Correlating Cranial Base Flexure And Posterior Cranial Base Length With Vertical Skeletal Patterns

Anuradha Rawat, Sanjeev Datana, SS Agarwal, Vishvaroop, SK Bhandari

Department of Orthodontics & Dentofacial Orthopedics, Armed forces medical college, Pune, India

ABSTRACT

Background: The cranial base has pivotal role in development of craniofacial structures. Both anterior and posterior cranial bases and the angle between the two affect the position of maxilla and mandible. Objectives: To evaluate the effect of cranial base angle and posterior cranial base length in various vertical facial types. Methodology: The study sample consisted of pre-treatment lateral cephalogram of 135 subjects (63 males and 72 females, age 14-21 years) with skeletal class I pattern. These were divided into three groups of normodivergent, hypodivergent and hyperdivergent facial types with 45 subjects in each group. Two angular parameters i.e Saddle angle (NSAr) and Articular angle (SArGo) and one linear parameter Posterior cranial base length (SAr) were used in cephalometric analysis. Inter-group comparison of means of all measurements were studied using ANOVA with Bonferroni’s correction for multiple group comparison.

Results: Saddle angle and articular angle did not show significant difference across three study groups. Highly significant difference in posterior cranial base length was observed between hypodivergent and hyperdivergent groups. Saddle angle and Posterior Cranial base length showed significant positive correlation in hypodivergent whereas Saddle angle and Articular angle showed significant negative correlation in hypodivergent and hyperdivergent groups. Conclusion: The cranial base angle does not affect the vertical facial patterns but posterior cranial base length does affect the hyperdivergent and hypodivergent facial types. Cranial base angle found to correlate with posterior cranial base in hypodivergent facial pattern whereas Saddle angle correlated negatively with articular angle in both hyperdivergent and hypodivergent facial types.

Keywords: Cranial base angle, Saddle angle, Cranial base flexure
INTRODUCTION

The cranial base has been an area of enormous interest to orthodontist since long and hence it was studied extensively by the researchers. It forms the floor of the cranial vault and extends from foramen caecum to occipital bone. Cephalometrically, it is divided into two parts, anterior (Sella to Nasion) and posterior (Sella to Basion or Sella to Articulare) by sella turcica which forms an angle in center called saddle angle. At birth, it is approximately 142° but decreases to 130° at 5 years of age and becomes relatively stable by 5 to 15 years of age. Enlow described cranial base as a template of growth over which face develops and thus any changes in cranial base could directly affect the angle, size, structure and positioning of various parts of face. The nasomaxillary complex is related to anterior part of cranial base and mandible to posterior part. Hence, changes in base angle and its length could directly affect the position of maxilla and mandible, thus affecting the type of facial pattern or malocclusion. Therefore, a thorough understanding of morphological features of cranial base could be of great importance in early diagnosis and prediction of developing facial pattern and management of malocclusion. Various studies conducted on different malocclusion found correlation between cranial base angle and the sagittal skeletal pattern. Increase in cranial base flexure positioned the mandible anteriorly leading to class III tendency whereas decrease in cranial base flexure positioned the mandible posteriorly resulting in class II tendency.

As condyle is a part of mandible and it articulates with glenoid fossa, its position is affected by change in position of mandible due to variation in cranial base angle. Opening of cranial base angle rotate mandible in clockwise direction whereas closing of the angle would lead to anticlockwise rotation of mandible until it is compensated by decrease or increase in articular angle. There is abundance of literature showing effect of cranial base angle on sagittal facial pattern but very limited data is available in literature assessing its effect on vertical facial patterns. Therefore the purpose of our study was to evaluate the effect of cranial base angle and posterior cranial base length on various vertical facial types.

