COMPREHENSIVE EVALUATION OF FACTORS LEADING TO CLASS III SUBDIVISION MALOCCLUSION USING 3-D CBCT

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Abstract

Introduction: Several studies have been conducted to assess skeletal and dental asymmetry on Class II subdivision cases but no studies have yet been published to assess such asymmetries for patients with Class III subdivision malocclusion. The purpose of the study was to assess the maxilla-mandibular dimensional and positional asymmetry along with asymmetry at glenoid fossa level and to find out true dental asymmetry at molar and canine level in class III subdivision malocclusion.

Materials and Methods: A split mouth prospective study was conducted on Angle’s Class III subdivision malocclusions (n=15) and CBCT scans were analyzed with 3-D Dolphin software. 3-D and 2-D measurements were recorded to assess asymmetry between class I and class III sides. 2-D measurements were recorded to assess the position of glenoid fossa, joint spaces and condyle dimension, position and their angulation.

Results: Statistically significant differences were found in glenoid fossa depth, position of the maxilla, mandible, as well as in gonial angle. Statistically significant dental differences were also found for the position of the mandibular first molars and canines along with total asymmetry (combined skeletal and dental) in maxilla and mandible.

Conclusions: The components contributing to Class III subdivision malocclusion were multifactorial involving glenoid fossa asymmetry, positional asymmetry in maxilla and mandible. Mandibular dimensions were more on class III side but it was not statistically significant. True dental asymmetry was also found in mandible along with total asymmetry in maxilla and mandible.

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of both. For a more favorable treatment approach identifying the true dento-alveolar and skeletal characteristics of a Class III subdivision malocclusion is essential.

Several studies\textsuperscript{1-8} have been conducted to assess skeletal and dental asymmetry on Class II subdivision cases, but no studies have yet been published to assess asymmetry for patients with Class III subdivision malocclusion. Hence the present study was planned to identify and quantify skeletal and dental asymmetries in Class III subdivision malocclusion accurately by using a 3-D CBCT imaging system.

**Material & Method:**

This prospective study includes 15 subjects of Class III subdivision malocclusion selected from the outpatient department of orthodontics on the basis of inclusion criteria. The ethical clearance was obtained by Ethical committee and the consent was taken from all selected patients. Sample size was calculated by formula of Pocock\textsuperscript{9,10} for split mouth design.\textit{n} = \textit{f}(\alpha,\beta) \times \frac{\sigma}{\left|\mu_1 - \mu_2\right|}.

Where \(\sigma\) is the standard deviation of the within-person differences \((\mu_1 - \mu_2)\), and \textit{f}(\alpha,\beta)\) is a function of power and significance level. Assuming \(\sigma = 1, \mu_1 - \mu_2 = 1\) (to detect minimum difference of 1 mm between molar of right and left side), \textit{f}(\alpha,\beta)\) = 10.5 at 5\% significant level with 90\% power. From the above formula the required sample size was found to be 11. Sample size determination is an important step while planning a statistical study.\textsuperscript{11}

Each subject was clinically examined extra-orally and intraorally. Patients with lateral mandibular shift during closure, any craniofacial syndromes, history of facial trauma, previous orthodontic treatment, and patients with excessive crowding and spacing were excluded from the study. Erupted permanent dentition from first molar to first molar in both arches and one side of the arch with a Class I molar relationship and the other side with at least a half-step Class III molar relationship or greater were selected for the study.

**Head positioning in CBCT machine:**

Patients were instructed to stand with erect posture with teeth in maximum intercuspation. Frankfurt horizontal plane was made parallel with floor and midsagittal plane perpendicular to floor. All the CBCT scans were recorded by a single operator using the CS9300 Carestream CBCT unit. The exposure parameters for CBCT full skull (88 KV, 10 mA and 300 \(\mu\)m voxel size and exposure 3732 mGy.cm\(^2\)) were kept constant for all subjects. Using Dolphin 3DVersion 11.7 Premium software, the CBCT volumes were converted into three-dimensional reconstruction models of the craniofacial osseous and dental structures. The methodology used for 3-D measurements were similar to the one described by Bauer\textsuperscript{12} for the development of a Cartesian coordinate system (Figure 1) and orientation of the 3D reconstructed images.

