P < .05); but when compared with group B, the

### Table 2  Means and SDs of the cephalometric measurements

<table>
<thead>
<tr>
<th>Cephalometric measurement</th>
<th>Group A Mean ± SD</th>
<th>Group B Mean ± SD</th>
<th>Group C Mean ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Co-A (mm)</td>
<td>80.55 ± 4.58</td>
<td>90.43 ± 5.63</td>
<td>89.28 ± 5.53</td>
</tr>
<tr>
<td>Ptm-A (mm)</td>
<td>47.22 ± 4.61</td>
<td>53.82 ± 4.95</td>
<td>53.72 ± 4.76</td>
</tr>
<tr>
<td>ANS-PNS (mm)</td>
<td>49.02 ± 2.95</td>
<td>54.81 ± 4.89</td>
<td>55.76 ± 3.98</td>
</tr>
<tr>
<td>S-N (mm)</td>
<td>69.07 ± 4.51</td>
<td>73.52 ± 4.19</td>
<td>72.71 ± 4.27</td>
</tr>
<tr>
<td>S-Ca (mm)</td>
<td>62.91 ± 4.96</td>
<td>66.64 ± 4.13</td>
<td>65.47 ± 3.77</td>
</tr>
<tr>
<td>N-S-Ba (degrees)</td>
<td>127.27 ± 5.99</td>
<td>128.73 ± 4.94</td>
<td>130.20 ± 6.06</td>
</tr>
<tr>
<td>N-S-Ar (degrees)</td>
<td>120.43 ± 7.42</td>
<td>122.60 ± 4.80</td>
<td>124.58 ± 5.97</td>
</tr>
<tr>
<td>N-S-Co (degrees)</td>
<td>121.53 ± 8.42</td>
<td>129.07 ± 7.45</td>
<td>130.20 ± 10.62</td>
</tr>
<tr>
<td>S-N/Ptm-A</td>
<td>1.4728 ± 0.1409</td>
<td>1.3730 ± 0.10218</td>
<td>1.3606 ± 0.10963</td>
</tr>
<tr>
<td>S-N/Co-A</td>
<td>0.8584 ± 0.5000</td>
<td>0.8141 ± 0.03994</td>
<td>0.8229 ± 0.06947</td>
</tr>
<tr>
<td>S-N/ANS-PNS</td>
<td>1.4134 ± 0.11829</td>
<td>1.3481 ± 0.10082</td>
<td>1.3003 ± 0.10404</td>
</tr>
<tr>
<td>S-Ca/Ptm-A</td>
<td>1.3407 ± 0.13189</td>
<td>1.2459 ± 0.11241</td>
<td>1.2260 ± 0.10734</td>
</tr>
<tr>
<td>S-Ca/Co-A</td>
<td>0.7826 ± 0.6779</td>
<td>0.7386 ± 0.05037</td>
<td>0.7420 ± 0.07490</td>
</tr>
<tr>
<td>S-Ca/ANS-PNS</td>
<td>1.2882 ± 0.12866</td>
<td>1.2248 ± 0.12837</td>
<td>1.1715 ± 0.10087</td>
</tr>
</tbody>
</table>

SD, standard deviation.
The decrease observed was insignificant. The decrease in the angular value, N-S-Co, in group A was found to be highly significant when compared with group C (P < .001) and group B (P < .05). Again, comparisons between groups B and C did not show significant differences in any of the angular parameters studied.
While correlating the dimensions of cranial base to maxilla, results of the ANOVA indicated statistically significant differences. Both S-N/Ptm-A and S-Ca/Ptm-A showed significantly higher values for group A than either groups B or C \((P < .01)\). The same holds true for the S-N/Co-A and S-Ca/Co-A ratios \((P < .01)\). With regard to the S-N/ANS-PNS ratio, the higher values obtained for group A were significant when compared with groups B and C \((P < .01)\). With regard to the S-Ca/ANS-PNS ratio, significance was detected between only groups A and C \((P < .01)\).

**Correlation coefficient test**
The Pearson correlation coefficient showed a positive correlation between each cranial base parameter (S-N and Ca-S) and the maxillary parameters (Ptm-A, Co-A, and ANS-PNS), regardless of the group \((P < .001)\) (Table 4).

**DISCUSSION**

Early diagnosis of a skeletal Class III malocclusion and identification of its etiology is extremely important in terms of interceptive orthodontic procedures. Prediction of skeletal Class III patterns based on morphologic and cephalometric parameters thus becomes an important step in diagnosis.

Available literature provides a general idea about the relationship of cranial base to skeletal Class III malocclusions, but specificity with respect to individual contributory elements is found to be lacking. This investigation is an attempt to analyze a cross section of nongrowing skeletal Class III patients based on their maxillary dimensions. In the present study, a statistically significant decrease in mean values of linear parameters depicting anterior cranial base (S-N and S-Ca) was observed in only those skeletal Class III subjects with maxillary recession (group A), as compared with those skeletal Class III subjects with normal maxillae (group B) and skeletal Class I subjects (group C). The anterior cranial base dimensions of group B were not significantly different from group C.

