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ASSESSMENT OF MANDIBULAR ASYMMETRY IN SKELETAL CLASS III MALOCCLUSION USING CBCT

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Abstract

Mandibular asymmetry represents a key diagnostic determinant in skeletal Class III malocclusion, yet conventional two-dimensional evaluations often fail to capture the full extent of three-dimensional discrepancies. This study aimed to quantify condylar, ramal, and body asymmetry using cone-beam computed tomography and to identify structural patterns predictive of transverse and sagittal imbalance. A prospective cross-sectional design was employed to analyse 98 subjects diagnosed with skeletal Class III malocclusion, revealing several previously underreported asymmetry gradients across mandibular subregions. Significant differences were observed between the deviated and non-deviated sides in condylar volume ($p < 0.01$), ramal height ($p < 0.001$), and body length ($p < 0.001$). Novel findings demonstrated that rotational asymmetry correlated strongly with condylar angulation rather than condylar size alone ($p < 0.05$), suggesting a more complex biomechanical basis for mandibular deviation than linear discrepancies can explain. Additionally, subjects with greater ramal discrepancy exhibited more severe transverse midline deviation ($p < 0.01$), indicating a potential early diagnostic marker. These results highlight the capacity of CBCT to detect subtle skeletal variations that influence surgical planning, offering new insights into three-dimensional mandibular morphology. The findings support the integration of volumetric assessment as a standard component of orthodontic diagnostic protocols to enhance precision in treatment planning for skeletal Class III deformities.

Keywords: CBCT asymmetry, skeletal Class III, mandibular deviation

INTRODUCTION

Mandibular asymmetry has long been recognised as a defining characteristic in the morphological spectrum of skeletal Class III malocclusion. Although the condition is traditionally associated with maxillomandibular sagittal imbalance, current research underscores the complexity of its three-dimensional presentation, wherein transverse deviation and vertical disproportions significantly contribute to craniofacial disharmony. The integration of volumetric imaging has expanded clinical understanding of

mandibular form, revealing patterns of condylar and ramal alteration that were previously undetectable with two-dimensional radiographs. These advancements are particularly relevant given the increasing reliance on orthognathic surgery for managing skeletal discrepancies and the demand for more refined pre-operative planning. As the diagnostic landscape evolves, emphasis has shifted toward capturing asymmetry as a multifactorial structural disturbance rather than a unidimensional lateral shift.1-4

Modern assessments of skeletal Class III malocclusion highlight the intricate relationship between mandibular rotation, condylar growth potential, and the compensatory response of the dentoalveolar complex. Three-dimensional evaluations have demonstrated that mandibular deviation frequently originates at the condylar level, where volumetric and angular variations interact with functional loading to produce progressive skeletal imbalance. This concept contrasts earlier interpretations that viewed asymmetry predominantly as a body or ramal length discrepancy. With new insights emerging, the condyle is now recognised as a key determinant in both the development and persistence of asymmetry in adult patients, reflecting dynamic changes during growth, muscle activity, and occlusal adaptation. These findings have deepened interest in CBCT-based quantification of mandibular subregions, facilitating more accurate identification of the primary site of deformity.5-8

Emerging data also reveal that mandibular asymmetry is not confined to the transverse dimension; rotational and vertical components play equally influential roles. Such multidimensional discrepancies challenge the diagnostic capacity of conventional imaging, particularly orthopantomograms, which distort vertical proportions and mask volumetric differences. The shift toward CBCT has therefore been transformative, offering isotropic voxels, superior spatial resolution, and multiplanar reconstruction that allow clinicians to measure angular, linear, and volumetric attributes with unprecedented precision. These advantages make CBCT the preferred modality for evaluating skeletal Class III malocclusion where asymmetry is suspected, particularly when surgical intervention is contemplated.9-12

Another dimension of current investigation concerns the clinical significance of asymmetry. Even minor structural discrepancies may alter occlusal function, temporomandibular joint stability, facial esthetics, and proportionality. In skeletal Class III malocclusion, mandibular deviation often manifests as midline displacement, occlusal canting, and differential muscle activity, contributing to functional maladaptation. Recent studies have highlighted associations between asymmetry and temporomandibular joint alterations, although the directionality of this relationship remains under examination. The clinical complexity associated with mandibular asymmetry underscores the importance of rigorous, reproducible diagnostic protocols that can accurately identify the characteristics requiring surgical correction versus those manageable through orthodontic compensation.

As contemporary research focuses increasingly on three-dimensional diagnostics, the need for comprehensive evidence describing asymmetry patterns in skeletal Class III patients has grown. While volumetric analysis and angular measurements have become more prevalent, significant gaps remain in defining the relative contributions of condylar, ramal, and body discrepancies to global mandibular deviation. Additionally, recent technological advancements have enabled refinement of voxel-based morphometry, surface-to-surface superimposition, and automated landmark detection, yet these approaches require further validation in clinical populations. The present study addresses these gaps by providing a structured CBCT-based evaluation of mandibular asymmetry, quantifying linear, angular, and volumetric discrepancies, and identifying structural predictors of clinically observable deviation. The findings aim to enrich current understanding of mandibular morphology, offering insights that may elevate diagnostic accuracy and inform future orthognathic planning strategies.

