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Relationship between cranial base flexure and sagittal jaw relationships

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ABSTRACT

Introduction

Flexure of the cranial base plays a crucial role in the study of the craniofacial complex. The outcome of orthodontic treatment can be predicted if growth and flexure of the cranial base is understood.

Aim

The aim of this study was to determine the relationship between cranial base flexure and sagittal jaw relationships in a sample of Black South African subjects.

Methodology

A sample of pre-treatment lateral cephalograms of 300 patients with a mean age of 17.72 years was divided into three equal groups according to gender and skeletal classification.

Age differences were tested using the Kruskal-Wallis test. Cranial base flexure differences were first tested using ANOVA and further evaluated using Student's *t*-test.

Results

Age distribution was similar in all three in all classes of sagittal jaw relationship. Class II subjects demonstrated a significantly larger cranial base flexure when compared with Class I and Class III subjects respectively.

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4. **Abdul K Seedat:** Assisted with proof reading of the research - 10%

ACRONYM

CBF: Cranial Base Flexure

Conclusion

In this study sample, a larger cranial base flexure is a feature of Class II sagittal jaw relationship whilst both Class I and Class III sagittal jaw relationships are associated with smaller cranial base flexures. There were no significant differences between the Class I and Class III sagittal jaw relationship samples.

Keywords

Cranial base flexure, skeletal classification, sagittal jaw relationship.

INTRODUCTION

Flexure of the cranial base occurs when the anterior and posterior limbs flex or extend relative to each other in the midsagittal plane about a vertex located at sella turcica.

Cranial Base Flexure (CBF), measured as the inferior angle, has been the subject of research as it affects the relative positions of the two limbs of the cranial base, thus influencing a wide range of spatial relationships that exist between the cranial base and the face.[1]

The cranial base plays a key role in craniofacial growth by helping to integrate the anatomically and functionally different patterns of growth in various adjoining regions of the skull, such as components of the brain, the nasal cavity, the oral cavity, and the pharynx.[2] Architecturally, the cranial base provides a platform on which the brain grows and around which the face develops.

The maxilla is attached to the inferior surface of the anterior limb of the cranial base, while the mandible articulates with the posterior limb. From this geometric arrangement of the jaws, it may be reasonable to assume that variations in growth and flexure of the cranial base may influence the individual jaw positions and the relationship of the jaws to the cranial base and also to one another.[3]

It has been hypothesized that the opening of CBF will displace the mandible more distally towards a Class II sagittal jaw relationship tendency whilst closing of CBF will displace the mandible more anteriorly towards a Class III sagittal jaw relationship.[4] A study by Hopkin, Houston and James demonstrated that CBF increased significantly from skeletal Class III through Class I up to Class II subjects.[5]

The role of CBF and its potential interaction with, and its contribution to, normal development of sagittal jaw relationships is both a frequently addressed and a clinically relevant topic in orthodontics and craniofacial biology.[6]

Brodie[7] stated that successful treatment of sagittal jaw malrelationships depends significantly on the growth of the patients' craniofacial complex. Baccetti and co-workers[8] reported that orthopaedic treatment of Class III malocclusion with maxillary expansion and face mask therapy can have favourable long-term results when the patient's pre-treatment cephalometric measurements exhibit a more pronounced obtuse CBF.

They concluded that a more acute CBF is an unfavourable sign in the long term prognosis of orthopaedic treatment of Class III malocclusion. Cranial base flexure may also provide a clear advantage with easier patient selection, thus allowing the clinician to predict what the final outcome of treatment would be before it may be initiated.

For example, growing patients who exhibit favourable pre-treatment CBF values may have more stable results after early orthopaedic treatment with a combination treatment of maxillary expansion and face mask appliances, while others could benefit from treatment later in life with orthodontics and orthognathic surgery.

