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RESEARCH ARTICLE

THREE-DIMENSIONAL EVALUATION AND COMPARISON OF CONDYLE-FOSSA RELATIONSHIP, THEIR POSITION AND SYMMETRY USING CBCT IN VARIOUS SAGITTAL SKELETAL MALOCCLUSIONS

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Abstract

Introduction: Three-dimensional evaluation and comparison of condyle-fossa relationship, their position and symmetry using CBCT in various sagittal skeletal malocclusions.

Aims and Objectives: To evaluate and compare the size and morphology of right and left fossa and condyle, condyle-fossa relationship, position and symmetry in various malocclusions.

Materials and Methods: Sixty eight subjects with a mean age of 18.2±3.5 years, were divided into three sagittal Skeletal malocclusion (Class I,Class II. Class III) groups. 15 Linear and 2 Angular variables were evaluated from the CBCT images obtained from Carestream CS 9300C 3D system. The digitization and measurements were carried out using Trophy Dicom CS 3D software.

Statistical Analysis: Independent "t" test and Karl Pearson's coefficient of correlation.

Results: On comparison between the Right and Left sides, Angle Md.Co.Pro-MS Plane in Group I (p=0.007**)and C.Co-MS Planein Group II (p=0.047*)was significant. On Comparison of Concentric positioning of condyles, the mean differences in Group II on the Right side (p =0.039 *) and on the Left side (p =0.004**) were significant.

Conclusion: In Skeletal Class I malocclusion, width and height of condyle was increased on the left side. Anterior joint space was decreased significantly in Skeletal Class II malocclusion. Superior joint space was significantly decreased and width of mandibular fossa was increased on both the sides in Skeletal Class III malocclusion. The condyles were anteriorly placed in all skeletal malocclusions but greatest difference was present in Class II.

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Introduction:-

The temporomandibular joint (TMJ) is a synovial ginglymoarthrodial joint. which allows for various mandibular movements, it'smorphology is dependent on the amount of functional forces subjected to the TMJ and its surrounding structures since form and function are interlinked to each other[1]. These occlusal forces may vary according to a person's functional requirement and dentofacial morphology. Henceforth, it can be assumed that both the fossa and condyle differ in subjects with varied skeletal malocclusions[2].

The position of condyle in glenoid or mandibular fossa is significant in Orthodontics for mandibular functional positions and in TMJ dysfunctions which may be different in various sagittal skeletal malocclusions. Controversy exists even today over the clinical importance of the position of condyle in the TMJ as the "optimal position of the condyle in the glenoid fossa" is often the most sought after question in dentistry. Dynamic changes like growth, remodeling, occlusal alterations and reaction to functional changes affect the final condylar position. **Pullinger**[3]in his study on Class II malocclusion found non-concentric positioning of the mandibular condyles and it was supported by a study by **Vitral**[4] on Class II Division 1 subdivision malocclusion. **Gianelly**[5] observed the positioning of condyle in the mandibular fossa in Class II Division 2 malocclusion and said that these patients have a strong musculature oriented in an anterior direction with a widely different TMJ loading. **Rodrigues**[6]in his study on Class I malocclusion found out that the posterior joint space difference was significant on the right side and condyles did not show concentric positioning in their mandibular fossae. Also, in his next study on Class II Division 1 and Class III malocclusions[7]**,** he found non-concentric positioning of condyles in fossae in both malocclusions.

TMJ examination on Orthopantomogram, Lateral cephalogram, True lateral and Transpharyngeal radiographs have always been jeopardized by the overlapping of neighbouring structures like the mastoid process, petrous region of the temporal bone, and the articular eminence[8].Cone Beam Computed Tomography (CBCT) imaging is a non-invasive and accurate diagnostic modality with less radiation for obtaining images which allows clear visualization without any overlapping and the possibility of estimating the exact dimensions of the skeletal structures. The main objectives of this study were:

1. To evaluate and compare the size and morphology of condyle, fossa and mandible of both right and left side in various sagittal skeletal malocclusions using CBCT.
2. To evaluate and compare the condyle-fossa relationship, position and symmetry between right and left condyles in various sagittal skeletal malocclusions using CBCT.

In this study, we have evaluated the condyle fossa relationship and its association with the mandible in all 3 sagittal skeletal malocclusions and have also included 17 different parameters which gives a full extent description of the TMJ and its associated structures which wasn't the case with previous studies with less parameters involved and in separate individual malocclusions.

Materials and Methods:-

Sample size is calculated on the basis of variation in mandibular fossa and condylar distance among the positive groups.The sample size calculated to be 20 in each malocclusion group and power of the study will be 80 %.Well-defined CBCT obtained from 90 human subjects and out of which according to inclusion and exclusion criteria CBCT samples of 68 subjects were selected and grouped into three Sagittal Skeletal malocclusion groups: Group I – Skeletal Class I malocclusion, Group II – Skeletal Class II malocclusion and Group III – Skeletal Class III malocclusion on the basis of ANB angle[9,10] and β angle[11]**[Table 1(a)].**An informed consent was acquired from all subjects participating in the study. An approval was obtained from the University's Ethical Committee before starting of the study.

