

Comparison of Chin Position and Sagittal Lip Position in Untreated Class I, Class II, and Class III Adult Subjects: A Comprehensive Cephalometric Analysis

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ABSTRACT

Objectives: Accurate evaluation of facial esthetics requires coordinated assessment of skeletal, dentoalveolar, and soft-tissue components. The anteroposterior position of the chin and the sagittal posture of the lips are key determinants of perceived profile harmony and treatment goals in orthodontics.

Aim: This study aims to compare chin position, using Cartesian Gnathion coordinates, and sagittal lip position, using standard soft-tissue reference lines, among untreated adult skeletal Class I, Class II, and Class III subjects.

Materials and Methods: 42 adults (14 per class) were analyzed using ANB and Wits appraisal for classification. Chin position was assessed using Gn-X and Gn-Y coordinates; lip position was measured relative to Burstone's B-line.

Results: Class III subjects showed the most anterior Gn-X values, while Class II subjects had retrusive mandibles and more protrusive upper lips. Class III subjects exhibited prominent lower lips. Moderate correlations existed between chin projection and lower lip protrusion.

Conclusions: Chin and lip positions vary systematically with skeletal pattern, offering important implications for diagnosis and treatment planning.

Keywords: Craniofacial growth and development, Orthodontics, Cephalometrics, Chin and Lip position.

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INTRODUCTION

Contemporary orthodontics operates within a dynamic craniofacial environment in which both skeletal and soft-tissue structures continue to remodel through adolescence and adulthood. As a result, clinicians must anticipate long-term facial outcomes rather than limit treatment goals to dental correction alone. Soft-tissue morphology particularly lip posture and skeletal components such as chin position are central in determining facial harmony, treatment stability, and esthetic outcomes.¹

Burstone emphasized that malocclusion, tooth stability, and facial appearance are strongly influenced by the mass, posture, and function of the perioral soft tissues. Variations in sagittal lip projection across malocclusion types and populations can alter the perceived facial profile and influence treatment planning.² Holdaway further demonstrated that skeletal parameters alone are

insufficient to predict soft-tissue behaviour, underscoring the importance of quantitative soft-tissue cephalometric assessment. Lip thickness, taper, and incisor inclination produce variable but predictable effects on sagittal lip position, highlighting the need to evaluate soft tissues independently rather than assume a direct reflection of underlying skeletal form.³

Chin position remains one of the most influential determinants of lower facial esthetics. Classic implant studies by Björk and Skieller showed that mandibular growth consists of rotational and remodelling changes at the symphysis and lower border, ultimately shaping chin projection.⁴ Later longitudinal work confirmed substantial individual variation in the displacement of pogonion and gnathion, influenced by mandibular rotation patterns, condylar growth, and dentoalveolar compensation.^{4,7}

Soft-tissue research consistently identifies malocclusion-specific differences in lip posture: Class II subjects typically display increased upper-lip prominence, whereas Class III individuals exhibit greater lower-lip projection. These patterns emphasize the need to interpret lip position within the context of skeletal classification.⁶⁻⁸

Despite extensive literature on soft-tissue esthetics and mandibular growth, relatively few studies have simultaneously examined chin position and sagittal lip posture in adults across skeletal Classes I, II, and III using standardized cephalometric methods. The Cartesian coordinate system introduced by Del Santo Jr. offers a more stable and distortion-free approach for quantifying chin position than conventional angular analyses.⁵

Therefore, this study aims to integrate skeletal chin projection and soft-tissue lip posture into a unified cephalometric assessment of untreated adult skeletal Class I, II, and III subjects to enhance diagnostic precision and support esthetically driven orthodontic treatment planning.

1. MATERIALS AND METHODS:

Study Design

Retrospective, cross-sectional cephalometric study.

Sample Size and Sampling

The sample size was determined to provide adequate statistical power for detecting the anticipated intergroup difference. Using a standard deviation of 7.66 and an expected mean difference of 8.61, calculations were based on a two-tailed 95% confidence level ($Z_{1-\alpha/2}=1.96$) ($Z_{\{1-\alpha/2\}} = 1.96$) ($Z_{1-\alpha/2}=1.96$) and 80% power ($Z_{\beta}=0.84$) ($Z_{\{\beta\}} = 0.84$) ($Z_{\beta}=0.84$). Substitution of these parameters into the standard formula yielded an estimated requirement of 12.4 subjects per group. To ensure sufficient precision and maintain the desired power, the value was rounded upward, resulting in a final sample size of 13 participants per group. This sample size is therefore appropriate to reliably detect the targeted effect while minimizing the risk of Type II error.

Source of data:

The Present study was conducted in the Department of Orthodontics and Dentofacial Orthopaedics. Pre-existing lateral cephalograms of orthodontic patients for treatment purposes were collected, according to selection criteria, maintaining the confidentiality of patient's details.