Very few studies have been conducted to determine whether this relationship between CBF and sagittal jaw relationships exists in Black subjects. This study was aimed to determine the relationship between CBF and sagittal jaw relationships in a sample of Black South African subjects. The objectives of this study were:

1. To determine the reference norm values of the CBF of Black South African patients.

2. To determine whether there are gender differences for CBF.

3. To determine correlations between CBF and sagittal jaw relationships.

MATERIALS AND METHODS

Permission to conduct this research using the hospital records was obtained from the Head of the Department of Orthodontics and also from the Dean of the School of Oral Health Sciences Sefako Makgatho Health Sciences University, South Africa.

Pre-treatment lateral cephalograms were selected from the patient records in the Department of Orthodontics, Sefako Makgatho Health Sciences University. The selected lateral cephalograms were assessed visually by the principal investigator and later re-assessed by the supervisor.

Lateral cephalograms which satisfied the following inclusion criteria were selected for this study:

1. Lateral cephalograms of Black patients of South African origin. Race and citizenship were verified by referring to hospital files.

2. Pre-treatment lateral cephalograms of patients with no history of orthodontic treatment or orthognathic surgery.

3. Lateral cephalograms of good quality and acceptable standards without any image distortions. The selected lateral cephalograms were carefully assessed by the principal investigator to ensure that the images had been taken with the teeth in centric occlusion.

4. Lateral cephalograms of patients aged between 12 and 24 years (CBF becomes relatively stable from 14 to 18 years in males and 12 to 16 years in females).[9]

The pre-treatment lateral cephalograms of three hundred (100 Class I, 100 Class II and 100 Class III) with an equal number of males and females, that met the selection criteria were selected for this study.

The lateral cephalograms were scanned to transform their analogue images into digital formats using an EPSON V700™ scanner (Seiko Epson, Nagano, Japan), and the images were then displayed on the LCD SVGA computer monitor (Axper, Inc.) with a 32 bit colour quality.

The lateral cephalometric images were then stored numerically on a separate computer storage software programme (Microsoft Picture Package®) in tagged image file formats (jpeg). The digital image resolution was set at 120 dots per inch (dpi) with a 64-bit grayscale image acquisition depth.

The digitised images consisted of a 1280 X 1024 pixel matrix which gave a pixel size of 1.3 mm. The lateral cephalometric images were individually transferred into the digital cephalometric analysis software programme (Orthview®, Orthotek, Netherlands) for tracing and analysis (Figure 1).

Figure 1. Orthview® cephalometric analysis programme.

This method of analysis was chosen for its precise reproducibility of the measurements and its significantly higher speed when compared with the performance of the manual tracing method.[10-13]

All the linear measurements were taken in millimetres and all the angular measurements were taken in degrees to the nearest two decimal places.

Table 1. Descriptive summary of age for the total sample.

Sample	Number	Mean age in years (±SD)	Median age in years	Range in years
Class I total	100	17.33 ± 4.61	16.5	12 to 24
Class II total	100	16.38 ± 4.42	15.0	12 to 24
Class III total	100	16.46 ± 4.86	15.0	12 to 24
Total sample	300	16.72 ± 4.63	15.5	12 to 24
p*-value			*0.255*	
SD = Standard deviation	***p*<0.05 is considered statistically significant.**			

Table 2. Gender comparisons of the mean ages in the three classes of sagittal jaw relationship.

Sample	Number	Mean age in years (±SD)	Median age in years	Range in years
Class I Males	50	16.92 ± 4.62	16.0	12 to 24
Class I Females	50	17.74 ± 4.61	18.5	12 to 24
***p*-value**			*0.449*	
Class II Males	50	16.22 ± 4.19	15.0	12 to 24
Class II Females	50	16.54 ± 4.68	15.0	12 to 24
***p*-value**			*0.812*	
Class III Males	50	16.98 ± 5.02	15.5	12 to 24
Class III Females	50	15.94 ± 4.68	14.0	12 to 24
p*-value			*0.314*	
SD = Standard deviation	***p*<0.05 is considered statistically significant.**			

Table 3. Descriptive summary of CBF values for the total sample.