Table – 1(a):- Distribution of subjects in Groups.

GROUPS (Total n = 68)	**MALOCCLUSION**	**ANB ANGLE (in degree)[9,10]**	**β ANGLE (in degree)[11]**
Group I (n = 25)	Skeletal Class I Malocclusion	1-4	27-35
Group II (n = 25)	Skeletal Class II Malocclusion	> 4	< 27
Group III (n = 18)	Skeletal Class III Malocclusion	≤ 0	>35

Inclusion Criteria:
1. Well defined CBCT of subjects with age ranging from 14-25 years (with a mean age of 18.2±3.5 years) which included both sexes having Skeletal Class I, II and III malocclusion on Sagittal plane.
2. Subjects with Normodivergent growth pattern (FMA of 25 +/- 5 degrees).
3. No history of previous orthodontic/orthopaedic and surgical treatment.
4. No history of trauma/systemic diseases/ bone deformities/ neuromuscular deformities.
5. All permanent teeth erupted except third molars.

Exclusion criteria:
1. Any congenital defect or pathology in head and neck region
2. Patients with CO-CR discrepancy and dual bite tendency clinically.
3. Any evidence of facial asymmetry, functional mandibular deviations, crossbites, open bites, temporomandibular disorders.
4. Loss of patient maximum intercuspation.
5. Damage/extorted CBCT 3D acquisitions.

Method:-

CBCT imaging was processed with the help of Carestream CS 9300C with the patient's teeth in centric occlusion (maximum occlusal intercuspation) and in natural head position with midsagittal plane perpendicular to floor. Patients were in standing position with lips and tongue in a resting position **[Fig 1(a)].** The images were captured using the CBCT machine at 0.30 voxel resolution with the scanning parameters of 80 Kvp, 4 mA, scanning time of 11.3 seconds. CBCT raw data was exported in the DICOM (Digital Imaging and Communication in Medicine) format and then imported into Trophy Dicom CS 3D software, **[Fig 1(b)].** A total of 17 variables were evaluated from the CBCT images based on the anatomical landmarks **[Fig 1(c)]** which included 15 Linear and 2 Angular measurements as enumerated in **[Table 1(b)] [Fig 2(a-f)]**[6,7,10,12]**.**

Fig 1(a):- Carestream CS 9300 CBCT machine with the patient in standing position for scanning of TMJ region.

Fig 1(b):- Trophy Dicom CS 3D imaging software.

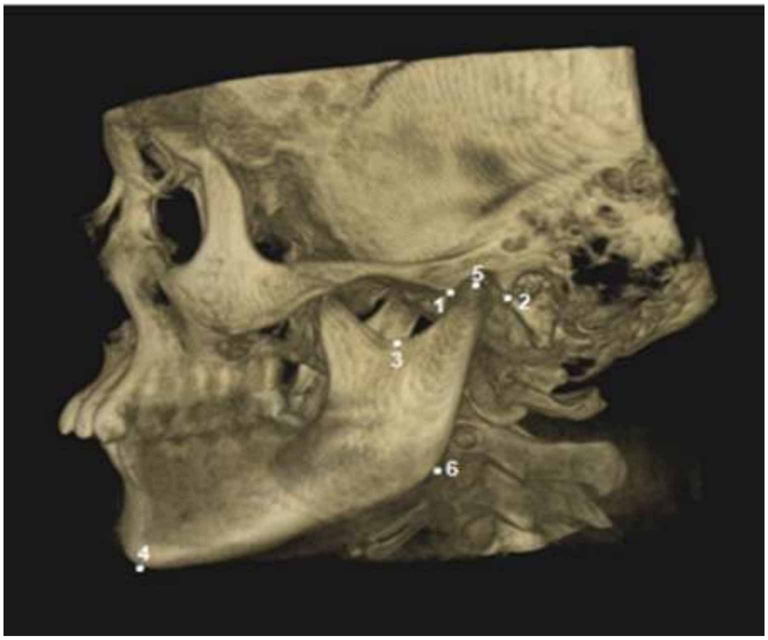

Fig 1(c):- Anatomic Landmarks used in CBCT study.

1. Tuberculum Articulare (Ta)
2. Processuspostglenoidalis (Pp)
3. Mandibular incisura (Mi)
4. Menton(Me)
5. Condylion(Co)
6. Gonion (Go)