![Figure 1: Showing Cartesian coordinate system.](image)

Yaw, pitch and roll were set to 0, 0, 0 during entire calculation. The x-axis was a line passing through right and left orbitale, y-axis was passing through mid-sella turcica and z-axis was set to Frankfort Horizontal, which is a line passing through right porion and right orbitale. All axes were perpendicular to each other.

The origin \((0, 0, 0)\) was located along the mid-sagittal plane, just below sella, and at the level of Frankfort Horizontal. It is created from the intersection of three planes (Figure 2).
The x-y plane (coronal plane) which passed through mid-sella and divided the skull from front to back. The x-z plane (transverse or axial plane) which passed through right porion and right and left orbitale. Lastly, the y-z plane (mid-sagittal plane) which passed through mid-sella and crista galli anterior-posteriorly and divided the skull into right and left halves. After orientation of the 3D reconstructed model, landmarks were plotted using sagittal, coronal, and axial slices of the CBCT volume (Figure 3).

The center of coordinate system represented cranial base (CB), foramen rotundum (FR) represented maxilla (Mx) and lingula represented mandible (Md).

Each landmark was given unique coordinates (x, y, z) when it was marked in 3D Dolphin. These coordinates copied and pasted into Microsoft Excel, where direct measurements in millimeters (mm) could be calculated by using the distance formula. In three dimensional space, the distance between cranial base \((x_1, y_1, z_1)\) which was \((0,0,0)\) and landmarks \((x_2, y_2, z_2)\) on class I and class III side was calculated by using distance formula:

\[
d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2 + (z_2 - z_1)^2}
\]

21 cephalometric landmarks were included in the study (Table 1) and following measurements were evaluated to see if there were any Class III side and Class I side differences. (Table 2)
Table 1: Showing landmarks included in the study.

| No | Landmark Name                  | Abbreviation | Description                                                                                                                                                                                                 |
|----|--------------------------------|--------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1  | Cranial base (0,0,0)           | CB           | Centre of coordinate system                                                                                                                                                                                |
| 2  | Foramen rotundum               | FR           | The center of lower border of the meatus of the canal as it enters the cranial fossa                                                                                                                       |
| 3  | Zygion                         | Zyg          | Located by drawing a tangent parallel to midsagittal plane at the most lateral point of the zygomatic arch across section of greatest bizygomatic width.                                                     |
| 4  | Angulare                       | Ang          | Angulare was located where maxillary and mandibular orbital rims meet and zygomatic arch inserts.                                                                                                |
| 5  | Incisive foramen               | IF           | Also called anterior palatine foramen, or nasopalatine foramen is a funnel-shaped opening in the bone of the oral hard palate immediately behind the incisor teeth where blood vessels and nerves pass. |
| 6  | Lingula                        | Ln           | Tongue like flap of bone that overlap the mandibular foramen anteromedially.                                                                                                                                  |
| 7  | Gonion                         | Go           | Most posteroinferior point at the angle of the mandible, formed by bisecting the angle formed by the junction of ramal and mandibular plane.                                                                 |
| 8  | Condylion                      | Co           | Most superior, lateral, and posterior point on the condyle                                                                                                                                                   |
| 9  | Menton                         | Me           | The most inferior midpoint of the chin on the outline of the mandibular symphysis.                                                                                                                        |
| 10 | Mental foramen                 | MeF          | Present on the anterior surface of the mandible located below the interval between the premolars. It transmits the terminal branches of the inferior alveolar nerve and vessels.                |
| 11 | Genial tubercle                | GT           | measured mid-point between the two genial tubercles                                                                                                                                                         |
| 12 | Gonial angle                   | Go Angle     | Angle formed by the points Co, Go and Me at G or constructed point at the junction of ramal plane and mandibular plane.                                                                                  |
| 13 | Condylar height                | CH           | Perpendicular distance between the condylion to the point on the true horizontal plane passing along the mandibular notch.                                                                               |
| 14 | Condylar diameter MD           | Cd-MD        | It is the largest medio-lateral dimension of the condyle in axial section.                                                                                                                                   |
| 15 | Condylar diameter AP           | Cd- AP       | It is the largest antero-posterior dimension of the condyle in axial section.                                                                                                                               |
| 16 | Glenoid fossa depth            | GF depth     | Perpendicular distance from the deepest point of the mandibular fossa to the point on the true horizontal plane passing along the most inferior point of the articular tubercle. |
| 17 | Glenoid fossa width            | GF width     | Distance from the most inferior point of articular tubercle to the corresponding point on the posterior wall of mandibular fossa on true horizontal plane.                                                   |
| 18 | Superior space joint space SJs |              | Distance from condylion to the top most point on the roof of glenoid fossa.                                                                                                                                  |
| 19 | Anterior space joint space AJs |              | Distance between the most prominent point on the anterior aspects of condyle with the most anterior point on mandibular fossa.                                                                              |
| 20 | Posterior space joint space PJs |              | Distance between the most prominent point on the posterior aspects of condyle with the most posterior point on mandibular fossa.                                                                           |
| 21 | Condylar axis angle             | CA angle     | Angle between the long axis of condylar process ans perpendicular line to the mid sagittal plane in the axial view.                                                                                         |