The study incorporated pre-existing lateral cephalograms of 39 patients (both males and females) in the age group of 18-30 years were taken. The 39 lateral cephalograms were divided into 3 groups, Group A, Group B, and Group C, with 13 in each group consisting of both males and females.

Inclusion Criteria

- Age 18–30 years at the time of radiograph (to minimize residual growth).
- Untreated adults with complete permanent dentition except third molars.

- Good-quality pre-treatment lateral cephalogram in natural head position, teeth in centric occlusion and lips relaxed.
- Skeletal classification based on ANB and Wits appraisal.

Exclusion Criteria

- History of previous orthodontic, orthognathic or craniofacial surgery.
- Craniofacial syndromes, clefts or major facial trauma.
- Significant facial asymmetry (clinical or radiographic).
- Poor-quality cephalograms (motion blur, double images, open-mouth or mandibular protrusion).

Skeletal Classification

Subjects were classified into skeletal Class I, II or III according to combined ANB angle and Wits appraisal:

- **Class I:** ANB 0–4°, Wits 0 to –3 mm
- **Class II:** ANB >4°, Wits ≥ –1 mm
- **Class III:** ANB <0°, Wits ≤ –4 mm

Cephalometric landmarks (A, N, B, occlusal plane) were traced according to standard cephalometric definitions.

Radiographic Acquisition and Orientation

All cephalograms were originally taken with the Frankfort plane approximately horizontal, in natural head position, with the lips in relaxed contact and teeth in centric occlusion.

Each radiograph was reoriented so that a constructed line through Sella–Nasion (SN) is rotated –7° to approximate the true horizontal.

A Cartesian coordinate system was defined:

- Horizontal axis: SN – 7° (X-axis).
- Vertical axis: perpendicular to X-axis through Sella (S) as the origin (0,0).

Landmarks and Measurements

Hard-tissue landmark:

- **Gnathion (Gn):** Most anteroinferior point on the bony chin, identified on the mandibular symphysis was traced manually on the lateral cephalogram.

From the traced lateral cephalogram, the following measurements were recorded:

- **Gn-X (mm):** Horizontal coordinate of Gn relative to S.
- **Gn-Y (mm):** Vertical coordinate of Gn relative to S.

Soft-tissue landmarks:

The following soft-tissue points were traced: subnasale (Sn), labrale superius (Ls), labrale inferius (Li), soft-tissue pogonion (Pos).

Reference line for lips:

- **Burstone's B-line:** Line joining subnasale to soft-tissue pogonion but located to evaluate lip prominence; in practice it is similar to the soft-tissue A–B line used by Burstone.

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Lip variables:

- UL-B: Distance from Ls to B-line.
- LL-B: Distance from Li to B-line.

Distances were measured manually on the traced lateral cephalogram. Positive values denote a point anterior to the line, negative posterior.

Statistical Analysis

- All statistical analysis were performed by using the SPSS software 23.0.
- The mean and the standard deviation was calculated for each variable.
- Analysis of the data between groups was carried out using ANOVA test and post hoc test respectively if the data is parametric. If not Kruskal wallis test was used.
- $P < 0.05$ was considered as statistically significant.

2. RESULTS

The present study compared skeletal chin position and soft-tissue lip posture among adult skeletal Class I, Class II, and Class III subjects using standardized Cartesian coordinate and linear cephalometric measurements.

Chin Position (Cartesian Coordinates)

Table no.1 - Comparison of chin position using Cartesian coordinates among the three groups of the study using ANOVA test				
Co-ordinates	Class I	Class II	Class III	P-value
X-coordinates	65.26±8.75	58.03±8.17	70.31±11.02	0.0076
Y-coordinates	92.23±5.86	93.73±6.59	96.58±10.44	0.3715

$P < 0.05$ is considered as statistically significant

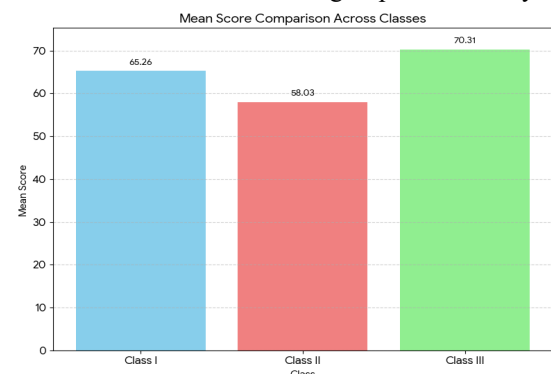
Analysis of the X-coordinate values showed marked variation in the anteroposterior location of the chin across the three skeletal groups. Class III subjects demonstrated the most anterior chin position, followed by Class I, whereas Class II subjects exhibited the most posteriorly positioned chin. In contrast, the Y-coordinate values, representing vertical chin placement, showed relatively similar distributions across all groups, indicating minimal vertical positional differences of the chin among Classes I, II, and III.