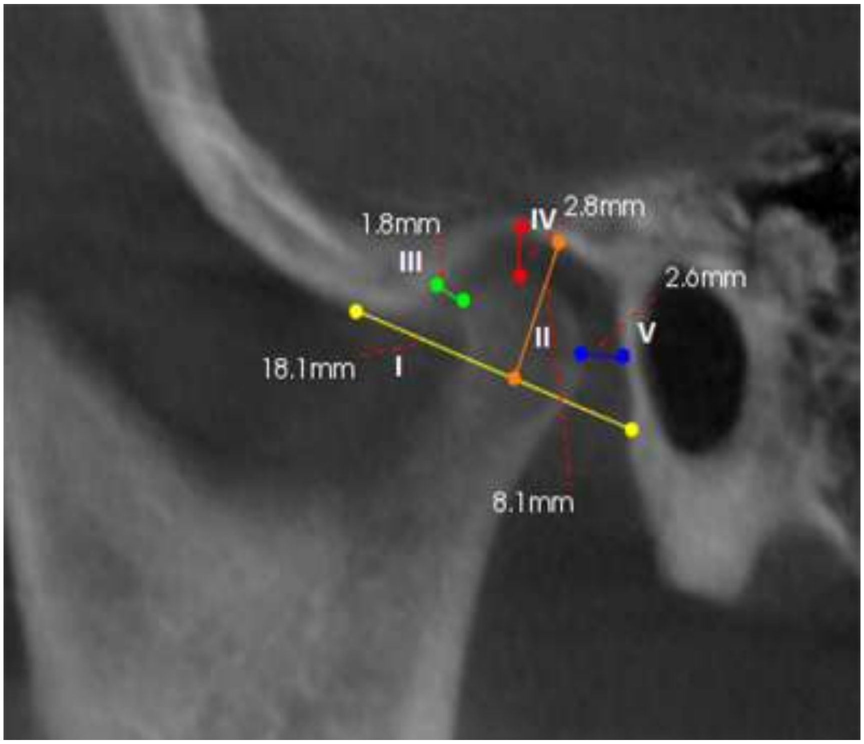

Fig 2(a):- CBCT Variables and their measurements.

I- Width of mandibular fossa (yellow)
II-Height of mandibular fossa (orange)
III- Anterior joint space (green)
IV- Superior joint space (red)
V- Posterior joint space (blue)

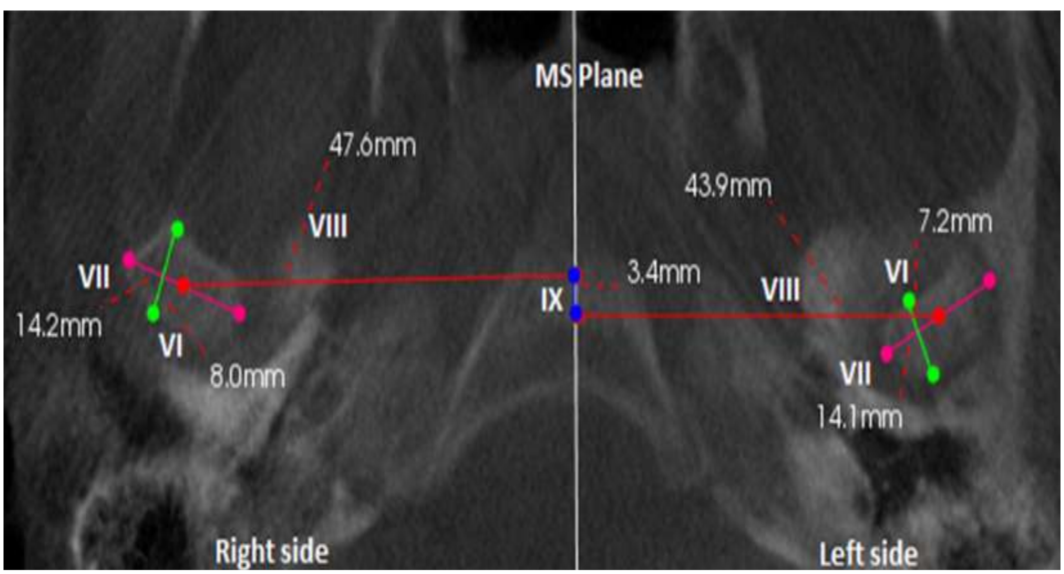

Fig 2 (b):-CBCT Variables and their measurements.

VI-Greatest Anteroposterior diameter (green) on both right and left condyles
VII-Greatest Mediolateral diameter (pink) on both right and left condyles
VIII-Distance between geometric centers of condylar process and midsagittal plane (red) on the right and left side
IX-Anteroposterior difference between geometric center of right and left condylar process (blue)