Table 2: Showing measurements evaluated to see if there were any Class III side and Class I side differences.

| S.No | 3 D skeletal parameters | 3- D dental parameters | 2- D parameters | Derived indices |
|------|-------------------------|-------------------------|----------------|-----------------|
| 1    | Cranial Base to Maxilla | CB to MB cusp tip of U6 | Gonial angle (Co-Go-Me) | Condylar Asymmetry Index (CH_r-CH_l/ (CH_r+CH_l) x 100) |
To test for reliability five out of 15 subjects were randomly selected, and the CBCT orientations and measurements were repeated by the same examiner. Dahlberg's formula \( ME = \sqrt{\frac{\sum d^2}{2n}} \) was used to check method error where \( d \) is the difference between the original and repeated measurements and \( n = 5 \), sample that was repeated.

### Statistical Analysis:

| Measurement Pairs | PAIRED SAMPLE T TEST | 95% Confidence Interval of the Difference |
|-------------------|----------------------|----------------------------------------|
|                   | Correlation | Mean Difference (mm) | Std. Deviation | Std. Error Mean | Lower | Upper |
|                   | \( r \) | \( P \) value | Mean | Std. Deviation | Mean |
| CB to Zygion      | CB to cusp tip of upper canine | Condylar height (CH-0₁) | Condylar position Cd pos- (PJs-AJs/PJs+AJs X 100) |
| CB to Angulare    | CB to MB cusp tip of L6 | Condylar diameter MD |
| CB to Mandible (Lingula) | CB to cusp tip of lower canine | Condylar diameter AP |
| CB to Gonion      | Maxilla to MB cusp tip of U6 | Condylar axis angle |
| CB to Condylion   | Maxilla to cusp tip of upper canine | Glenoid fossa depth |
| CB to Mental foramen | Mental foramen to MB cusp tip of L6 | Glenoid fossa width |
| Maxilla to Incisive Foramen | Mental foramen to cusp tip of lower canine | Superior Joint space /Vertical depth |
| Mandible to mental foramen | Anterior Joint space (AJs) |
| Mandible to Genial Tubercle | Posterior Joint space (PJs) |
| Condylion to Gonion (Ramus length) |
| Gonion to menton (Body length) |
| Condylion to menton (Total body length) |
| Foramen rotundum to Mental foramen |

| Measurement Pairs | PAIRED SAMPLE T TEST | 95% Confidence Interval of the Difference |
|-------------------|----------------------|----------------------------------------|
|                   | Correlation | Mean Difference (mm) | Std. Deviation | Std. Error Mean | Lower | Upper |
|                   | \( r \) | \( P \) value | Mean | Std. Deviation | Mean |