MATERIAL AND METHODS

This retrospective observational study was conducted in the department of Orthodontics and Dentofacial Orthopedics of a tertiary care teaching institute. The study sample consisted of 135 patients (63 males and 72 females, aged 14-21 years) with skeletal class I pattern. These were selected from the institutional archives of the patients who reported to the department for treatment of malocclusion. The records included pre-treatment lateral cephalograms and health records of the patients. The subjects were included with the following criteria-

Inclusion criteria
1. Skeletal class I pattern
2. Patients with age ranging from 14 to 21 years
3. Permanent dentition
4. No history of previous orthodontic treatment
5. No facial disharmony, systemic problems or major trauma.

Exclusion criteria
1. Any congenital anomaly/syndrome
2. Poor quality radiographs/inadequate records

Lateral cephalograms were taken with patient in the Natural Head Position and with the same machine (PLANMECA 2002 CC Proline Panoramic X-ray machine) and with a standarised technique. Lateral cephalograms were traced using 0.3mm matte acetate tracing paper using a 0.03" lead pencil. A single operator performed the tracings in a standardized manner. To ascertain intra-operator variation, 15 cephalograms were retracted after one week and kappa score came out to be 0.8 indicating a strong intraoperator agreement. The lateral cephalograms of 135 patients meeting the inclusion criteria of the
study were categorized into three groups based on FMA and GoGn to SN angles as:
Group 1: normodivergent (FMA 25°±2 and GoGn to Sn 32°±2) (n=45)
Group 2: hypodivergent (FMA<23° and GoGn to Sn <30°) (n=45)
Group 3: hyperdivergent (FMA>27° and GoGn to Sn >34°) (n=45)

Cephalometric analysis
The following landmarks were used for cephalometric analysis:
Point A: It is the deepest point on the midline between the anterior nasal spine and alveolar crest between the two central incisors.
Point B: It is the deepest point between the alveolar crest of the mandible and the mental process.
Articulare (Ar): Intersection of the posterior border of the condyle and the posterior cranial base.
Sella (S): Centre of sella turcica.
Nasion (N): Most anterior point on frontonasal suture.
Gonion (Go): Lowermost point at the intersection of mandibular and ramal planes.

Angular measurements-
1. N-S-Ar (Saddle angle)- formed by joining N, S and Ar points. It represents the cranial base flexure.
2. S-Ar-Go (Articular angle)- formed by joining the points S, Ar and Go.

Linear measurement-
1. S-Ar line (Posterior cranial base length)- measured from points S to Ar

Statistical analysis
Statistical analysis was performed using the statistical package for the social sciences for windows (SPSS- V10.5). The following values were calculated for each variable: mean, standard deviation (SD), minimum and maximum.

Inter-group comparison of means of angular measurements and linear measurement were studied using analysis of variance (ANOVA) with Bonferroni’s correction for multiple group comparisons.

In the entire study a “p” value of less than or equal to 0.05 was accepted as indicating statistical significance and “p” value of less than or equal to 0.01 was accepted as indicating highly statistical significance.

RESULTS
The distribution of mean ± SD of saddle angle in Group 1, Group 2 and Group 3 was 123.60 ± 6.95, 125.40 ± 6.63 and 124.47 ± 7.99 respectively. The distribution of mean saddle angle did not show significant difference across the three study groups (P-value>0.05 for all).

The distribution of mean articular angle also did not differ significantly across three study groups (P-value>0.05 for all). It was 141.47 ± 6.82, 142.60 ± 6.03 and 147.13 ± 9.93 for Group 1, Group 2 and Group 3 respectively (Table 1, Figure 1).

The distribution of mean ± SD of posterior cranial base length in Group 1, Group 2 and Group 3 was 30.93 ± 2.55, 33.33 ± 2.97 and 28.33 ± 4.19 respectively (Table 2, Figure 2).

There was no significant difference in mean posterior cranial base length when comparing group 1 with group 2 and 3 both but there was a highly significant difference between Group 2 and Group 3 for the same (P-value<0.001).

