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RESEARCH ARTICLE

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 foundin mandible along with total asymmetry in maxilla and mandible.

Introduction:-

Class III subdivision possess asymmetric molar relationship on both sidesi.e normal occlusal relation on one side of the arches and a class III occlusion on the other side, which may be due to skeletal, dental reasons or combination

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

Several studies[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[9,10] for split mouth design. $n=f(\alpha,\beta)\ \chi\ \frac{\sigma^2}{\mu_1-\mu_2}$

, where σ is the standard deviation of the within-person differences ($\mu_1 - \mu_2$), and $f(\alpha,\beta)$ 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), $f(\alpha,\beta) = 10.5$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.[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 theCS9300 Carestream CBCT unit. The exposure parameters for CBCT full skull (88 KV, 10 mA and 300 µm 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[12] for the development of a Cartesian coordinate system (Figure 1) and orientation of the 3D reconstructed images.

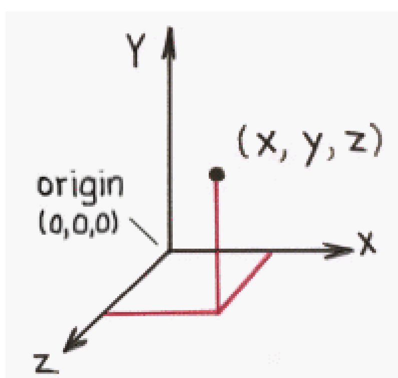

Figure 1:- Showing Cartesian coordinate system.

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).

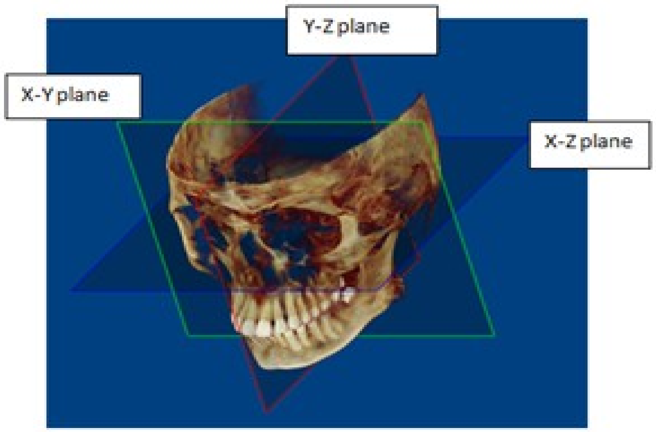

Figure 2:- Showing the intersection of three planes.

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 3 D reconstructed model, landmarks were plotted using sagittal,coronal, and axial slices of the CBCT volume (Figure 3).

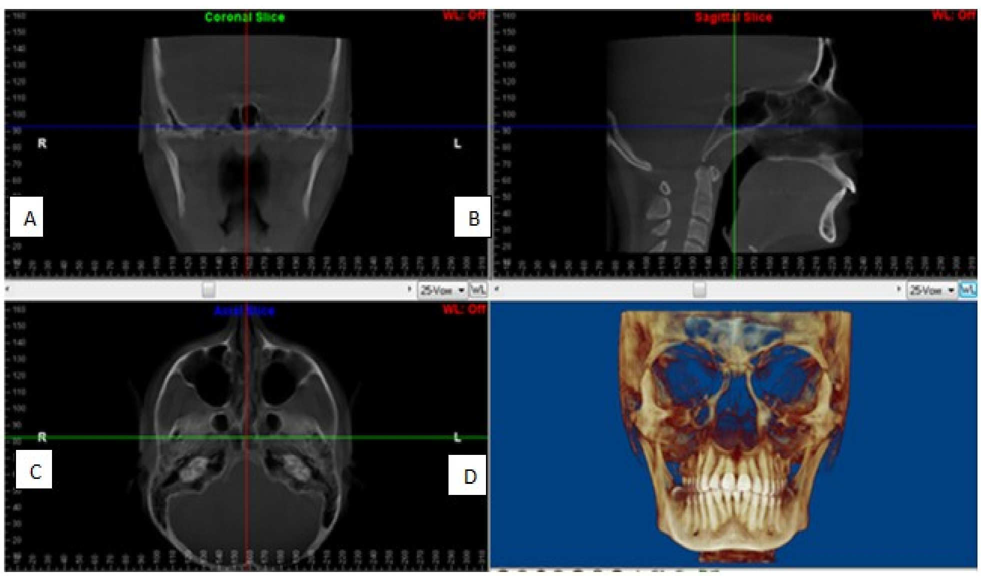

Figure 3:- Showing landmarks plotted using sagittal, coronal, and axial slices of the CBCT volume.