**3 D skeletal measurements**

| Pair | CBMxIII – CBMxI | .935 | .000 | -2.16800 | 3.67913 | .94995 | -4.20543 | -.13057 | .039* |
| Pair 2 | CBZygIII – CBZygI | .941 | .038 | -1.32200 | 4.52386 | 1.16805 | -3.82723 | 1.18323 | .277 |
| Pair 3 | CBAngIII – CBAngI | .982 | .000 | -3.12867 | 3.18240 | .82169 | -4.89102 | -1.36631 | .002* |
| Pair | Measurements | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|------|--------------|---|---|---|---|---|---|---|---|---|
| 1 | CBMdIII – CBMdI | .821 | .011 | .27933 | 5.33051 | 1.37633 | -2.67260 | 3.23127 | .842 |
| 2 | CBGoIII – CBGoI | .900 | .000 | 2.38200 | 3.09067 | .79801 | .67045 | 4.09355 | .010* |
| 3 | CBCoIII – CBCoI | .862 | .000 | -1.47467 | 3.48885 | .90082 | -3.40672 | .45739 | .124 |
| 4 | CBMeFIII – CBMeFI | .857 | .006 | 1.57133 | 2.73128 | .70521 | .05880 | 3.08387 | .043* |
| 5 | MxIFIIII – MxIFI | .951 | .000 | -.31146 | 3.82791 | .98836 | -3.23449 | -.99484 | .700 |
| 6 | MdMeFIII – MdMeFI | .822 | .000 | .31200 | 3.18115 | .82137 | -1.44966 | 2.07366 | .710 |
| 7 | MdGTHIII – MdGTI | .847 | .000 | -.58933 | 3.27482 | .84555 | -2.40287 | 1.22420 | .497 |
| 8 | CoGoIII – CoGoI | .914 | .000 | .46333 | 2.04013 | .52676 | -1.69645 | 1.59312 | .394 |
| 9 | GoMeIII – GoMel | .960 | .000 | 1.21800 | 3.40351 | .87878 | -1.66800 | 3.10280 | .187 |
| 10 | CoMeIII – CoMel | .977 | .000 | .29933 | 2.46333 | .63603 | -1.06481 | 1.66348 | .645 |
| 11 | MxMdIII – MxMdI | .836 | .000 | -.55133 | 5.32479 | 1.37486 | -3.50011 | 2.39744 | .694 |

**3D Dental measurements**

| Pair | Measurements | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|------|--------------|---|---|---|---|---|---|---|---|---|
| 12 | CBU6III - CBU6I | .575 | .025 | -1.68067 | 3.07344 | .79356 | -3.38268 | 0.2135 | .043* |
| 13 | CBU3III – CBU3I | .846 | .000 | -1.59133 | 1.67951 | .43365 | -2.52141 | -1.66125 | .003* |
| 14 | CBL6III - CBL6I | .713 | .003 | 1.25533 | 2.08174 | .53750 | .10250 | 2.40816 | .035* |
| 15 | CBL3III – CBL3I | .961 | .000 | .86333 | 1.49512 | .38604 | .03536 | 1.69130 | .042* |
| 16 | MxU6III-MxU6I | .884 | .000 | .48733 | 5.81086 | 1.50036 | -2.73061 | 3.70528 | .750 |
| 17 | MxU3III-MxU3I | .948 | .000 | .57667 | 3.90379 | 1.00795 | -1.58518 | 2.73851 | .576 |
| 18 | MeFL6III-MeFL6I | .801 | .001 | 2.82667 | 4.06807 | 1.05037 | -5.07949 | -0.57385 | .018* |
| 19 | MeFL3III-MeFL3I | .839 | .000 | 2.43467 | 3.24641 | .83822 | -4.23247 | -0.63687 | .012* |
| 20 | GoAngIII –GoAngI | .637 | .011 | 1.29333 | 4.79039 | 1.23687 | -1.35949 | 3.94616 | .030* |
| 21 | CHIII – CHI | .691 | .004 | .05333 | 2.88267 | .74430 | -1.54304 | 1.64970 | .944 |
| 22 | Cd MDIII – CdMDI | .653 | .008 | .74667 | 1.52403 | .39350 | -0.99731 | 1.59065 | .079 |
| 23 | Cd AP III – CdAP I | .712 | .003 | .19333 | 1.01733 | .26267 | -.37004 | .75671 | .474 |
| 24 | GF dep III – GFdep I | .858 | .000 | -.61333 | .94934 | .24512 | -1.13906 | -.08761 | .025* |
| 25 | GF wid III – GF wid I | .781 | .001 | .84667 | 1.66813 | .43071 | .07711 | 1.77045 | .069 |
| 26 | SJ SIII –SJ SSI | .817 | .000 | -.23333 | .58635 | 1.5140 | -.55804 | .09138 | .146 |
| 27 | AJ SIII – | .843 | .003 | .13333 | .55119 | .14232 | -1.71919 | .43857 | .365 |
Selection of appropriate statistical test is very important for analysis of research data. Statistical analysis was performed using SPSS version 20.0. The null hypothesis was that no significant difference would exist between the Class III side and the Class I side for all measurements of Class III Subdivision malocclusions. In order to test this hypotheses, descriptive statistics (mean and standard deviation) were calculated for 33 pairs of variable. Paired samples correlations and paired samples t-tests were used to see if relationship existed between the variables on the Class III side and the Class I side. The alpha value was set at α=0.05 for this study.