The Correlation analysis between Saddle angle (N-S-Ar), Articular angle (S-Ar-Go) and Posterior Cranial base (S-Ar) (Table 3) showed that:

- Saddle angle (N-S-Ar) and Posterior Cranial base (S-Ar) showed statistically significant positive correlation in Group 2 (P-value<0.01) whereas it was found insignificant in other two groups (Figure 3.1).
- Articular angle (S-Ar-Go) and Posterior Cranial base (S-Ar) did not show statistically
significant correlation in all three study groups (P-value>0.05 for all) (Figure 3.2).

- Saddle angle (N-S-Ar) and Articular angle (S-ArGo) did not show statistically significant correlation in Group 1 (P-value>0.05). Saddle angle (N-S-Ar) and Articular angle (S-ArGo) showed statistically significant and negative correlation in Group 2 and Group 3 (P-value<0.05 for both) (Figure 3.3).

Table 1 - Inter-group comparison of means of angular measurements.

<table>
<thead>
<tr>
<th>Measurements (Degrees)</th>
<th>Group 1 (Normodivergent) (n=45)</th>
<th>Group 2 (Hypodivergent) (n=45)</th>
<th>Group 3 (Hyperdivergent) (n=45)</th>
<th>P-value (Inter-Group)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saddle angle (N-S-Ar)</td>
<td>123.60 ± 6.95</td>
<td>125.40 ± 6.63</td>
<td>124.47 ± 7.99</td>
<td>0.999 &lt;sup&gt;NS&lt;/sup&gt;</td>
</tr>
<tr>
<td>Articular angle (S-ArGo)</td>
<td>141.47 ± 6.82</td>
<td>142.60 ± 6.03</td>
<td>147.13 ± 9.93</td>
<td>0.999 &lt;sup&gt;NS&lt;/sup&gt;, 0.158 &lt;sup&gt;NS&lt;/sup&gt;, 0.354 &lt;sup&gt;NS&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

P-value by analysis of variance (ANOVA) with Bonferroni’s correction for multiple group comparisons. P-value<0.05 is considered to be statistically significant. NS-Statistically non-significant.

Table 2 - Inter-group comparison of means of linear measurements studied.

<table>
<thead>
<tr>
<th>Measurements (mm)</th>
<th>Group 1 (Normodivergent) (n=45)</th>
<th>Group 2 (Hypodivergent) (n=45)</th>
<th>Group 3 (Hyperdivergent) (n=45)</th>
<th>P-value (Inter-Group)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cranial base (S-Ar)</td>
<td>30.93 ± 2.55</td>
<td>33.33 ± 2.97</td>
<td>28.33 ± 4.19</td>
<td>0.160 &lt;sup&gt;NS&lt;/sup&gt;, 0.111 &lt;sup&gt;NS&lt;/sup&gt;, 0.001 &lt;sup&gt;***&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

P-value by analysis of variance (ANOVA) with Bonferroni’s correction for multiple group comparisons. P-value<0.05 is considered to be statistically significant. <sup>***</sup>P-value<0.001, NS-Statistically non-significant.

Table 3 - Correlation analysis between angular and linear measurement studied.

<table>
<thead>
<tr>
<th></th>
<th>Group 1 (Normodivergent) (n=45)</th>
<th>Group 2 (Hypodivergent) (n=45)</th>
<th>Group 3 (Hyperdivergent) (n=45)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saddle angle (N-S-Ar)</td>
<td>-0.288 NS</td>
<td>0.610</td>
<td>0.010 &lt;sup&gt;***&lt;/sup&gt;</td>
<td>-0.417</td>
</tr>
<tr>
<td>Articular angle (S-ArGo)</td>
<td>0.166 &lt;sup&gt;NS&lt;/sup&gt;</td>
<td>-0.499</td>
<td>0.059 &lt;sup&gt;NS&lt;/sup&gt;</td>
<td>0.344</td>
</tr>
<tr>
<td>Saddle angle (N-S-Ar)</td>
<td>-0.228 &lt;sup&gt;NS&lt;/sup&gt;</td>
<td>-0.592</td>
<td>0.020 &lt;sup&gt;NS&lt;/sup&gt;</td>
<td>-0.921</td>
</tr>
</tbody>
</table>

P-vaules by Pearson’s correlation analysis. P-value<0.05 is considered to be statistically significant correlation. <sup>***</sup>P-value<0.001, <sup>NS</sup>-Statistically non-significant.
**Figure 1:** Inter-group comparison of means of angular measurements.

