Journal of Chemical Health Risks

www.jchr.org

JCHR (2025) 15(4), 984-991 | ISSN:2251-6727

Assessment of Cranial Base Parameters in Adults with Class I, Class II and Class III Skeletal Patterns

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(Received: 16 May 2025 Revised: 20 June 2025 Accepted: 12 July 2025)

KEYWORDS

Cranial base parameters , skeletal patterns, orthodontic diagnosis, Class I ,II and III malocclusions, cephalometric study, NemoCeph software.

ABSTRACT:

INTRODUCTION :There is a wide variation in the cranial base parameters among various races based on their genetic patterns, ethnicity and family traits as compared to the standard norms published in the literature. Hence there is a need to assess the cranial base parameters of the patients visiting the department of Orthodontics and Dentofacial Orthopaedics, A.J Institute of Dental sciences, Mangalore to their standard norms.This study helps in establishing the relationship of craniofacial patterns in the development of different types of malocclusion namely class I, class II and class III.

OBJECTIVE :To assess the cranial base parameters of adults with class I skeletal pattern visiting the department with their standard norms.

MATERIALS AND METHODS :The sample size included pretreatment lateral cephalograms from 456 patients exhibiting a Class I, Class II and Class III skeletal patterns. These cephalograms were analysed to assess the cranial base parameters at various anatomical landmarks. The age range of the subjects was between 18 and 40 years.

RESULT :When compared to cephalometric norms, AR-PTM, PTM-N, and BA-PTM values were lower, while BA-N and SN values were higher. BA-S and N-S angles showed no significant differences. PTM-N values were lowest among Class II subjects, while BA-N values were highest in Class III. Class II individuals showed greater PTM-A measurements, whereas SN values were highest in Class III, followed by Class II and Class I. FH-SN angles were highest in Class III, and other angles like N-S-Ar and N-S-Ba showed no significant differences across groups. Identifying cranial base characteristics improves diagnostic accuracy, treatment planning, and early intervention opportunities in orthodontics and orthognathic procedures.

1. Introduction

The cranial base plays a critical role in craniofacial development, influencing skeletal relationships and orthodontic treatment planning. Divided into anterior, middle, and posterior fossae, it guides jaw development and impacts malocclusions like Class I, II, and III based on cranial base length and angulation. Variations in cranial base dimensions strongly correlate with skeletal discrepancies, with increased angles linked to Class II patterns and reduced angles associated with Class III malocclusions.

Ethnic diversity, developmental factors, and synchondroses influence cranial base growth, with early intervention being crucial for atypical development. Advanced imaging technologies like CBCT provide precise measurements, enhancing diagnosis and treatment plans. Genetic studies suggest cranial base morphology may be influenced

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JCHR (2025) 15(4), 984-991 | ISSN:2251-6727

by specific genes, opening possibilities for predictive testing.

Meta-analyses show cranial base parameters predict malocclusion types and vertical growth patterns, impacting facial aesthetics and occlusal stability. Flexion of the cranial base affects mandibular rotation and jaw positioning, contributing to skeletal classification. Longitudinal studies reveal gradual cranial base angle changes during growth, underscoring the need for thorough assessment in orthodontics.

This study investigates cranial base characteristics across skeletal groups, aiming to improve understanding and strategies for diagnosing and treating malocclusions.

2. Objectives

To assess the cranial base parameters of adults with class I skeletal pattern visiting the department with their standard norms.

To evaluate and compare the linear measurements of the cranial base in class I , class II and class III skeletal patterns

To evaluate and compare the angular measurements of the cranial base in class I , class II and class III skeletal pattern.

3. Methods

An observational study was conducted among adult patients visiting the department of Orthodontics and Dentofacial Orthopedics, A.J Institute of Dental sciences, Mangalore.

Study records from the archives and patients who have visited the department of Orthodontics and Dentofacial Orthopedics, A.J Institute of Dental sciences, Mangalore.