Results:
Method errors ranged from 0.25 to 0.94. The orientations, landmarks identification and measurements used in this study were found to be repeatable and reliable. The pairs of measurements were compared with each other in Table 3 using paired samples correlations and t tests. All 33 pairs of measurements showed statistically significant correlations with one another when the entire sample was evaluated. The r values ranged from 0.73 to 0.99, and all were significant at the p<0.05 level (Table 3).

| Pair | 3-D Parameters | Mean difference (mm) | Std. Deviation | 95% Confidence Interval of the Difference | P-value |
|------|----------------|----------------------|----------------|----------------------------------------|---------|
| 30   | AJ SI          |                      |                |                                        |         |
| 31   | PJ SIII – PJ SI| .527 .043 .03333 .75372 .19461 -.45073 .38406 .866 |
| 32   | Cd posIII – Cd posI | .877 .012 .95800 16.7244 .31824 -.10.2197 8.30370 .828 |
| 33   | CA AngIII – CA AngI | .744 .001 .84000 7.03347 1.81603 -.305501 4.73501 .651 |

Table 3: Showing paired sample t test.
(+)* sign indicates class III value is greater than class I and (-)* sign indicates class I value is greater than III *statistical significant

Table 4: Showing condylar position on class III and class I side. The more number of patients showed posterior positioning on class III side in comparison to class I side.

| CONDYLAR POSITION | CLASS I side (n=15) | CLASS III side (n=15) |
|-------------------|---------------------|-----------------------|
| ANTERIOR          | 7 (47%)             | 4 (26%)               |
| POSTERIOR         | 8 (53%)             | 11 (74%)              |

Table 5: Showing measurement of each variable on individual x, y and z axis. The differences between the Class III and Class I side parameters are shown in each dimension: transverse (x-axis), vertical (y axis), and anterior-posterior (z axis).
Discussion:
There are few studies\textsuperscript{14,15} which compared the asymmetry of class III malocclusion patient from normal occlusion. Mouakeh\textsuperscript{14} did a study on 2-D lateral cephalogram. Assessment of facial asymmetry using PA cephal and Orthopantomogram have been previously reported.\textsuperscript{16} Lee\textsuperscript{15} et al compared the mandibular dimensions of subjects with asymmetric skeletal Class III malocclusion and normal occlusion using CBCT but the study was not a true 3-D study because they measured the parameters in two dimensions only. To the best of our knowledge no study has been reported on evaluation of asymmetry in class III subdivision malocclusion patients. So, present study was planned to explore skeletal and dental asymmetry in Class III subdivision malocclusion.

The result of present study showed statistically significant difference in the position of the maxilla relative to the cranial base between Class III and Class I side (mean difference -2.16 mm, Table III). The maxilla of the Class III side was actually positioned medially (2.28 mm), farther backward (-0.89 mm), and more inferior (-0.86 mm) than the maxilla of class I side (Table V). This downward and backward rotation of maxilla on class III sides contributes a retropositioned maxilla.