**Figure 2:** Inter-group comparison of mean of posterior cranial base (S Ar).
Figure 3.1: Scatter diagram showing correlation between Saddle angle (N-S-Ar) and Posterior Cranial base (S-Ar) in each study group along with corresponding regression lines (which shows type of correlation).

Figure 3.2: Scatter diagram showing correlation between Articular angle (S-ArGo) and Posterior Cranial base (S-Ar) in each study group along with corresponding regression lines (which shows type of correlation).
DISCUSSION

One of the primary objectives in the field of orthodontics is ascertaining the etiology and correct diagnosis of a malocclusion which helps in planning the treatment objectives and treatment mechanics for the patient. Many a times the dental malocclusions are associated with underlying skeletal dysplasia which can directly influence various treatment decisions. Cranial base angle and anterior and posterior cranial base length has been put forward to be one of the possible indicators of a skeletal malocclusion. Several studies have been conducted to find a correlation between the cranial base and sagittal jaw position. A possible association was first suggested by Young and Bryce\(^{10}\) and demonstrated by Bjork.\(^{1}\) Later many studies were conducted to evaluate the correlation between the cranial base and sagittal jaw relationship.

Ricketts\(^{11}\) and Hopkin\(^{8}\) studied the effect of growth of posterior cranial base on position of mandible and found that it influences the sagittal relationship of upper and lower jaw. In other studies done by Hopkin\(^{12}\), James\(^{13}\) and Houston\(^{14}\) on class III, class II Div 1 and class II Div 2 malocclusion respectively, the cranial base angle was found to be smaller in class III malocclusion and larger in class II malocclusion when compared to common control groups of class I malocclusion.

In contradiction to above studies various other researchers have found minimal or no significant effect of cranial base on skeletal patterns\(^{15-18}\).

According to Enlow\(^{19}\), cranial base which is under the effect of growth of brain influences maxillary growth. Even though mandible is not affected directly by these signals but its association with cranial base via glenoid fossa could also affect its position. Development of facial skeleton in vertical direction has been found to be associated with various skeletal units like, the alveolar processes, the nasomaxillary complex and the mandible.
These are all associated with normal and abnormal vertical growth pattern as stated by Opdebeeck and Bell. According to Enlow, closed cranial base flexure associated with brachycephalic type results in posterior and superior placement of maxilla whereas in dolichocephalic type more open cranial flexure placed maxilla anteriorly and inferiorly. It will lead to forward and upward rotation of mandible in first type and downward and backward in second. This suggests that this relationship between cranial base and rotation of mandible can affect the vertical relationship of jaws and so could be of diagnostic and therapeutic use. As there is dearth of literature regarding the effect of cranial base on vertical jaw relationship hence the present study was planned to evaluate the effect of cranial base flexure and posterior cranial base length in various vertical facial types.

The present study is a retrospective observational study in which pre-treatment lateral cephalogram of 135 subjects with skeletal class I pattern were taken and were divided into three groups of normodivergent, hypodivergent and hyperdivergent facial types based on Go-Gn and FMA with 45 samples in each group. In the present study two angular parameter i.e Saddle angle (NSAr) and Articular angle (SArGo) and one linear parameter Posterior cranial base length (SAr) were used to do cephalometric analysis.