Sample	Number	Mean CBF in degrees (±SD)	Median CBF in degrees	Range in degrees
Class I total	100	126.55 ± 6.28	126.45	108.5 to 140.7
Class II total	100	128.31 ± 6.51	128.45	113 to 149.6
Class III total	100	125.91 ± 5.33	126.25	112.4 to 136.8
p*-value			*0.015**	
SD = Standard deviation	***p*<0.05 is considered statistically significant.**			

Table 4. Comparison of mean CBF values between Class I, II and III subjects.

Sample	Number	Mean age in years (±SD)	Median age in years	Range in years
Class I total	100	126.55 ± 6.28	126.45	108.5 to 140.7
Class II total	100	128.31 ± 6.51	128.45	113 to 149.6
***p*-value**		*0.041**		
Class I total	100	126.55 ± 6.28	126.45	108.5 to 140.7
Class III total	100	125.91 ± 5.33	126.25	112.4 to 136.8
***p*-value**		*0.450*		
Class II total	100	128.31 ± 6.51	128.45	113 to 149.6
Class III total	100	125.91 ± 5.33	126.25	112.4 to 136.8
p*-value		*0.005**		
SD = Standard deviation	***p*<0.05 is considered statistically significant.**			

Table 5. Gender comparisons of the mean CBF values between the three classes of sagittal jaw relationship.

Sample	Number	Mean CBF in years (±SD)	Median CBF in years	Range in degrees
Class I males	50	125.42 ± 7.05	123.95	108.5 to 140.7
Class I females	50	127.69 ± 5.21	126.55	117.1 to 140.3
***p*-value**		*0.070*		
Class II males	50	127.28 ± 6.49	127.2	113.0 to 143.8
Class II females	50	129.33 ± 6.43	128.9	115.6 to 149.6
***p*-value**		*0.115*		
Class III males	50	148.10 ± 4.29	124.4	112.4 to 127.9
Class III females	50	126.74 ± 4.95	127.9	116.7 to 134.4
p*-value		*0.359*		
SD = Standard deviation	***p*<0.05 is considered statistically significant.**			

Cephalometric tracing and analysis was carried out by the principal examiner who plotted the landmarks on the digital image in a pre-determined sequence using a mouse-driven cursor (**Figure 2**).

Cephalometric tracing and analysis were completed immediately after plotting the last landmark on each cephalogram. The Wits appraisal[14] was used to classify the sagittal jaw relationship, and was measured and recorded for each lateral cephalogram. The CBF value for each lateral cephalogram, represented by the N-S-Ba angle[15] was also measured and recorded. Each lateral cephalogram was measured twice and the mean of the two measured values was used in calculating the results of this study.

In order to minimise investigator fatigue, only 10 lateral cephalograms were traced per day over a period of 30 days, by which stage all the selected lateral cephalograms had been traced and measured. The two main parameters which were of particular importance in this study were: cranial base flexure (represented by N-S-Ba angle) and skeletal classification (represented by Wits appraisal).

All statistical tests were performed on the SAS programme (SAS Institute Inc. Cary, NC), and the level of statistical significance was set at 5%. Intra-examiner and inter-examiner reliability were tested by randomly selecting and re-measuring 10% of the total sample, and the results analysed using the Student's t-test and the Pearson Correlation Coefficient.

Class and gender differences with regards to age were tested using Kruskal-Wallis test. ANOVA was first used to test for any significant CBF differences between the three classes of sagittal jaw relationship. This was followed by pairwise comparison of three classes of sagittal jaw relationship using a Student's *t*-test.