Adults belonging to 18-40 years of age and patients who have visited the department of Orthodontics and Dentofacial Orthopedics, A.J Institute of Dental sciences, Mangalore.

INCLUSION CRITERIA

Patients with Class I skeletal pattern with ANB angle which is 0 to 4

Patients with Class II skeletal pattern with ANB angle which is more than 4

Patients with Class III skeletal pattern with ANB angle which is less than 0

Age 18– 40 years

EXCLUSION CRITERIA

Patients without full complement of teeth till 2nd molar

Poor quality cephalograms

Patients with syndromes affecting the head and neck

Patients with trauma of head , neck and maxillo-facial area

ARMAMENTARIUM REQUIRED

Pretreatment lateral cephalograms of skeletal class I,II and III patients

Computer with NemoCeph software installed

ASSESMENT OF PRE TREATMENT LATERAL CEPHALOGRAM

Standardized lateral cephalograms which are taken by properly positioning the subject on the cephalostat with FH plane parallel to the floor and teeth in centric occlusion. All cephalograms had good definition of hard and soft tissue structures and profiles.

After calibrating the cephalograms in the software, the cephalograms were traced in the software and the selected landmarks for the study were identified and measured.

METHOD OF STUDY

The following linear measurements were taken

1. Sella to nasion [S – N]
2. Basion to pterygomaxillary fissure [Ba – Ptm]
3. Pterygomaxillary fissure to point A [Ptm – Point A]
4. Basion to nasion [Ba – N]
5. Sella to basion [S – Ba]

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6. Articulare to pterygomaxillary fissure [Ar – Ptm]

7. Pterygomaxillary fissure to nasion [Ptm – N]

The following angular measurements were taken

1. Basion , sella and nasion (Ba - S – N)

2. Nasion , sella and articulare (N – S – Ar)

3. FH plane and sella- nasion (FH plane - S – N)

METHOD OF DATA COLLECTION

In this cephalometric study, 456 lateral cephalograms from the archives and of patients who have visited the department of Orthodontics and Dentofacial Orthopedics, A.J Institute of Dental sciences, Mangalore have been collected. The measurements were done on the NemoCeph software. The samples have been divided into 3 groups based on the ANB values namely

Group A :Class I skeletal pattern with ANB which is 0 to 4
Group B : Class II skeletal pattern with ANB angle which is more than 4

Group C : Class III skeletal pattern with ANB angle which is less than 0

STATISTICAL ANALYSIS

Statistical test

Descriptive statistics was done.

Inferential analysis was done using ANOVA/kruskal wallis(BASED ON NORMALITY) was used to compare the mean between the groups.

Level of significance will be set at P≤0.05.

Statistical analysis was performed with IBM SPSS Statistics for Windows, version 23.0. Armonk, New York: IBM Corp.

4. Results

Table no. 1 Comparison of mean AR-PTM values (in mm) between 3 different Skeletal Malocclusion Classes using One-way ANOVA

Parameter	Classes	N	Mean	SD	Min	Max	p-value
AR-PTM	Class I	152	33.29	3.57	25.2	43.1	0.28
	Class II	152	33.11	3.34	25.1	43.6	
	Class III	152	33.76	4.16	20.0	44.5	

Mean AR-PTM values across Skeletal Malocclusion Classes revealed no significant differences (p-value: 0.28). Class I recorded 33.29 ± 3.57 mm (min: 25.2 mm, max: 43.1 mm), Class II had 33.11 ± 3.34 mm (min: 25.1 mm, max: 43.6 mm), and Class III showed 33.76 ± 4.16 mm (min: 20.0 mm, max: 44.5 mm).