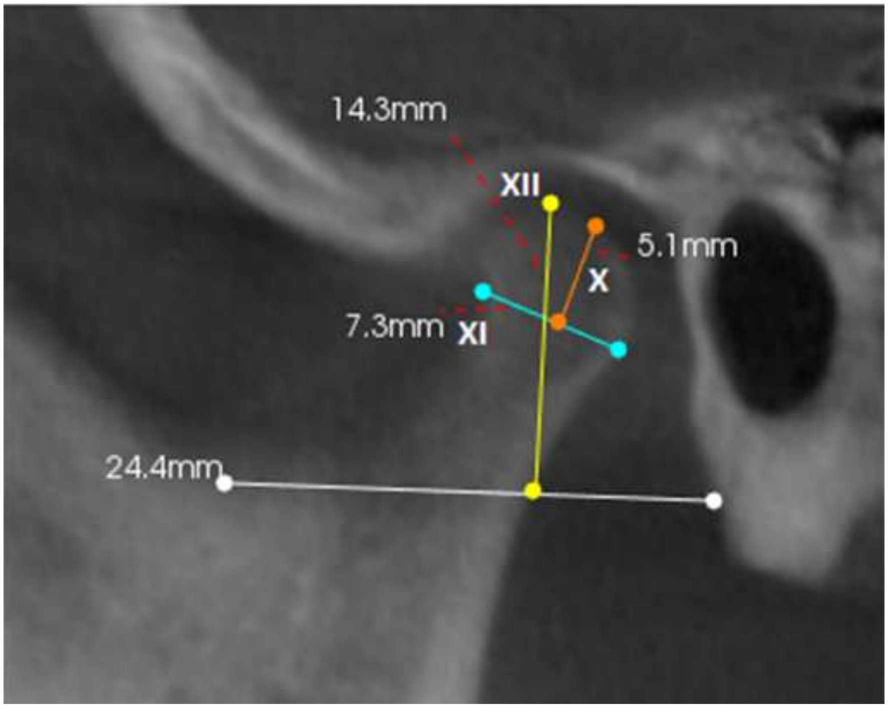

Fig 2(c):- CBCT Variables and their measurements

X - Height of condyle (orange)
XI -Width of condyle (cyan blue)
XII - Height of processuscondylaris (yellow)

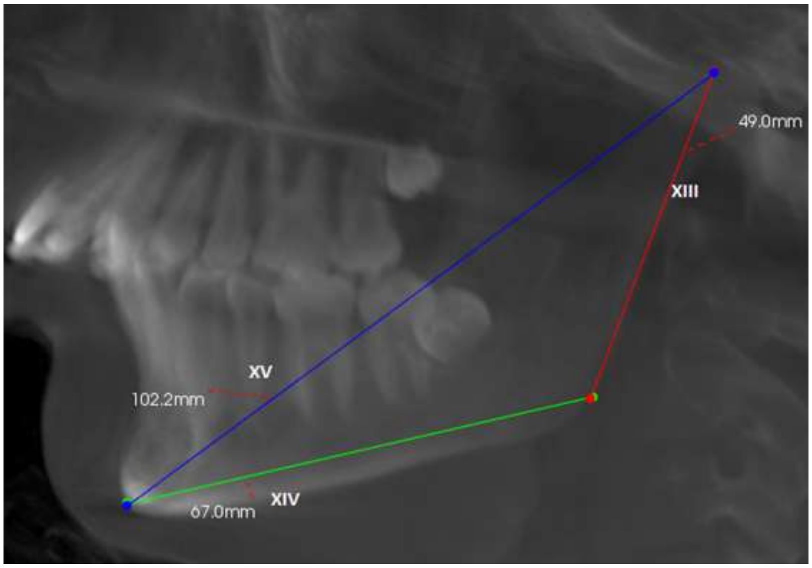

Fig 2(d) CBCT Variables and their measurements

XIII – Mandibular ramus length (red)
XIV – Mandibular body length (green)
XV – Total mandibular length (blue)

Table – 1(b):- CBCT Variables and their measurements:

S.NO	VARIABLE	ABBREVIATION	DEFINTION
A. LINEAR MEASUREMENTS :			
I.	**Width of the mandibular fossa**	**Wt-Md.Fossa**	It is the distance between the top of tuberculum articulare and procesuspostglenoidalis for both the left and right condyles in sagittal view [10] **[Fig 2(a)]**
II.	**Height of the mandibular fossa**	**Hi-Md.Fossa**	It is measured from the most superior point of the fossa to the plane formed by the most inferior point of the articular tubercle to the most inferior point of the auditory meatus for both the left and right condyles in sagittal view [10]**[Fig 2(a)]**
III.	**Anterior joint space**	**An-J.Space**	It is the shortest distance between the most anterior point of the condyle and the posterior wall of the anterior articular tubercle for both the left and right condyles in sagittal view [6,7] **[Fig 2(a)]**
IV.	**Superior joint space**	**Su-J.Space**	It is the shortest distance between the most superior point of the condyle and the most superior point of the mandibular fossa for both the left and right condyles in sagittal view [6,7] **[Fig 2(a)]**
V.	**Posterior joint space**	**Po-J.Space**	It is represented by the shortest distance between the most posterior point of the condyle and the posterior wall of the mandibular fossa for both the left and right condyles in sagittal view [6,7] **[Fig (2a)]**
VI.	**The greatest anteroposterior diameter of the mandibular condylar processes**	**AP-Md.Cond.Pro.**	It is recorded by measuring the maximum anteroposterior diameter for both the left and right condyles in axial view [6,7] **[Fig 2(b)]**
VII.	**The greatest mediolateral diameter of the mandibular condylar processes**	**ML-Md.Cond.Pro.**	It is recorded by measuring the maximum mediolateral diameter for both the left and right condyles in axial view [6,7] **[Fig 2(b)]**
VIII.	**The distance between the geometric centers of the condylar processes and the midsagittal plane**	**C.Co-MS Plane**	It is measured with a line that passes through the geometric centers of the condylar processes and perpendicular to the midsagittal plane for both the left and the right condyles in axial view [6,7] **[Fig 2(b)]**
IX.	**The anteroposterior difference between the geometric center of the right and left condylar processes**	**Dif-R&L.Co.Center**	It is recorded by measuring the linear distance between the geometric center of right and left condylar processes as reflected on the midsagittal plane in axial view [6,7] **[Fig 2(b)]**
X.	**Height of condyle**	**Hi-Cond.**	It is the linear distance between top of the condyle and crossectional line measured for both the left and right condyles in sagittal view [10] **[Fig 2(c)]**
XI.	**Width of condyle**	**Wt-Cond.**	It is the linear distance between most anterior and posterior point of condyle measured for both the left and right condyles in sagittal view [10] **[Fig 2(c)]**
XII.	**Height of processuscondylaris**	**Hi-Pro.Cond.**	It is the linear distance between the highest point of condyle and line that goes through mandibular incisura measured for