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 3 D 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 midsaggital 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 posterinferior 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 joint space	SJs	Distance from condylion to the top most point on the roof of glenoid fossa
19.	Anterior 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 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 saggital 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 $(CH_R\text{-}CH_L/ CH_R+CH_L)$ X 100

2.	CB to Zygion	CB to cusp tip of upper canine	Condylar height (CH-0_1)	Condylar position Cd pos- (PJs-AJs/PJs+AJs X 100)
3.	CB to Angulare	CB to MB cusp tip of L6	Condylar diameter MD	
4.	CB to Mandible (Lingula)	CB to cusp tip of lower canine	Condylar diameter AP	
5.	CB to Gonion	Maxilla to MB cusp tip of U6	Condyar axis angle	
6.	CB to Condylion	Maxilla to cusp tip of upper canine	Glenoid fossa depth	
7.	CB to Mental foramem	Mental foramen to MB cusp tip of L6	Glenoid fossa width	
8.	Maxilla to Incisive Foramen	Mental foramen to cusp tip of lower canine	Superior Joint space /Vertical depth	
9.	Mandible to mental foramen		Anterior Joint space (AJs)	
10.	Mandible to Genial Tubercle		Posterior Joint space (PJs)	
11	Condylion to Gonion (Ramus length)			
12	Gonion to menton (Body length)			
13	Condylion to menton (Total body length)			
14	Foramen rotundum to Mental foramen			

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[11] ME=$\sqrt{(\sum d^2/2n)}$was used to check method error where d is the difference between the original and repeatedmeasurements and n = 5, sample that wasrepeated.

Statistical Analysis:

Measurement Pairs		**PAIRED SAMPLE T TEST**							**P value**
		Correlation		**Mean Difference (mm)**	**Std. Deviation**	**Std. Error Mean**	**95% Confidence Interval of the Difference**		
		r	**P value**				**Lower**	**Upper**	
3 D skeletal measurements									
Pair 1	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 4	CBMdIII – CBMdI	.821	.011	.27933	5.33051	1.37633	-2.67260	3.23127	.842
Pair 5	CBGoIII – CBGoI	.900	.000	2.38200	3.09067	.79801	.67045	4.09355	.010*
Pair 6	CBCoIII –CBCoI	.862	.000	-1.47467	3.48885	.90082	-3.40672	.45739	.124
Pair 7	CBMeFIII – CBMeFI	.857	.006	1.57133	2.73128	.70521	.05880	3.08387	.043*
Pair 8	MxIFIII – MxIFI	.951	.000	-.31146	3.82791	.98836	-3.23449	-.99484	.700
Pair 9	MdMeFIII – MdMeFI	.822	.000	.31200	3.18115	.82137	-1.44966	2.07366	.710
Pair 10	MdGTIII – MdGTI	.847	.000	-.58933	3.27482	.84555	-2.40287	1.22420	.497
Pair 11	CoGoIII – CoGoI	.914	.000	.46333	2.04013	.52676	-.66645	1.59312	.394
Pair 12	GoMeIII – GoMeI	.960	.000	1.21800	3.40351	.87878	-.66680	3.10280	.187
Pair 13	CoMeIII – CoMeI	.977	.000	.29933	2.46333	.63603	-1.06481	1.66348	.645
Pair 14	MxMdIII – MxMdII	.836	.000	-.55133	5.32479	1.37486	-3.50011	2.39744	.694
3 D Dental measurements									
Pair 15	CBU6III - CBU6I	.575	.025	-1.68067	3.07344	.79356	-3.38268	.02135	.043*
Pair 16	CBU3III – CBU3I	.846	.000	-1.59133	1.67951	.43365	-2.52141	-.66125	.003*
Pair 17	CBL6III - CBL6I	.713	.003	1.25533	2.08174	.53750	.10250	2.40816	.035*
Pair 18	CBL3III – CBL3I	.961	.000	.86333	1.49512	.38604	.03536	1.69130	.042*
Pair 19	MxU6III-MxU6I	.884	.000	.48733	5.81086	1.50036	-2.73061	3.70528	.750
Pair 20	MxU3III-MxU3I	.948	.000	.57667	3.90379	1.00795	-1.58518	2.73851	.576
Pair 21	MeFL6III-MeFL6I	.801	.001	2.82667	4.06807	1.05037	-5.07949	-0.57385	.018*
Pair 22	MeFL3III-MeFL3I	.839	.000	2.43467	3.24641	.83822	-4.23247	-0.63687	.012*
Pair 23	Go AngIII –Go AngI	.637	.011	1.29333	4.79039	1.23687	-1.35949	3.94616	.030*
Pair 24	CHIII – CHI	.691	.004	.05333	2.88267	.74430	-1.54304	1.64970	.944
Pair 25	Cd MDIII – Cd MDI	.653	.008	.74667	1.52403	.39350	-.09731	1.59065	.079
Pair 26	Cd AP III – Cd AP I	.712	.003	.19333	1.01733	.26267	-.37004	.75671	.474
Pair 27	GF dep III – GFdep I	.858	.000	-.61333	.94934	.24512	-1.13906	-.08761	.025*
Pair 28	GF wid III – GF wid I	.781	.001	.84667	1.66813	.43071	.07711	1.77045	.069
Pair 29	SJ SIII –SJSI	.817	.000	-.23333	.58635	.15140	-.55804	.09138	.146
Pair	AJ SIII –	.843	.003	.13333	.55119	.14232	-.17191	.43857	.365

30	AJ SI								
Pair 31	PJ SIII – PJ SI	.527	.043	-.03333	.75372	.19461	-.45073	.38406	.866
Pair 32	Cd posIII – Cd posI	.877	.012	-.95800	16.7244	4.31824	-10.2197	8.30370	.828
Pair 33	CA AngIII – CA AngI	.744	.001	.84000	7.03347	1.81603	-3.05501	4.73501	.651

Selection of appropriate statistical test is very important for analysis of research data.[13]Statistical analysis was performed using SPSS version 20.0. The null hypothesis was that no significant difference would exists 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 comparedwith each other in Table 3 using pairedsamplescorrelations 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).

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).

PAIRED SAMPLE T TEST						
S.No.	**3-D Parameters**	**Mean difference (mm)**	**Std. Deviation**	**95% Confidence Interval of the Difference**		**P- value**
				Lower	**Upper**	
1.	CBMxIII –CBMxI (x axis)	-2.28667	3.86114	-4.42489	-0.14844	.038*
	CBMxIII– CBMxI (y axis)	-0.86000	3.25418	-2.66211	0.94211	.323
	CBMxIII – CBMxI (z axis)	-0.89333	2.23206	-2.12941	0.34274	.143
2.	CBAngIII - CBAngI(x axis)	-1.45333	3.03735	-3.13536	0.22870	.085
	CBAngIII – CBAngI(y axis)	-1.86667	3.82093	-3.98263	0.24930	.079
	CBAngIII – CBAngI(z axis)	-1.86667	2.61852	-3.31676	-0.41658	.015*
3.	CBGoIII – CBGoI (x axis)	-2.26667	5.84278	-5.50229	.96896	.155
	CBGoIII – CBGoI (y axis)	1.29333	2.04467	0.16103	2.42563	.028*
	CBGoIII – CBGoI (z axis)	2.10667	3.46750	0.18643	4.02690	.034*
4.	CBMeFIII – CBMeFI (x axis)	3.87333	5.07761	1.06145	6.68522	.010*
	CBMeFIII – CBMeFI (y axis)	-1.22667	3.11826	-2.95350	0.50017	.150
	CBMeFIII – CBMeFI (z	0.30667	2.64804	-1.15977	1.77310	.661