Table no. 2 Comparison of mean PTM-N values (in mm) between 3 different Skeletal Malocclusion Classes using One-way ANOVA Test followed by Tukey's post hoc Test

Parameter	Classes	N	Mean	SD	Min	Max	p-value [a]	Sig. Diff	p-value [b]
PTM-N	Class I	152	46.56	4.20	36.0	57.1	0.002*	I vs II	0.004*
	Class II	152	44.98	3.99	34.4	55.6		I vs III	0.92
	Class III	152	46.36	4.54	30.6	60.1		II vs III	0.01*

* - Statistically Significant

Note: a. One-way ANOVA Test & b. Tukey's post hoc Test

The comparison of mean PTM-N values among Skeletal Malocclusion Classes revealed statistically significant differences. Class I had a mean of 46.56 ± 4.20 mm, Class II had 44.98 ± 3.99 mm, and Class III had 46.36 ± 4.54 mm. Significant differences were found between Class I and II (p=0.004) and Class II and III (p=0.01), while Class I and III showed no significant difference (p=0.92).

Table no. 3 Comparison of mean BA-N values (in mm) between 3 different Skeletal Malocclusion Classes using One-way ANOVA Test followed by Tukey's post hoc Test

Parameter	Classes	N	Mean	SD	Min	Max	p-value [a]	Sig. Diff	p-value [b]
BA-N	Class I	152	87.51	6.72	73.0	108.3	<0.001*	I vs II	0.99
	Class II	152	87.56	6.65	65.8	108.0		I vs III	<0.001*
	Class III	152	90.55	7.11	74.4	108.0		II vs III	<0.001*

* - Statistically Significant

Note: a. One-way ANOVA Test & b. Tukey's post hoc Test

Class III demonstrated a significantly higher mean BA-N value (90.55 ± 7.11 mm) compared to Class I (87.51 ± 6.72 mm) and Class II (87.56 ± 6.65 mm), with a p-value of <0.001 indicating statistical significance. Pairwise comparisons revealed no difference between Class I and Class II (p=0.99), but significant differences between Class III and the other two classes (p<0.001 for each comparison).

Table no. 4 Comparison of mean BA-PTM values (n mm) between 3 different Skeletal Malocclusion Classes using One-way ANOVA Test followed by Tukey's post hoc Test

Parameter	Classes	N	Mean	SD	Min	Max	p-value [a]	Sig. Diff	p-value [b]
BA-PTM	Class I	152	40.99	3.82	31.7	51.4	0.04*	I vs II	0.04*
	Class II	152	41.93	3.52	30.9	52.6		I vs III	0.11
	Class III	152	41.88	4.14	30.6	52.7		II vs III	0.98

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JCHR (2025) 15(4), 984-991 | ISSN:2251-6727

* - Statistically Significant
Note: a. One-way ANOVA Test & b. Tukey's post hoc Test

The comparison of mean BA-PTM values among the three Skeletal Malocclusion Classes showed statistical significance overall (p=0.04). Class I had a mean of 40.99 ± 3.82 mm, Class II 41.93 ± 3.52 mm, and Class III 41.88 ± 4.14 mm. Pairwise comparisons indicated significance between Class I and II (p=0.04), while Class I vs III (p=0.11) and Class II vs III (p=0.98) were not significant. (Refer Fig no. 14)

Table no. 5 Comparison of mean BA-S values (in mm) between 3 different Skeletal Malocclusion Classes using One-way ANOVA

Parameter	Classes	N	Mean	SD	Min	Max	p-value
BA-S	Class I	152	24.00	9.29	15.6	96.7	0.25
	Class II	152	22.84	4.09	12.5	40.7	
	Class III	152	23.66	3.89	13.0	33.5	

Class I, II, and III exhibited mean BA-S values of 24.00 ± 9.29 mm, 22.84 ± 4.09 mm, and 23.66 ± 3.89 mm, respectively. Despite observed variations, statistical analysis revealed no significant differences among the groups (p-value = 0.25).