			both the left and right condyles in sagittal view [10] **[Fig 2(c)]**
XIII.	**Mandibular ramus length**	**Md-R.Length**	It is measured from the most superior point in the contour of the head of the mandibular Condyle to Gonion on both the left and right sides in sagittal view [12] **[Fig 2(d)]**
XIV.	**Mandibular body length**	**Md-B.Length**	It is measured from Gonion to Menton on both the left and right sides in sagittal view [12] **[Fig 2(d)]**
XV.	**Total mandibular length**	**Total Md-Length**	It is measured from the most superior point in the contour of the condylar head to Menton on both the left and right sides in sagittal view [12] **[Fig 2(d)]**
B. ANGULAR MEASUREMENTS :			
XVI.	**The angle between the long axis of the mandibular condylar process and the midsagittal plane**	**Angle Md.Co.Pro-MS Plane**	It is the angle between the long axis of the condylar process and midsagittal plane for both the left and right condyles in axial view [6,7] **[Fig 2(e)]**
XVII.	**Tuberculum articulare angle**	**Tub-Art. Angle**	It is the angle between the plane of the posterior wall of the articular tubercle and the plane obtained from the most inferior point of the articular tubercle to the most inferior point of the auditory meatus measured for both the left and right condyles in sagittal view [10] **[Fig 2(f)]**

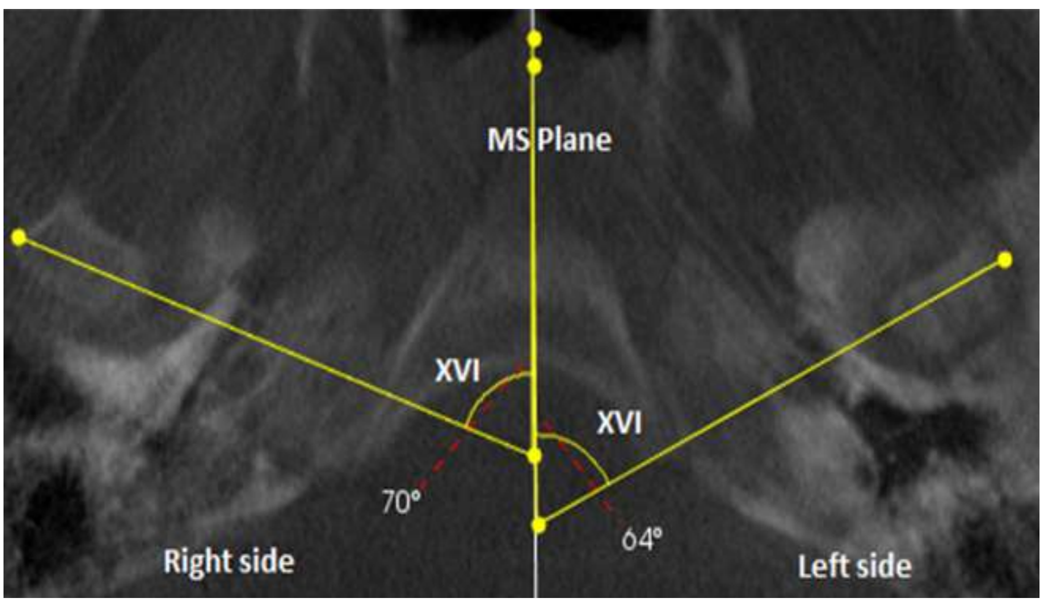

Fig 2 (e):- XVI-Angle between long axis of condyle and the midsagittal plane (yellow).