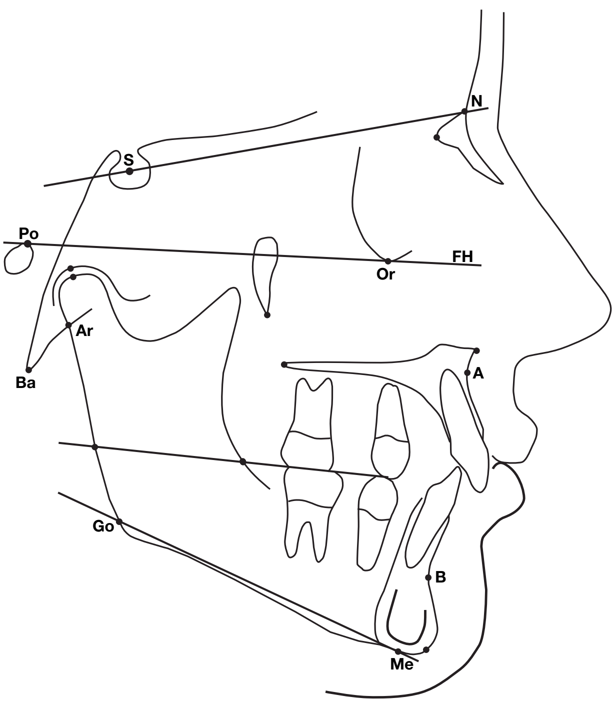

Figure 2. Cephalometric landmarks and their interpretations.[16]

RESULTS

Table 1 summarizes descriptive statistics for the total sample with regards to age. The mean age for the total sample was 16.72 ± 4.63 years (range = 12 to 24 years). The mean ages for Class I, II and III samples were 17.33 ± 4.61 years (range = 12 to 24 years); 16.38 ± 4.42 years (range = 12 to 24 years) and 16.46 ± 4.86 years (range = 12 to 24 years) respectively.

The normality of the distribution of age could not be confirmed statistically, thus a non-parametric analysis of variance known as the Kruskal-Wallis test was used to investigate whether there were any significant age differences. The results of the Kruskal-Wallis test showed no statistically significant age differences between the three classes of sagittal jaw relationship (p>0.05) (**Table 1**).

When the median ages of male and female subjects were compared in the three classes of sagittal jaw relationship, the results of Kruskal-Wallis test also showed no statistically significant differences (p>0.05). The sample was further tested to determine the presence of any significant gender differences with regards to age in each class of sagittal jaw relationship (**Table 2**).

Table 3 summarizes descriptive statistics for the total sample with regards to CBF. The largest mean CBF value was found in skeletal Class II (128.31° ± 6.51°) subjects, while the smallest mean CBF value was found in subjects having skeletal Class III (125.91° ± 5.33°) patterns.

The normality of the underlying distribution of CBF was substantiated statistically, thus a parametric ANOVA was used to test for any significant CBF differences. The results of ANOVA showed statistically significant CBF differences between the three classes of sagittal jaw relationship (p<0.05).

Table 1. Descriptive summary of age for the total sample.

	Name	Definition
Ar	Articulare	The point of intersection of the dorsal contour of the mandibular condyle and the temporal bone.
Ba	Basion	The anterior border of the foramen magnum.
S	Sella	The centre of the pituitary fossa.
Na	Nasion	A cephalometric landmark on the bony profile at the junction of the frontal and nasal bones.
Point A	Point A	The deepest point in the bony concavity of the premaxilla below the anterior nasal spine.
Point B	Point B	The deepest point in the profile curvature of the mandible.
Go	Gonion	The point on the angle of mandible where the posterior and lower borders meet.
Me	Menton	The most inferior point on the bony chin.
U1	Upper molar	Mesiobuccal cusp tip of maxillary first permanent molar.
Pre	Premolar/ primary molar	Cusp tip of mandibular first premolar or first primary molar.

In recognition that the ANOVA tests revealed significant differences, the three classes of sagittal jaw relationship were paired and compared for statistical difference using a Student's *t*-test (Table 4). These results showed that the mean CBF value of Class II subjects was significantly larger in comparison with the mean CBF values of the skeletal Class I and Class III subjects respectively (*$p<0.05$).