Table no.2 - Pairwise comparison of chin position using Cartesian coordinates between the three groups of the study using post hoc test			
Co-ordinates	Groups compared	Mean difference	P-value
X-coordinates	Class I - Class II	-7.23	0.13
	Class I - Class III	5.0462	0.36
	Class II - Class III	12.27	0.0056

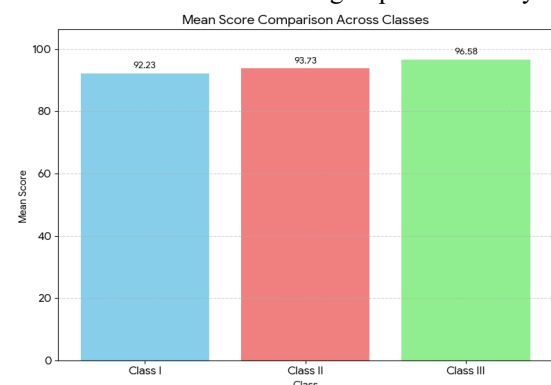
Y-coordinates	Class I - Class II	1.50	0.87
	Class I - Class III	4.35	0.34
	Class II - Class III	2.85	0.63

$P < 0.05$ is considered as statistically significant
Pairwise comparisons further clarified these patterns. The largest difference in anteroposterior chin location was observed between Class II and Class III subjects, with Class III displaying a distinctly more forward chin position. Comparisons involving Class I showed smaller differences with both Class II and Class III. Vertical chin position remained comparable among all groups, with no meaningful differences detected.

Graph no.1 - Comparison of chin position as per X-coordinates between the three groups of the study



Graph no.2 - Comparison of chin position as per Y-coordinates between the three groups of the study



Lip Position

Table no.3 - Comparison of lip position in upper and lower region assessed using ANOVA test				
Region	Class I	Class II	Class III	P-value
UL	4.46±1.27	4.62±1.79	4.27±2.24	0.8880
LL	2.31±1.53	3.58±2.36	5.30±2.46	0.0046

$P < 0.05$ is considered as statistically significant
 Evaluation of soft-tissue lip position revealed that upper lip (UL) measurements were similar across all skeletal classes, with no notable differences in the sagittal placement of the upper lip among Class I,

Class II, and Class III subjects. However, lower lip (LL) position exhibited a clear pattern of variation: Class III individuals showed the greatest lower-lip protrusion, Class II subjects demonstrated intermediate values, and Class I subjects displayed the least protrusive lower lips.

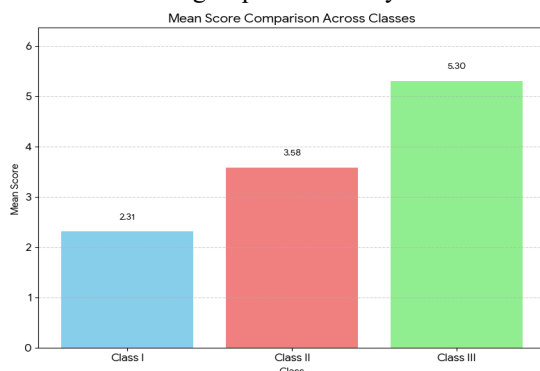
Table no.4 - Pairwise comparison of lip position in upper and lower region between the three groups of the study using post hoc test			
Region	Groups compared	Mean difference	P- value
UL	Class I - Class II	0.15	0.97
	Class I - Class III	-0.19	0.9605
	Class II - Class III	-0.3402	0.8778
LL	Class I - Class II	1.26	0.3037
	Class I - Class III	2.992	0.0032
	Class II - Class III	1.723	0.1186

$P < 0.05$ is considered as statistically significant. Pairwise analysis indicated that this variation was most evident between Class I and Class III subjects, with the latter presenting a distinctly more protrusive lower lip. The differences between Class I–Class II and Class II–Class III were comparatively smaller.

Graph no.3 - Comparison of upper lip position between the three groups of the study



Graph no.4 - Comparison of lower lip position between the three groups of the study



3. DISCUSSION

This study provides an integrated evaluation of skeletal chin projection and sagittal lip posture across untreated adult skeletal Class I, Class II, and Class III subjects. By employing Cartesian coordinate analysis for chin assessment and standardized soft-tissue measurements for lip evaluation, the findings reaffirm classical cephalometric trends while offering quantitative refinement to the understanding of sagittal facial imbalance.