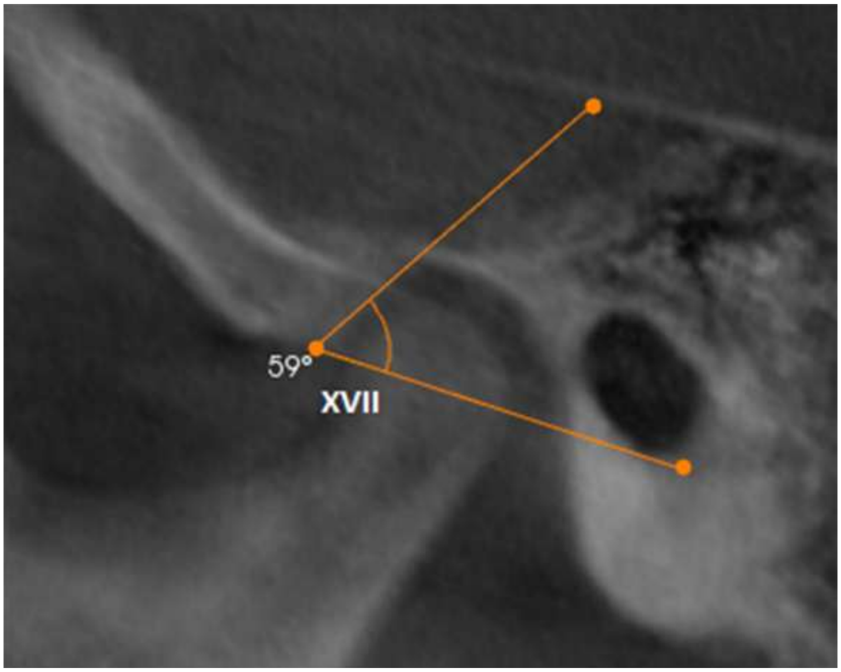

Fig 2 (f):-XVII. Tuberculum Articulare angle (orange).

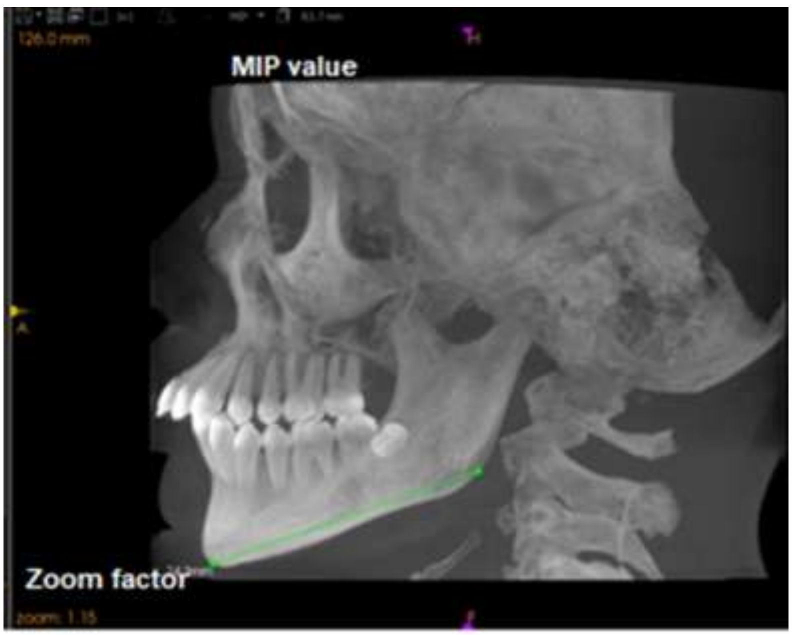

Fig 2 (g):- Sagittal view: For measuring variables like mandibular body length, the MIP value is set at 80-85 mm and Zoom factor value at 1-1.5.

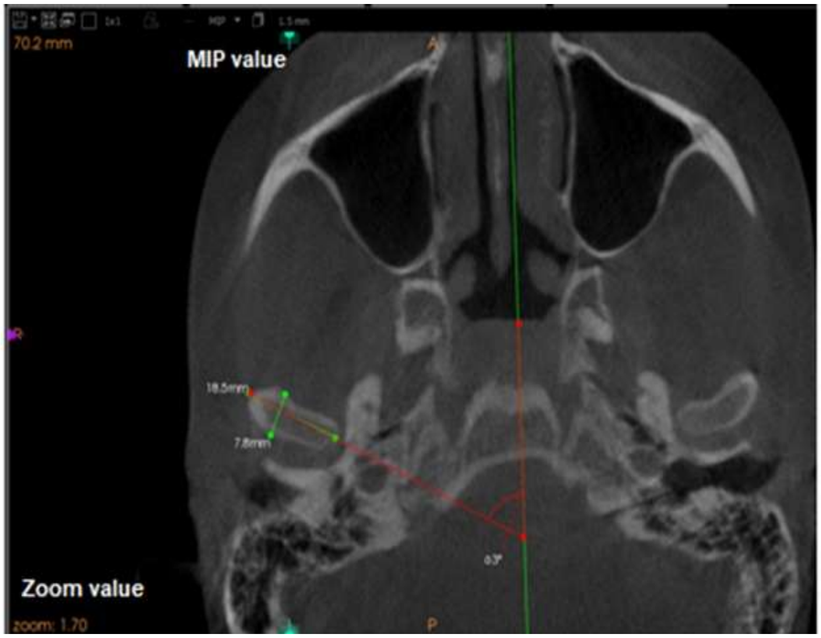

Fig 2 (h):-Axial view: Variables being measured keeping MIP value at 1.3-2.3 mm and zoom factor at 1.7.

The images were selected on a computer and all the variables were analysed using Orthogonal slicing in two major selected views – Sagittal and Axial views. In Sagittal view, **9 variables** like Wt-Md.Fossa, Hi-Md.Fossa, An-J.Space, Su-J.Space, Po-J.Space, Hi-Cond., Wt-Cond., Hi-Pro.Cond., Tub-Art Angle were analysed keeping the MIP (Maximum Intensity Projection) value at 3.5-4.5 mm and Zoom factor value at 1.5-2.5 and while measuring **3 variables** like Md-R.Lengt, Md-B.Length, Total Md-Length, the MIP value was kept at 80-85 mm and Zoom factor value at 1-1.5 **[Fig 2(g)]** for the proper visualization of skeletal structures being analysed and for proper standardization.