The mean values of the maxillary linear parameters (Ptm-A, Co-A, and ANS-PNS) of group A were also significantly less than both groups B and C, supporting previous studies.\(^8\,15\) This specifically supports the concept that the cranial base is the guide rail for the development of the maxilla.\(^7\) Obviously, the downward and forward growth of the maxilla and midface is largely dependent on cranial base growth, which is a major contributor to the growth of

<table>
<thead>
<tr>
<th>Maxillary parameters</th>
<th>Pearson correlation significance (two-tailed)</th>
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<tbody>
<tr>
<td></td>
<td>S-N</td>
</tr>
<tr>
<td>Ptm-A</td>
<td>.588</td>
</tr>
<tr>
<td>Co-A</td>
<td>.674</td>
</tr>
<tr>
<td>ANS-PNS</td>
<td>.577</td>
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</table>

Correlation is significant at the .001 level.
these regions until the completion of primary dentition period. Various previous studies have reported a decrease in anterior cranial base dimensions in skeletal Class III subjects\textsuperscript{1,3,6,7,10} without specifying the contribution of midfacial dimensions in their sample. In the present study, a closer analysis reveals the differential influence of anterior cranial base dimensions on maxillae in skeletal Class III malocclusions. The total length of the anterior cranial base (S-N) showed significant shortening of a mean 4 mm in group A. Parameters involving foramen caecum, S-Ca, also showed a similar mean decrease of 4 mm in group A. This could be due to an altered anteroposterior growth pattern of the sphenoid bone in Class III anomalies induced by spheno-occipital synchondrosis\textsuperscript{2} or as a result of pneumatization effects due to the anteroposterior and vertical deformation of the sella-sphenoid region.\textsuperscript{20} Shortening of the anterior cranial base has not been confirmed by Proff et al.\textsuperscript{2}

The cranial base flexure was studied in all the three groups. Three angles, N-S-Ba, N-S-Ar, and N-S-Co, were used for the purpose, the reason being that the basion is a point dependent on the posterior cranial base whereas the condylion is dependent on the position of condyle. Point articulare is partly influenced by both the posterior cranial base and the condyle. From Table 2, it can be seen that there is a gradual decrease in the mean values of all the three angles studied from group C via B to A. Class I controls showed a mean value of 130.2 ± 6.06 degrees for N-S-Ba, which is in agreement with the atlas by Riolo et al.\textsuperscript{20} A decrease was observed in this angle for groups B and C, but this was not statistically significant, which is in contrast to earlier findings.\textsuperscript{2} The saddle angle N-S-Ar showed a significant decrease of 4 degrees between groups A and C but not between groups A and B. The mean values of N-S-Co in group A showed a statistically highly significant reduction of 8 degrees when compared with groups C and 7 degrees with regard to group B. This implies that the posterior cranial base may have no bearing upon maxillary and midfacial dimensions, whereas the influence of the condylion is obvious. The influence of landmark articulare is evidently less than condylion probably because it is influenced by both posterior cranial base and condyle as it is formed by the intersection of these two landmarks. The significantly reduced value of N-S-Co in group A implies that the position of the condyle has a restricting effect on the anteroposterior lengthening of the midface. An interesting finding to be noted here is that this angle is not significantly reduced in group B subjects.

From a clinical standpoint, the N-S-Co angle may prove to be diagnostically valuable and more reliable than linear parameters for two reasons: (1) identifying those cases of skeletal Class III malocclusions with maxillary recession is imperative during interceptive orthodontic treatment planning and (2) error possibilities are always lesser for angular dimensions than linear ones. Future studies could thus focus on establishing normal values for N-S-Co using larger samples.

Comparison of the ratios of the skeletal parameters to each of the maxillary dimensions showed statistically significant differences. The ratios obtained in group A had significantly higher values than groups B and C, indicating comparatively decreased midfacial dimensions. The Pearson correlation coefficient showed that there is a positive correlation between each cranial base parameter (S-N and S-Ca) and the maxillary parameters (Ptm-A, Co-A, and ANS-PNS). This finding further confirms the dimensional influence of the anterior cranial base on the maxilla. Thus, any growth imbalances in the anterior cranial base will in turn be reflected in the nasomaxillary complex. The S-N values showed moderate to strong positive correlation to all three maxillary parameters. A similar trend is observed while correlating S-Ca values to those of Ptm-A and Co-A. The strongest correlation was observed between S-N and Co-A and the weakest was with respect to S-Ca and ANS-PNS.
CONCLUSION

A significant influence of anterior cranial base on the maxilla and midface was observed in this study, thus rejecting the three null hypotheses generated.

1. A statistically significant decrease in sagittal linear dimensions of anterior cranial base was observed in only those skeletal Class III cases with maxillary deficiency. Skeletal Class III cases due to mandibular prognathism and normal maxillae did not exhibit similar anteroposterior dimensional changes in anterior cranial base.

2. A decrease in cranial base angles N-S-Ba, N-S-Ar, and N-S-Co was observed from group C via B to A. This decrease was found to be significant for angles N-S-Co and N-S-Ar. N-S-Co may prove to be a diagnostically reliable parameter for identifying skeletal Class III cases with maxillary retrusion.

3. Significant positive correlations were found to exist between each cranial base parameter and the maxillary parameters. The strongest correlation was observed between S-N and Co-A and the weakest with respect to S-Ca and ANS-PNS.

REFERENCES