Result was consistent with the study by Mouakeh\textsuperscript{14} M who compared the class III patients with class I patients using 2D lateral cephalogram and he found that maxilla was more posteriorly positioned in patients with class III malocclusion.

In maxilla, statistically significant asymmetry was also found at angulare level relative to the cranial base between Class III side and Class I side (mean difference -3.12 mm, Table III). The angulare on Class III side was positioned more medial (-1.45 mm), more posterior (-1.86 mm), and more inferior (-1.86 mm) than the Class I side (Table V). These asymmetries in the maxilla (CB-Mx and CB-Ang) is most likely a positional or rotational difference rather than a dimensional asymmetry because mean difference between maxilla (foramen rotandum) to incisive foramen was -0.311 mm (Table III) but it was not statistically significant that indicates the length of maxilla was symmetric skeletally.

In mandible, there was a significant difference in the position of the gonion relative to the cranial base between Class III side and Class I side (mean difference 2.38 mm, Table III). The gonion on Class III side was positioned more medial (-2.26 mm), more anteriorly (2.10 mm), and more superior (1.29 mm) than the Class I side (Table V).
No study measured the position of the gonion relative to the cranial base in class III patients. Significant difference was also found in the position of the mental foramen relative to the cranial base between Class III and Class I side (mean difference 1.57 mm, Table III). Mental foramen on Class III side was positioned more lateral (3.87 mm), more anteriorly (0.30 mm), and more superior (1.22 mm) than the Class I side (Table V). These differences in the position of gonion and mental foramen relative to cranial base contributes positional asymmetry in mandible.

Present study found mandibular dimensions on Class III side like total body length, body length, ramus height and condylar height were larger than dimensions on Class I side but these differences was not statistically significant (Table III). Similarly, Mouakeh\textsuperscript{14} M found effectivemandibular length (Co-Gn) was significantly greater in patients with Class III malocclusion as compare to normal occlusion patients. Lee\textsuperscript{15} et al found statistically significant difference between class I and class III malocclusion in ramus height.

Intermaxillary comparisons relating the position of the maxilla to the mandible on both the Class III and Class I sides showed no significant differences (Table III).

The position of the maxillary molars and canines in relation to the cranial base wassignificantly different. Class I side measurement of CB-U6 and CB-U3 were greater than the Class III side measurement by 1.68 mm and 1.59 mm respectively (Table III), which includes maxillary displacement as well as dental shifts within the jaw, because if maxilla is displaced anteriorly or posteriorly, teeth will also be displaced along with maxilla.

True dental asymmetry is the amount of dental displacement within maxilla. The difference in the position of the maxillary molars and canines in relation to the maxilla (foramen rotundum) between class III and class I were 0.48 mm and 0.57 mm respectively (Table III), but these differences were not statistically significant, which indicates maxillary molars and canines has compensated the distal displacement of maxilla upto some extent.

The position of the mandibular molars and canines with respect to cranial base was different and statistically significant. Class III side measurement of CB-L6 and CB-L3 were greater than the Class I side measurement by 1.25 mm and 0.86 mm respectively (Table III), this total asymmetry includes mandibular displacement as well as dental shifts within the jaw.

True dental asymmetry was the amount of dental displacement within mandible. The difference in the position of the mandibular molars and canines in relation to the mandible (mental foramen) between class III and class I were 2.82 mm and 2.43 mm respectively (Table III) and these differences were statistically significant which indicates mandibular molars has mesially displaced by 2.82 mm and canines by 2.43 mm.

In 2D parameters, gonial angle of Class III side was found to be larger than Class I side and the difference was statistically significant (Table III). This could contribute to the increase in total mandibular length in patients with Class III malocclusion, although the larger mandibular length on Class III side was not statistically significant. Similarly, Lee\textsuperscript{15} et al in their study found statistically significant difference between asymmetric skeletal class III malocclusion and normal occlusion with large gonial angle in class III malocclusion.