In Axial view, **5 variables** like AP-Md.Cond.Pro., ML-Md.Cond.Pro., C.Co-MS Plane, Dif-R&L.Co.Center, Angle Md.Co.Pro-MS Plane were analysed keeping the MIP value at 1.3-2.3 mm and Zoom factor value at 1.3-2.3 **[Fig 2(h)].** Measurement of all these variables were assessed for evaluating the Concentric positioning of the condyles in their fossae in different sagittal Skeletal malocclusion groups for both the right and left sides.

Statistical Methods:-

SPSS 16.0 windows software was used for performing all the statistical analysis. Mean + SD were used for summarizing data. A weighted kappa coefficient was calculated for evaluation of the intra-examiner agreement in measuring the variables of TMJ. Comparisons between groups were assessed by using independent “t” test.

Degree of linear relationship between two variables were assessed using Karl Pearson’s coefficient of correlation.

A p-value of >0.05 was deemed non-significant; p<0.05* as just significant; p<0.01** as moderately significant; and p<0.001*** as highly significant.

Table – 2(a):-Comparision between the variables of Right side and Left side of Fossa, Condyle in Group I, Group II and Group III Mandible.

		GROUP I						**GROUP II**						**GROUP III**					
S. N	**Variables**	**Right side**		**Left side**		**Mean Difference (right-left)**	**p-value (paired t test)**	**Right side**		**Left side**		**Mean Difference (right-left)**	**p-value (paired t test)**	**Right side**		**Left side**		**Mean Difference (right-left)**	**p-value (paired t test)**
		Mean	**SD**	**Mean**	**SD**			**Mean**	**SD**	**Mean**	**SD**			**Mean**	**SD**	**Mean**	**SD**		
A .LINEAR MEASUREMENTS: (in mm)																			
I	**Wt-Md.Fossa**	20.50	1.38	20.67	1.25	-0.17	0.464	21.31	2.24	21.2	2.44	0.11	.645	22.3	3.07	22.34	2.94	-0.04	0.864
II	**Hi-Md.Fossa**	8.20	0.91	8.07	0.94	0.13	0.259	7.67	0.84	7.70	0.86	-0.03	.802	8.31	1.42	7.84	0.87	0.47	0.057
III	**An-J.Space**	2.11	0.41	2.01	0.57	0.1	0.365	1.93	0.51	1.86	0.40	0.07	.447	2.11	0.62	1.88	0.42	0.23	0.096
IV	**Su-J.Space**	3.02	0.77	3.02	0.66	0	1.000	2.83	0.98	2.97	0.88	-0.14	.434	2.22	0.83	2.31	0.64	-0.09	0.621
V	**Po-J.Space**	2.28	0.62	2.08	0.58	0.2	0.066	2.74	1.76	2.88	1.59	-0.14	.518	2.28	0.71	2.27	0.83	0.01	0.933
VI	**AP-Md.Cond.Pro**	7.69	0.78	7.86	0.79	-0.17	0.151	7.78	0.98	7.90	0.82	-0.12	.143	7.75	0.75	7.77	0.91	-0.02	0.876
VII	**ML-Md.Cond.Pro**	17.58	2.50	17.50	2.49	0.08	0.655	16.98	2.10	16.89	2.20	0.09	.561	17.48	3.36	17.33	3.04	0.15	0.545
VIII	**C.Co-MS Plane**	47.42	2.57	47.23	2.84	0.19	0.609	46.78	2.74	46.01	2.81	0.77	**.047***	46.97	3.73	46.49	3.74	0.48	0.237
IX	**Dif-R&L.Co. Center**	0.00	0.00	1.71	1.14	-1.71	NS	0.00	0.0	2.06	1.03	-2.06	NS	0.0	0.00	2.57	1.22	-2.57	NS
X	**Hi-Cond.**	5.53	0.57	5.54	0.83	-0.01	0.976	6.16	0.57	6.24	0.86	-0.08	.578	6.15	0.78	6.43	0.83	-0.28	0.086
XI	**Wt-Cond.**	9.20	1.06	9.51	0.80	-0.31	0.120	9.32	1.25	9.38	1.14	-0.06	.841	8.96	1.10	9.22	0.94	-0.26	0.234
XII	**Hi-Pro.Cond.**	16.30	2.05	16.32	2.31	-0.02	0.897	16.23	2.84	15.96	3.04	0.27	.391	17.78	3.62	17.49	3.82	0.29	0.190
XIII	**Md-R.Length**	54.44	5.87	54.55	6.33	-0.11	0.909	49.52	4.61	49.41	4.94	0.11	.862	54.13	7.05	53.88	6.74	0.25	0.735
XIV	**Md-B.Length**	108.7	7.34	108.1	7.96	0.6	0.345	99.80	7.11	100.19	7.16	-0.39	.618	110.53	10.81	110.69	10.08	-0.16	0.810
XV	**Total Md-Length**	71.78	6.16	70.55	7.54	1.23	0.201	66.98	5.51	67.07	5.23	-0.09	.913	73.17	7.60	72.76	7.25	0.41	0.724
B. ANGULAR MEASUREMENTS: (in degrees)																			
XVI	**Angle Md.Co.Pro-MS Plane**	72.56	7.73	68.64	5.54	3.92	**.007****	68.24	7.64	66.28	6.45	1.96	.235	68.72	6.53	70.06	6.93	-1.34	.420
XVIII	**Tub-Art Angle**	59.68	7.03	58.92	6.73	0.76	.464	56.2	7.88	53.72	9.10	2.48	.091	54.39	9.40	56.94	11.57	-2.55	.191