	axis)					
6.	CBU6III – CBU6I (x axis)	-0.33333	5.92473	-3.61434	2.94767	.831
	CBU6III – CBU6I (y axis)	-0.82000	1.13402	-1.44800	-0.19200	.014*
	CBU6III – CBUZI (z axis)	-1.98667	1.65135	-2.90115	-1.07218	.000*
7.	CBU3III – CBU3I (x axis)	-0.09333	4.24592	-2.44464	2.25798	.933
	CBU3III – CBU3I (y axis)	-0.20000	1.24154	-0.88754	0.48754	.543
	CBU3III – CBU3I (z axis)	-1.92000	2.18737	-3.13132	0.70868	.004*
8.	CBL6III – CBL6I (x axis)	-1.17333	5.95668	-4.47204	2.12537	.458
	CBL6III – CBL6I (y axis)	-0.02000	1.21314	-0.65182	0.69182	.950
	CBL6III – CBLZI (z axis)	-2.95333	4.90421	-5.66919	-0.23747	.035*
9.	CBL3III – CBL3I (x axis)	-2.78667	3.34020	-4.63641	0.93692	.006*
	CBL3III – CBL3I(y axis)	0.17333	1.27193	-0.53104	0.87771	.606
	CBL3III – CBL3ZI (z axis)	-0.74000	2.75183	-2.26391	0.78391	.315

Discussion:-

There are few studies[14,15] which compared the asymmetry of class III malocclusion patient from normal occlusion. Mouakeh[14]did a study on 2-D lateral cephalogram.Assessment of facial asymmetry using PA ceph and Orthopantomogram have been previously reported.[16]Lee[15]et alcompared 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 -2.16mm, 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 (TableV). This downward and backward rotation of maxilla on class III sides contributes a retropositioned maxilla.

Result was consistent with the study by Mouakeh[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 asymmetrywas 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 (-1.86mm), 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 thelength 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 (2.10mm), 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 (TableV). These difference in the position of gonion and mental foramen relative to cranial base contributes positional asymmetry in mandible.

Present study foundmandibular 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[14] M found effectivemandibular length (Co-Gn) was significantly greater in patients with Class III malocclusion as compare to normal occlusion patients. Lee[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 rotandum) 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 mmand 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[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 foundstatisticallysignificantdifference 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 (TableIII) 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[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 angulated 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.[18]

Condyle on Class III side showed larger diameter both anteroposteriorly and mesiodistally with flatter or smaller axial condylar angles than the normal occlusion sidebut these differences were not statistically significant (Table III), which grossly coincided with prior studies[19,20]in respect to condylaraxis 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 compare to condyle on class I side (Table III).This is incontrast to results found by Seren[21] 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 found 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[22]and Pullinger[23] et alfound that condyle is positioned more forward in Class II Division 1 andmore backward in Class III patients which is similar to our study. While Cohlmia[24] et al found a more anterior condyle position in Class III patients than Class I patients. Miranda[25] et al also found that in class III malocclusion with vertical long pattern, condyleare located more anteriorly than class I malocclusion.

The condylar asymmetry index value (>3%) between class I and class III side were present in 66.7% patients only (10 out of 15 patients) indicating the presence of asymmetry between both condyles, although present study did not find statistically significant difference in condylar height between sides of class III subdivision.

None of the previous studies calculated the prevalence of condylar asymmetry in Class III subdivision patients.

Table VI showed asymmetry of various parameters in different axis (X,Y and Z axis). Transverse dimension (X-axis) showed statistically significant difference in CB-Mx, CB-MeF, CB-L3 parameters; vertical dimension (Y-axis) showed statistically significant difference in CB-Go, CB-U3 parameter and anteroposterior dimension (Z- axis) showed statistically significant difference in CB-Go, Go-Me, CB-U6, CB-U3, CB-L6 parameters.

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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