Table no. 6 Comparison of mean FH-SN values (in degrees) between 3 different Skeletal Malocclusion Classes using One-way ANOVA Test followed by Tukey's post hoc Test

Parameter	Classes	N	Mean	SD	Min	Max	p-value [a]	Sig. Diff	p-value [b]
FH-SN	Class I	152	6.30	0.76	4.6	11.0	<0.001*	I vs II	0.91
	Class II	152	6.34	0.88	4.5	10.4		I vs III	<0.001*
	Class III	152	6.76	1.09	4.6	11.1		II vs III	<0.001*

Class III exhibited the highest mean FH-SN value (6.76 ± 1.09 degrees) compared to Class I (6.30 ± 0.76 degrees) and Class II (6.34 ± 0.88 degrees), with statistical significance (p<0.001). Pairwise comparisons showed no significant difference between Class I and II (p=0.91), but Class III had significantly higher values than both Class I and II (p<0.001).

Table no. 7 Comparison of mean N-S-AR values (in degrees) between 3 different Skeletal Malocclusion Classes using One-way ANOVA

Parameter	Classes	N	Mean	SD	Min	Max	p-value
N-S-AR	Class I	152	124.59	5.92	109.0	140.0	0.28
	Class II	152	124.01	5.70	111.0	140.0	
	Class III	152	123.45	6.83	105.0	140.0	

The comparison of mean N-S-AR values among the three Skeletal Malocclusion Classes showed no statistically significant difference. Class I had a mean value of 124.59 ± 5.92 degrees, Class II showed 124.01 ± 5.70 degrees, and Class III had 123.45 ± 6.83 degrees with a p-value of 0.28. Despite minor variations, the measurements were consistent across classifications.

Table no. 8 Comparison of mean N-S-BA values (in degrees) between 3 different Skeletal Malocclusion Classes using One-way ANOVA

Parameter	Classes	N	Mean	SD	Min	Max	p-value
N-S-BA	Class I	152	130.86	5.52	116.0	146.0	0.84
	Class II	152	130.53	5.24	118.0	149.0	
	Class III	152	130.89	6.78	111.0	145.0	

Class I, Class II, and Class III showed mean N-S-BA values of 130.86 ± 5.52, 130.53 ± 5.24, and 130.89 ± 6.78 degrees respectively, with no significant differences (p-value = 0.84). The values were consistent across classifications, indicating no substantial variation. (Refer Fig no. 18)

Table no. 9 Comparison of mean PTM-A values (in mm) between 3 different Skeletal Malocclusion Classes using One-way ANOVA Test followed by Tukey's post hoc Test

Parameter	Classes	N	Mean	SD	Min	Max	p-value [a]	Sig. Diff	p-value [b]
PTM-A	Class I	152	47.00	4.11	29.7	57.6	<0.001*	I vs II	0.001*
	Class II	152	48.82	5.00	34.1	85.7		I vs III	0.04*
	Class III	152	45.79	3.61	34.5	57.1		II vs III	<0.001*

Statistical analysis showed significant differences in mean PTM-A values among Skeletal Malocclusion Classes (p<0.001). Class I had a mean of 47.00 ± 4.11 mm, Class II 48.82 ± 5.00 mm, and Class III 45.79 ± 3.61 mm. Pairwise comparisons revealed Class II had higher values than Class I (p=0.001) and Class III (p<0.001), while Class I was greater than Class III (p=0.04). (Refer Fig no. 19)

Table no. 10 Comparison of mean SN values between 3 different Skeletal Malocclusion Classes using One-way ANOVA Test followed by Tukey's post hoc Test

Parameter	Classes	N	Mean	SD	Min	Max	p-value [a]	Sig. Diff	p-value [b]
SN	Class I	152	63.96	6.49	7.6	83.4	0.04*	I vs II	0.28
	Class II	152	64.86	4.60	48.5	76.8		I vs III	0.03*
	Class III	152	65.44	4.12	54.6	82.2		II vs III	0.59

The mean SN values among Class I, II, and III showed significant differences (p=0.04). Class III had the highest mean (65.44 ± 4.12), followed by Class II (64.86 ± 4.60), and Class I (63.96 ± 6.49). Pairwise comparisons revealed Class I significantly differed from Class III (p=0.03), while Class II and Class III showed no significant difference (p=0.59).