Present study also found statistically significant difference in the depth of the mandibular fossa between class I and ClassIII side. Class III side showed shallower fossa depth than class I side indicating asymmetric mandibular fossa depth in Class III subdivision (Table III) while glenoid fossa width on Class III side was wider than Class I side but this difference was statistically insignificant. Similar findings were obtained by Elias G. Katsavrias\textsuperscript{17} who found wider and shallow fossa with more elongated condyle in class III patients. A previous study of the computed tomographic (CT) analysis of condyle-fossa relationship in skeletal Class I and Class II vertically growing males reported that, in skeletal Class II cases, condyle is more angled and positioned more posteriorly in glenoid-fossa and there is decreased superior joint space and constricted glenoid width in comparison with skeletal Class II subjects.\textsuperscript{18}

Condyle on Class III side showed larger diameter both anteroposteriorly and mesiodistally with flatter or smaller axial condylar angles than the normal occlusion side but these differences were not statistically significant (Table III), which grossly coincided with prior studies\textsuperscript{19,20} in respect to condylar axis angle.
Class III side showed smaller superior and posterior joint space and greater anterior joint space than Class I side i.e condyle on Class III side were positioned more posteriorly and superiorly in the mandibular fossa as compared to condyle on class I side (Table III). This is in contrast to results found by Seren et al, in a comparison of adult Class III and normal subjects using CT, found a smaller anterior joint space in Class III but did not find any difference in posterior joint space.

There was statistically insignificant difference in condylar position between class III and class I side. Class III side condyle showed more posterior positioning than class I side. (Table IV). Ricketts and Pullinger et al found that condyle is positioned more forward in Class II Division 1 and more backward in Class III patients which is similar to our study. While Cohlmia et al found a more anterior condyle position in Class III patients than Class I patients. Miranda et al also found that in class III malocclusion with vertical long pattern, condyle are located more anteriorly than class I malocclusion.

The following conclusions were drawn from the study:
1. The components contributing to Class III subdivision malocclusion were multifactorial.
2. A significant skeletal difference was found in the position of the maxilla relative to the cranial base and at the level of angulare (positional or rotational skeletal asymmetry but not dimensional)
3. A significant skeletal asymmetry in mandible relative to the cranial base was found at various levels (cranial base to gonion 2.38 mm, cranial base to mental foramen 1.57 mm). The mandible on class III side was anteriorly positioned with larger gonial angle than class I side. Mandible on class III side was larger than class I side but it was not statistically significant.
4. Significant difference was found in the depth of the glenoid fossa indicating asymmetric positioning of glenoid fossa which might be the contributing factor for the class III subdivision.
5. Total asymmetry (skeletal as well as dental) was found in maxilla and mandible relative to cranial base.
6. True dental asymmetry was found in mandible with respect to mental foramen but not in maxilla.

Further research with larger sample size can be conducted to confirm the findings of the present study.