The results of a Student's t-test showed no statistically significant differences between the mean CBF value of skeletal Class I subjects and the mean CBF of skeletal Class III subjects ($p>0.05$). From the results of this study, we have established a reference norm value (Class 1) for this sample to be 126.55° ± 6.28° (Table 3).

Table 5 summarizes the gender comparisons of the mean CBF values amongst the three individual classes of sagittal jaw relationship. When the mean CBF values of the male and female subjects were compared in three classes of sagittal jaw relationship, the results of a Student's *t*-test showed no statistically significant differences ($p>0.05$).

DISCUSSION

It has been previously demonstrated that during growth, CBF becomes relatively stable from 14 to 18 years in males and 12 to 16 years in females.[9,18,19]

In the present study, the total sample age ranged from 12 years to 24 years because it represented the age distribution of patients who sought orthodontic treatment at Medunsa Oral Health Centre, University of Limpopo. The mean age in this study was similar to that of studies by Klocke et al.[19] and Hayashi[20] who also selected their samples from their respective populations. From the geometric arrangement of the cranial base and the jaws, we expected CBF to increase significantly from skeletal Class III, *via* Class I up to Class II subjects.[5]

The results of this study demonstrated a significantly larger CBF in the skeletal Class II sample, when compared with the CBF values of Class I and Class III samples ($p<0.05$) respectively (Table 4). Similar findings were reported by Sayin and Türkkahraman[21] and also by Tanabe et al.[22] This finding was expected because, as the cranial base flattens out, the mandible, which articulates with the posterior limb of the cranial base, becomes distally positioned towards a Class II sagittal jaw relationship tendency.[16]

The results of the present study showed no statistically significant difference ($p>0.05$) between Class I and Class III subjects with regards to the CBF values (Table 5). Similar findings were reported by Anderson and Popovich[23] and by Alves et al.[16] who also found no statistically significant CBF differences between Class I and Class III samples. Previous growth studies[24] have demonstrated that the cranial bases in Class I and Class III subjects grow and flex in similar manners.

Flexure of the cranial base has also been shown to record great variability in the mean values of more than 8° amongst Class I and Class III subjects.[25,26,27] This large variability explains why a statistically significant difference with regards to the mean CBF values between Class I and Class III subjects was not found in this study.

CONCLUSION

The reference norm value of the CBF of Black South African subjects in our sample has been established (126.55° ± 6.28°). This study found no statistically significant gender differences with regards to CBF in this sample. The results do suggest that a larger CBF is a feature of Class II sagittal jaw relationship while a smaller CBF is associated with both Class I and Class III sagittal jaw relationships.

This study suggests that there is definitely a relationship between CBF and sagittal jaw patterns. The authors recommend that further research on this topic be undertaken on a multicentre level using a larger sample size of Black South African subjects in order to determine whether or not similar results will be found in other parts of South Africa.