Statistical Comparison Between Sample Means and Standard Reference Values

- AR-PTM: Significantly lower, mean difference -3.8125 (95% CI: -4.3853 to -3.2397), p < 0.001.
- PTM-N: Substantially lower, mean difference -6.2421 (95% CI: -6.9157 to -5.5685), p < 0.001.

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JCHR (2025) 15(4), 984-991 | ISSN:2251-6727

- BA-N: Higher, mean difference 4.4093 (95% CI: 3.3331 to 5.4854), $p < 0.001$.
- BA-PTM: Reduced, mean difference -3.6086 (95% CI: -4.2209 to -2.9962), $p < 0.001$.
- BA-S: No significant difference, mean difference 0.8956 (95% CI: -0.5928 to 2.3840), $p = 0.236$.
- FH-SN: Lower, mean difference -0.7013 (95% CI: -0.8238 to -0.5788), $p < 0.001$.
- N-S-AR: No significant difference, mean difference 0.3921 (95% CI: -0.8238 to 1.3413), $p = 0.416$.
- N-S-BA: Slightly lower, mean difference -0.7382 (95% CI: -1.6235 to 0.1471), $p = 0.102$.
- PTM-A: Lower, mean difference -4.3970 (95% CI: -5.0560 to -3.7381), $p < 0.001$.
- SN: Higher, mean difference 8.5405 (95% CI: 7.5009 to 9.5802), $p < 0.001$.

Summary indicates significant deviations in AR-PTM, PTM-N, BA-PTM, PTM-A, and SN, with conformity observed in BA-S, N-S-AR, and N-S-BA.

5. Discussion

The present study was conducted with the primary objective of evaluating and comparing cranial base parameters, both linear and angular, among adults presenting with Class I, Class II, and Class III skeletal malocclusions. Cranial base morphology has long been considered a cornerstone in understanding craniofacial development, and its relationship with sagittal skeletal discrepancies is of profound clinical significance. By analysing multiple cephalometric parameters across different skeletal patterns, this study provides meaningful insights into the role of cranial base configurations in shaping skeletal malocclusions and facial esthetics.

Analysis of Linear Parameters

Among the linear cranial base measurements, the Ptm-N (pterygomaxillary fissure to nasion) distance emerged as one of the most diagnostically relevant parameters, showing statistically significant differences between skeletal classes. The mean Ptm-N values were found to be lowest in Class II subjects (44.98 ± 3.99 mm), suggesting a more posterior positioning of the maxilla or anterior cranial base in these individuals. This reduced anterior cranial base length may directly contribute to mandibular retrognathism, a hallmark of Class II skeletal patterns. These results corroborate earlier studies by McCarthy et al. (1980)18 and Ghafari et al. (1989)22, both of which highlighted the role of reduced anterior cranial base length in predisposing individuals to Class II malocclusions.

In contrast, Class III subjects demonstrated increased values in BA-N (basion to nasion) measurements (90.55 ± 7.11 mm), significantly higher than those in Class I and Class II groups. A longer cranial base may create a more anterior displacement of the mandible, favouring mandibular prognathism. This aligns with the cranial base angle theory, which suggests that the relative length and inclination of the cranial base significantly affect maxillomandibular relationships—a theory validated by Siriwat and Jarabak (1985)20 and Tulloch et al. (1997)27. Increased posterior cranial base length provides a structural framework that permits forward positioning of the mandible, thus contributing to Class III skeletal profiles.