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References:
1. Alavi DG, Begole EA, Schneider BJ. Facial and dental arch asymmetries in Class II subdivision malocclusion. Am J Orthod Dentofacial Orthop 1988;93:38-46.
2. Rose JM, Sadowsky C, Begole EA, Moles R. Mandibular skeletal and dental asymmetry in Class II subdivision malocclusions. Am J Orthod Dentofacial Orthop 1994;105:489-95.
3. de Araujo TM, Wilhelm RS, Almeida MA. Skeletal and dental arch asymmetries in class II division I subdivision malocclusions. J Clin Pediatr Dent. 1994;18(3):181-5.
4. Janson GR, Metaxas A, Woodside DG, de Freitas MR, Pinzan A. Three-dimensional evaluation of skeletal and dental asymmetries in Class II subdivision malocclusions. Am J Orthod Dentofacial Orthop. 2001;119(4):406-18.
5. Janson G, de Lima KJRS, Woodside DG, et al. Class II subdivision malocclusion types and evaluation of their asymmetries. Am J Orthod Dentofacial Orthop. 2007;131(1):57-66.
6. Sanders DA, Rigali PH, Neace WP, Uribe F, Nanda R. Skeletal and dental asymmetries in Class II subdivision malocclusions using cone-beam computed tomography. Am J Orthod Dentofacial Orthop 2010;138:542.e1-20; discussion 542-3.
7. Minich CM, Ara ujo EA, Behrents RG, Buschang PH, Tanaka OM, Kim KB. Evaluation of skeletal and dental asymmetries in Angle Class II subdivision malocclusion using cone-beam computed tomography. Am J Orthod Dentofacial Orthop 2013;144:57-66.
8. Gupta A, Jain S, Kuriakose M. Holistic evaluation of skeletal and dental asymmetries in Class II subdivision malocclusions – A 3-D prospective study. IJMSCR. 2020;3(6):101-115.
9. Pocock SJ. Clinical trials: a practical approach. Chichester, United Kingdom: Wiley; 1983. p. 129-41.
10. Pandis N. Sample calculation for split-mouth designs. Am J Orthod Dentofacial Orthop 2012;141(6):818-19.
11. Jain S, Gupta A, Jain D. Estimation of sample size in dental research. Int Dent Med J Adv Res 2015;1:1-6.
12. Bauer M. Displacement of the Proximal Segment Immediately Following Bilateral Sagittal Split Osteotomy: A Three-Dimensional Study Using Cone Beam CT. 2006.
13. Jain S, Gupta A, Jain D. Common Statistical Tests in Dental Research. J Adv Med Dent Scie Res 2015;3(3):38-45.
14. Mouakeh M. Cephalometric evaluation of craniofacial pattern of Syrian children with Class III malocclusion. Am J Orthod Dentofacial Orthop 2011;119:640-49.
15. HyoYeongLee,a Mohamed Bayome,b Seong-Hun Kim,c Ki BeomKim,d Rolf G. Behrents,e and Yoon-Ah Kookf Mandibular dimensions of subjects with asymmetric skeletal Class III malocclusion and normal occlusion compared with cone-beam computed tomography Am J Orthod Dentofacial Orthop 2012;142:179-85).
16. Hirpara N, Jain S, Hirpara VS, Punyani PR. Comparative assessment of vertical facial asymmetry using posteroanterior cephalogram and orthopantomogram. J Biomed Sci 2017; 6(1):1-7. https://doi.org/10.21767/2254-609X.100052
17. Elias G. Katsavrias, Demetrios J. Halazonetis. Condyle and fossa shape in Class II and Class III skeletal patterns: A morphometric tomographic study. Am J Ortho DentofacOrthop. 2005; 128:337-46 1987;91:200-6.
18. Chaukse A, Jain S, Dubey R, Maurya R, Shukla C, Sthapak A. Computed tomographic analysis of condyle-fossa relationship in skeletal class I and skeletal class II vertically growing males. J Orthod Res 2015;3:170-4.
19. Westesson PL, Bifano JA, Tallents RH, Hatala MP. Increased horizontal angle of the mandibular condyle in abnormal temporomandibular joints. A magnetic resonance imaging study. Oral Surg Oral Med Oral Pathol1991;72:359-63.
20. Ueki K, Nakagawa K, Takatsuka S, Shimada M, Tanaka OM. Computed tomography evaluation of temporomandibular joint alterations in patients with class II division 1 subdivision malocclusions: condyle-fossa relationship. Am J Orthod Dentofacial Orthop2004;126:48-52.
21. Seren E, Akan H, Toller MO, Akyar S. An evaluation of the condylar position of the temporomandibular joint by computerized tomography in Class III malocclusions: a preliminary study. Am J Orthod Dentofacial Orthop1994;105:483-8.
22. Rickets RM. Provocations and perceptions in cranio-facial orthopedics. Dental science and facial art. RMO Denver: Rocky Mountain Orthodontics; 1989.
23. Pullinger AG, Solberg WK, Hollender L, Petersson A. Relationship of mandibular condylar position to dental occlusion factors in an asymptomatic population. Am J Orthod Dentofacial Orthop1987;91:200-6
24. Cohlmia JT, Ghosh J, Sinha PK, Nanda RS, Currier GF. Tomographic assessment of temporomandibular joints in patients with malocclusion. Angle Orthod1996;66:27-35
25. Arieta-Miranda JM, Silva-Valencia M, Flores-Mir C, Paredes-Sampen NA, Arriola-Guillen LE. Spatial analysis of condyline position according to sagittal skeletal relationship, assessed by cone beam computed tomography. Prog Orthod2013;14:36.