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References

1. Lieberman DE, Mc Carthy RC. The ontogeny of the cranial base angulation in humans and chimpanzees and its implications for reconstructing pharyngeal dimensions. J Hum Evl. 1999; 36: 487-517.
2. Sperber GH. Handbook of Craniofacial Embryology, 2nd ed. London: Cambridge University Press, 1989: pp101-18.
3. Dhopatkar A, Bhatia S, Rock P. An investigation into the relationship between cranial base angle and malocclusion. Angle Orthod. 2002; 72: 456-63.
4. Zhou L, Mok CW, Hägg U, Mc Grath C, Bendeus M, Wu J. Anteroposterior dental arch and jaw-base relationships in a population sample. Angle Orthod. 2008; 78: 1023-9.
5. Hopkin GB, Houston WJB, James G.A. The cranial base as an aetiological factor in malocclusion. Angle Orthod. 1968; 38: 250-5.
6. Kim YH, Sato K, Mitani H, Shimizu Y, Kikuchi M. Asymmetry of the sphenoid bone and its suitability as a reference for analyzing craniofacial asymmetry. Am J Orthod Dentofacial Orthop. 2003; 124: 656-62.
7. Brodie AG. The behaviour of the cranial base and its components as revealed by serial cephalometric roentgenograms. Am J Orthod. 1953; 25: 148-60.
8. Baccetti T, Franchi L, Mc Namara. Cephalometric variables predicting the long-term success or failure of combined rapid maxillary expansion and facial mask therapy. Am J Orthod Dentofacial Orthop. 2004; 126: 16-22.
9. Melsen B. Time and mode of closure of the spheno-occipital synchondrosis determined on human autopsy material. Acta Anat. 1972; 83: 112-8.
10. Chen YJ, Chen SK, Chang HF, Chen KC. Comparison of landmark identification in traditional versus computer-aided digital cephalometry. Angle Orthod. 2000; 70: 387-92.
11. Schulze RKW, Gloede MB, Doll GM. Landmark identification on direct digital versus film-based cephalometric radiographs: a human skull study. Am J Orthod Dentofacial Orthop. 2002; 122: 635-42.
12. Gregston MD, Kula T, Hardman P, Glaros A, Kula K. A comparison of conventional and digital radiographic methods and cephalometric analysis software: I. Hard Tissues. Sem Orthod. 2004; 10: 204-11.

13. McClure SR, Sadowsky PL, Ferreira A, Jacobson A. Reliability of digital versus conventional cephalometric radiology: a comparative evaluation of landmark identification error. Sem Orthod. 2005; 11: 98-110.
14. Jacobson A. The Wits appraisal of jaw disharmony. Am J Orthod. 1975; 67: 125-38.
15. Bjork A. The face in profile. Sven Tandlak Tdskr. 1947; 40: 1-15.
16. Alves PVMS, Mazuchelli J, Patel PK, Bolognese AM. Cranial base angulation in Brazilian patients seeking orthodontic treatment. J Craniofacial Surg 2008; 19: 334-8.
17. Downs WB. Variation in facial relationships: their significance in treatment and prognosis. Am J Orthod. 1948; 34: 812-40.
18. Henneberke M, Prahl-Andersen B. Cranial base growth for Dutch boys and girls: A multilevel approach. Am J Orthod Dentofacial Orthop. 1994; 106: 503-12.
19. Klocke A, Nanda RS, Kahl-Nieke B. Role of cranial base flexure in developing sagittal jaw discrepancies. Am J Orthod Dentofacial Orthop. 2002; 122: 386-91.
20. Hayashi I. Morphological relationship between the cranial base and dentofacial complex obtained by reconstructive computer tomographic images. Eur J Orthod. 2003; 25: 385-91.
21. Sayin M, Türkkahraman. Cephalometric evaluation of non-growing females with skeletal and dental class II, division 1 malocclusion. Angle Orthod. 2005; 75: 656-60.
22. Tanabe Y, Taguchi Y, Noda T. Relationship between cranial base structure and maxillofacial components in children aged three to five years. Eur J Orthod. 2002; 24: 175-81.
23. Anderson D, Popovich F. Relation of cranial base flexure to cranial form and mandibular position. Am J Physical Anthrop. 1983; 61: 181-7.
24. Wolfe SM, Araujo E, Behrents RG, Buschang PH. Craniofacial growth of class III subjects six to sixteen years of age. Angle Orthod. 2011; 81: 211-6.
25. El-Batran M, Soliman N, El-Wakil K. The relationship between cranial base and maxillo-facial morphology in Egyptian children. J Comp Human Biol. 2008; 59: 287-300.
26. Arat M, Koklu A, Özdiler E, Rübendüz M, Erdoğan B. Craniofacial growth and skeletal maturation: A mixed longitudinal study. Eur J Orthod. 2001; 23:355-61.
27. Kuroe K, Rosas A, Molleson T. Variation in the cranial base orientation and facial skeleton in dry skulls sampled from three major populations. Eur J Orthod. 2004; 26: 201-7.