The PTM-A (pterygomaxillary fissure to point A) measurements were significantly greater in Class II individuals (48.82 ± 5.00 mm) as compared to Class I and Class III. This finding may indicate an anteroposterior elongation of the maxillary base or positional differences in the maxilla, contributing to the posterior positioning of the mandible and a resultant Class II profile. These differences in maxillary positioning underscore the significance of cranial base orientation in influencing not just the mandible, but also the spatial configuration of the midface. This supports the findings of Battagel et al. (1996)26, who reported cranial base- induced differences in maxillary positioning across malocclusion classes.

SN (Sella-Nasion) values, indicative of anterior cranial base length, were found to be highest in Class III subjects (65.44 ± 4.12 mm), followed by Class II and then Class I, with the differences being statistically significant. These results affirm the hypothesis that an elongated anterior cranial base can play a role in advancing the mandible, as also noted by Singh et al. (2007)36 and Almeida et al. (2008)37.

Interestingly, some linear parameters such as AR-PTM (Articulare to Pterygomaxillary fissure) and BA-S (Basion to Sella) did not exhibit statistically significant differences between the skeletal classes. The AR-PTM measurement is largely reflective of posterior cranial base length and its stability across the groups might suggest that this dimension is less prone to variation in

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the presence of malocclusions. This aligns with the findings of Björk and Skieller (1977)16, who emphasized the relative constancy of certain cranial base dimensions after the adolescent growth spurt.

Angular Parameters and Skeletal Patterns

Among angular measurements, the FH-SN angle (Frankfort horizontal to Sella-Nasion plane) exhibited statistically significant differences. Class III subjects had the highest FH-SN angle values, signifying a steeper cranial base inclination. This steeper inclination has been associated with increased mandibular projection and anterior facial height, which are typical characteristics of Class III skeletal patterns. The findings are consistent with those reported by Ricketts (1960)15 and Buschang et al. (2002)31, who posited that an increased cranial base angle is a marker for mandibular advancement.

Conversely, angles such as N-S-Ar (Nasion-Sella-Articulare) and N-S-Ba (Nasion-Sella- Basion), which are indicative of cranial base flexure, did not show statistically significant differences across the groups. This might suggest that while certain angular relationships are altered in the presence of skeletal malocclusion, others remain stable and may not contribute directly to sagittal discrepancies. Buschang and Hinton (2005)35 proposed that such inconsistencies may result from individual genetic variability and compensatory environmental adaptations.

Deviation from Standard Cephalometric Norms

When the study sample was compared with established cephalometric reference norms, several parameters, including AR-PTM, PTM-N, and BA-PTM, were found to be significantly lower, whereas BA-N and SN values were significantly higher. These deviations emphasize the importance of using population-specific norms during diagnosis and treatment planning. Studies by Singh et al. (2007)36 and Almeida et al. (2008)37 support this assertion, noting substantial inter-population variability in cranial base morphology. As such, treatment protocols designed on Western norms may not be directly applicable to Indian patients without appropriate modification.

Clinical Implications

Understanding the variations in cranial base morphology is not merely an academic exercise; it has practical implications in the clinical setting. Cranial base length and angulation influence the spatial position of the jaws and can impact both orthodontic and orthognathic treatment outcomes. For instance, increased posterior cranial base length and reduced cranial base angle in Class III subjects suggest a structural predisposition to mandibular prognathism. In such cases, early diagnosis and orthopaedic interventions such as facemasks or chincups could be strategically implemented to guide growth. The significant differences observed in anterior cranial base lengths also highlight the need for maxillary protraction in Class II cases, consistent with the findings of Ramirez-Yanez et al. (2017)44 and Mehta et al. (2018)45.

Furthermore, cranial base morphology has been implicated in surgical stability post- orthognathic procedures. Mehta et al. (2018)45 showed that cranial base inclination could influence relapse rates following mandibular setback surgery. Therefore, incorporating cranial base assessments into pre-surgical planning may enhance predictability and stability of surgical corrections.

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JCHR (2025) 15(4), 984-991 | ISSN:2251-6727

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