The significant variation identified in the X-coordinate of the chin among the three skeletal groups reflects the inherent anteroposterior discrepancies that typify Class II and Class III patterns. As expected, Class II subjects presented with a markedly posterior chin position, whereas Class III individuals demonstrated the most anterior chin placement. These observations are consistent with established cephalometric and radiographic literature describing mandibular retrusion or increased clockwise mandibular rotation in Class II malocclusion, and enhanced mandibular projection or counterclockwise rotation in Class III malocclusion. Such skeletal contrasts contribute meaningfully to characteristic profile differences and reinforce the importance of chin projection as a primary determinant of lower facial esthetics.

Interestingly, the Y-coordinate of the chin did not differ significantly among skeletal classes, suggesting that vertical chin position is comparatively stable and less influenced by sagittal skeletal discrepancies. Vertical variations may instead be more closely tied to dentoalveolar compensations, lower facial height tendencies, or rotational growth pattern.

Post hoc analysis revealed the greatest difference in chin position between Class II and Class III subjects, underscoring the opposite ends of the sagittal spectrum they represent. This finding also highlights the utility of Cartesian coordinate systems, which offer linear, distortion-free quantification of skeletal landmarks. Unlike angular measurements that may be influenced by cranial reference plane inclinations or head posture variability, Cartesian systems provide a more faithful representation of true spatial displacement—particularly advantageous in borderline or surgical-case diagnosis.

With respect to soft tissues, the upper lip position did not differ significantly among groups. This aligns with evidence that the upper lip demonstrates limited adaptability to skeletal discrepancies. Influenced by factors such as soft-tissue thickness, nasolabial angle morphology, and maxillary incisor inclination, the upper lip often maintains relatively consistent sagittal projection despite underlying skeletal disharmony. Consequently, reliance on upper-lip posture alone for diagnosing sagittal discrepancies may be insufficient without concurrent evaluation of the chin and lower lip.

The lower lip, however, demonstrated significant variability across groups, with Class III subjects exhibiting the greatest protrusion, followed by Class II and Class I. This reflects the lower lip's strong dependence on mandibular projection and lower incisor inclination. In Class III individuals, forward mandibular positioning and dentoalveolar compensation commonly result in exaggerated lower-lip prominence, further accentuated by neuromuscular adaptation. The pronounced differences between Class I and Class III subjects reinforce the lower lip as a sensitive soft-tissue indicator of skeletal imbalance.

Clinically, these findings underscore the need to integrate skeletal and soft-tissue assessments when formulating orthodontic and orthognathic treatment plans. In Class II patients, enhancement of chin projection—whether through growth modification, camouflage strategies, or genioplasty—can substantially improve facial balance. In Class III patients, accurate appraisal of lower lip protrusion and chin position is essential for determining the feasibility of camouflage treatment versus the necessity for surgical correction. Recognizing the relative stability of the upper lip compared with the dynamic nature of the lower lip across malocclusions may also assist in predicting soft-tissue outcomes following extraction therapy, incisor retraction, or mandibular advancement procedures.

Overall, this study reinforces the interconnected yet differentially adaptive nature of skeletal morphology and soft-tissue behaviour. The combined use of Cartesian coordinate systems and soft-tissue evaluation offers a comprehensive framework for understanding sagittal profile discrepancies. Future research incorporating three-dimensional imaging, dynamic soft-tissue modelling, and larger samples may further advance the precision of cephalometric interpretation and treatment planning.

LIMITATIONS

Limitations include retrospective sampling, 2D imaging, and absence of soft-tissue thickness measurements. Future studies should incorporate CBCT-based 3D assessments and evaluate gender-specific soft-tissue responses.

4. CONCLUSION

This study demonstrated significant variation in anteroposterior chin position among skeletal Class I, II, and III adults, with the most retrusive chin observed in Class II subjects and the most prominent chin in Class III subjects. The vertical chin position remained relatively stable across groups, reflecting a predominantly sagittal disparity. Soft-tissue analysis revealed that upper-lip posture remains comparatively consistent among skeletal patterns, whereas lower-lip projection displayed a malocclusion-specific gradient. Class III subjects exhibited the most pronounced lower-lip protrusion,

suggesting strong soft-tissue adaptation to underlying mandibular displacement.

These findings reinforce the interdependent nature of skeletal morphology and soft-tissue adaptation, supporting the concept that sagittal facial balance cannot be reliably evaluated through hard-tissue assessment alone. The use of Cartesian coordinate systems enhances diagnostic precision for chin evaluation, while combined analysis of lip posture provides valuable insight into soft-tissue compensatory behaviour. *Overall, the study highlights the importance of soft-tissue-driven orthodontic planning and the need for integrated diagnostic approaches in managing sagittal discrepancies.*

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