In many of the previous studies, cranial base angle, anterior and posterior cranial base length were measured to investigate the role of cranial base and malocclusion. The posterior cranial base is measured cephalometrically from sella to either Articulare (Ar) or Basion (Ba). Basion point was found to be more appropriate because of its anatomic location and proximity to skull base. However Bjork advocated the use of articulare because of its ease of identification on lat cephalogram and therefore it was also used in many subsequent studies. Hence in the present study articulare was used as posterior limit for measurement of posterior cranial base.

There is no consistent data available in literature showing the effect of cranial base on various vertical jaw relationship. Some studies have associated it with open bite tendency while others have found no difference between normal and open bite group. In present study, the saddle angle showed mild increase in hypodivergent than hyper and normodivergent patterns but the difference was not statistically significant. This is in agreement with the study done by Subtelny and Sakuda on skeletal relationship in open bite and normal occlusion wherein no difference was found between the two groups in cranial flexure. Contrary to it, Xiao et al. found larger cranial base angle in low angle group than in high angle.

Articulare angle is constructed angle formed between posterior cranial base and posterior border of ramus, shows ramal inclination with respect to cranial base and depends on position of mandible. The angle increases in retrognathic mandible and decreases in prognathic mandible. In the present, study no statistically significant difference in articular angle was found among three groups studied.

Posterior cranial base length also called as lateral cranial base is based on posterior facial height and position of glenoid fossa. Short cranial bases are seen in vertical growth pattern and skeletal open bite. Similar were the finding in our study where posterior cranial base length was found to be least in hyperdivergent group compared to other two groups. The difference was found significant between hyperdivergent and hypodivergent groups. These findings are in consensus with the study by Subtenly and Sakuda wherein posterior cranial length was significantly shorter in open bite group than in control group.

Compensating mechanism between saddle angle and articular angle was described by Anderson and Popovich. Their results indicated high correlation between closing of articular angle and opening of cranial base.
angle so as to maintain the angle between the ramus and anterior cranial base. The present study also confirm the same. It showed statistically significant negative correlation between saddle angle and articular angle in both hypo and hyperdivergent groups. It suggests as saddle angle increases the articular angle tend to decrease so as to maintain the position of mandible. Therefore, with a more opening of cranial base angle, the mandible tend to rotate only slightly down and backward as it is compensated by closure of articular angle. Our study also showed significant positive correlation between saddle angle and posterior cranial base in hypodivergent group. No similar study was found which was done on vertical facial patterns but cranial base is found to shorten from class II, class I and class III malocclusion in other studies.\textsuperscript{27,28} Articular angle and posterior cranial base also showed weak correlation among different groups indicating that both the variables do not affect each other.

No consistent results exist in the literature on effect of the cranial base over different vertical skeletal patterns. According to the results of this study it can be concluded that there is no significant effect of cranial base flexure on various vertical facial types but posterior cranial base length is found to be less in hyperdivergent pattern. However, it is important to keep in mind that the vertical facial pattern can be affected by various other factors like mandibular length, gonial angle, maxillary length and position etc. Compensations in maxillomandibular structures can be induced by these variables. These compensations can minimize the effect of an abnormal morphological pattern of the cranial base. Hence the effects can be further studied after inclusion of other variables as well and similar study can also be conducted in vertical facial types in skeletal class II and class III sagittal patterns.

CONCLUSIONS

The cranial base angle is known to influence the craniofacial morphology. Based on the results of this study, following conclusions can be drawn:

1. The cranial base angle does not appear to affect the establishment of vertical facial patterns.
2. Posterior cranial base length is decreased in hyperdivergent group when compared to hypodivergent group.
3. Cranial base angle is found to correlate with posterior cranial base in hypodivergent facial pattern i.e a more obtuse cranial base angle is being associated with increased posterior cranial base length in hypodivergent group.
4. Saddle angle correlates negatively with Articular angle in both hyperdivergent and hypodivergent facial pattern. This suggests that increased saddle angle is compensated by decreased articular angle.

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