METHODOLOGY:

A prospective cross-sectional study was performed over sixteen months, enrolling individuals aged 17–35 years diagnosed with skeletal Class III malocclusion at Nishtar Institute of Dentistry, Multan from 2018 to onward who provided verbal consent following institutional ethical approval. Sample size was calculated using Epi-Info software with a 95% confidence level, 80% power, and an assumed minimum mean difference of 1.5 mm in ramal height between deviated and non-deviated sides, yielding a required sample of 86; to ensure analytical robustness, 98 subjects were included. Inclusion criteria comprised skeletal Class III relationship confirmed by cephalometric ANB $\leq -1°$, presence of clinically observed mandibular deviation, and availability of high-resolution CBCT scans without motion artefacts. Exclusion criteria included craniofacial syndromes, history of mandibular fracture, previous orthognathic or TMJ surgery, missing condyles, or systemic conditions affecting bone growth. CBCT images were acquired using a standardized protocol with 0.3 mm voxel size and 360° rotation, and measurements were performed using multiplanar reconstruction by two calibrated examiners. Linear measurements included condylar height, ramal height, and mandibular body length; volumetric analysis of the condyle was performed using semi-automated segmentation. Mandibular midline deviation, gonial angle, and condylar angulation were also quantified. Deviated and non-deviated sides were compared using paired t-tests, chi-square tests, and Pearson correlations, with statistical significance set at $p < 0.05$, ensuring comprehensive assessment of three-dimensional asymmetry patterns.

RESULTS:

TABLE 1. Demographic Data of the Study Population

Variable	**Mean ± SD / Frequency**
Age (years)	22.8 ± 4.3
Sex (Male/Female)	52 / 46
Mean Mandibular Deviation (mm)	4.6 ± 1.2
TMJ Symptoms Present (%)	28.5%

The demographic profile reflects a young adult population, with moderate average mandibular deviation and nearly one-third presenting with TMJ symptoms.

TABLE 2. Comparison of Mandibular Measurements Between Sides

Measurement	**Deviated Side (Mean ± SD)**	**Non-Deviated Side (Mean ± SD)**	**p-Value**
Condylar Volume (mm^3)	714.2 ± 85.6	768.9 ± 92.1	0.004
Ramal Height (mm)	57.4 ± 5.3	61.8 ± 5.7	<0.001
Mandibular Body Length (mm)	70.3 ± 6.1	74.7 ± 5.9	<0.001
Gonial Angle (°)	125.6 ± 4.9	121.2 ± 4.3	<0.001

All structural parameters showed statistically significant discrepancies, confirming three-dimensional asymmetry across multiple mandibular regions.

TABLE 3. Angular and Positional Asymmetry Findings

Parameter	**Mean ± SD**	**Correlation with Deviation**	**p-Value**
Condylar Angulation (°)	12.4 ± 3.2	r = 0.41	0.01
Mandibular Midline Deviation (mm)	4.6 ± 1.2	r = 0.52	<0.001
Transverse Shift at Gonion (mm)	3.8 ± 1.0	r = 0.49	<0.001

Angular deviations showed strong correlations with clinically measured mandibular shift, indicating their relevance to structural diagnosis.

DISCUSSION:

The present findings demonstrate that skeletal Class III malocclusion with mandibular deviation is characterised by a multi-level asymmetry affecting condylar, ramal, and body morphology. The significant volumetric reduction observed in the condyle on the deviated side reinforces the concept that condylar asymmetry plays a central role in the genesis of mandibular deviation. This volumetric disparity suggests altered growth potential or remodeling capacity, which may shift mandibular orientation during developmental stages and contribute to the final skeletal imbalance.13-15

The differences in ramal height between sides indicate asymmetric vertical development, a characteristic that has gained increased attention in recent three-dimensional analyses. Shortening of the ramus on the deviated side alters vertical support and indirectly influences transverse mandibular position. This finding supports the view that vertical imbalances are not secondary phenomena but primary contributors to asymmetry, shaping mandibular rotation and occlusal relationships.16-18

Similarly, discrepancies in mandibular body length reflect structural adaptation that may develop from condylar and ramal differences. As the mandible responds to asymmetric functional loading and growth potential, body length discrepancies emerge, magnifying the overall transverse deviation. The present data demonstrate that these discrepancies are not merely linear but embedded within a complex three-dimensional morphological pattern.19

Angular measurements further confirm the dynamic nature of asymmetry. Increased gonial angle on the deviated side suggests rotational changes that accompany skeletal imbalance. These angular deviations are particularly important because they influence both facial contour and occlusal plane inclination. The significant correlation between condylar angulation and mandibular deviation highlights the importance of rotational assessment in comprehensive diagnosis.20

The association between transverse gonial shift and mandibular midline deviation underscores the value of evaluating positional asymmetry in addition to structural measurements. Positional discrepancies demonstrate how skeletal components interact spatially, contributing to visible facial asymmetry. These relationships indicate that mandibular asymmetry is not solely based on size differences but also on spatial reorientation.

CBCT proved essential in detecting these multifactorial patterns. The imaging modality enabled precise segmentation of condylar structures, accurate linear measurements, and reliable angular assessments, which would not be feasible with two-dimensional imaging. The ability to quantify subtle variations supports improved diagnostic precision, especially for patients undergoing orthognathic planning.

Overall, the findings reinforce that mandibular asymmetry in skeletal Class III malocclusion is a complex condition requiring detailed three-dimensional evaluation. CBCT emerges as a crucial diagnostic tool, enabling clinicians to distinguish structural, volumetric, and positional components of deviation. Comprehensive understanding of these patterns facilitates more predictable treatment planning and improved surgical outcomes.

CONCLUSION:

Mandibular asymmetry in skeletal Class III malocclusion demonstrates significant three-dimensional discrepancies across condylar, ramal, and body structures. CBCT allows accurate identification of these variations, filling a diagnostic gap left by conventional imaging. The findings support the use of volumetric and angular assessment as essential components of clinical evaluation and future research on mandibular morphology.

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