A p-value of >0.05 Non-significant; *<0.05 Just significant; **<0.01 Moderately significant; ***<0.001 Highly significant

Table -2(b);comparision of the Right side variables of Fossa,Condyle and Mandible between Group I,Group II and Group III

RIGHT SIDE																			
S.N	Variables	Group I		Group II		Mean Difference	p-value (paired t test)	Group I		Group III		Mean Difference	p-value (paired t test)	Group II		Group III		Mean Difference	p-value (paired t test)
		Mean	SD	Mean	SD			Mean	SD	Mean	SD			Mean	SD	Mean	SD		
A .LINEAR MEASUREMENTS: (in mm)																			
I	Wt-Md.Fossa	20.5	1.38	21.31	2.24	-0.816	0.127	20.5	1.38	22.3	3.07	-1.8	0.013*	21.31	2.24	22.3	3.07	-0.99	0.229
II	Hi-Md.Fossa	8.2	0.91	7.67	0.84	0.532	.036*	8.2	0.91	8.31	1.42	-0.11	0.776	7.67	0.84	8.31	1.42	-0.63	0.074
III	An-J.Space	2.11	0.41	1.93	0.51	0.18	0.173	2.11	0.41	2.11	0.62	0	0.967	1.93	0.51	2.11	0.62	-0.17	0.319
IV	Su-J.Space	3.02	0.77	2.83	0.98	0.188	0.454	3.02	0.77	2.22	0.83	0.8	0.002**	2.83	0.98	2.22	0.83	0.61	.038*
V	Po-J.Space	2.28	0.62	2.74	1.76	-0.468	0.216	2.28	0.62	2.29	0.71	-0.01	0.971	2.74	1.76	2.28	0.71	0.46	0.3
VI	AP-Md.Cond.Pro	7.69	0.78	7.78	0.98	-0.09	0.728	7.69	0.78	7.75	0.75	-0.06	0.808	7.78	0.98	7.75	0.75	0.03	0.914
VII	ML-Md.Cond.Pro	17.58	2.5	16.98	2.1	0.6	0.363	17.58	2.5	17.48	3.36	0.1	0.913	16.98	2.1	17.48	3.36	-0.5	0.551
VIII	C.Co-MS Plane	47.42	2.57	46.78	2.74	0.632	0.404	47.42	2.57	46.97	3.73	0.45	0.642	46.78	2.74	46.97	3.73	-0.18	0.854
IX	Dif-R&L.Co.Center	0	0	0	0	0	NS	0	0	0	0	0	NS	0	0	0	0	0	NS
X	Hi-Cond.	5.53	0.57	6.164	0.57	-0.632	<0.001***	5.53	0.57	6.15	0.78	-0.62	0.005**	6.16	0.57	6.15	0.78	0.01	0.946
XI	Wt-Cond.	9.2	1.06	9.32	1.25	-0.124	0.708	9.2	1.06	8.96	1.1	0.24	0.478	9.32	1.25	8.96	1.1	0.36	0.33
XII	Hi-Pro.Cond.	16.3	2.05	16.23	2.84	0.068	0.923	16.3	2.05	17.78	3.62	-1.49	0.094	16.23	2.84	17.78	3.62	-1.56	0.122
XIII	Md-R.Length	54.44	5.87	49.52	4.61	4.916	0.002**	54.44	5.87	54.13	7.05	0.3	0.879	49.52	4.61	54.13	7.05	-4.61	0.013*
XIV	Md-B.Length	108.7	7.34	99.8	7.11	8.868	<0.001***	108.67	7.34	110.53	10.81	-1.86	0.506	99.8	7.11	110.53	10.81	-10.72	0.001***
XV	Total Md-Length	71.78	6.16	66.98	5.51	4.8	0.006**	71.78	6.16	73.17	7.6	-1.39	0.511	66.98	5.51	73.17	7.6	-6.19	0.003**
B. ANGULAR MEASUREMENTS: (in degrees)																			
XVI	Angle Md.Co.Pro-MS Plane	72.56	7.73	68.24	7.64	4.32	0.053	72.56	7.73	68.72	6.53	3.84	0.095	25	68.24	18	68.72	-0.48	0.83
XVII	Tub-Art Angle	59.68	7.03	56.2	7.88	3.48	0.106	59.68	7.03	54.39	9.4	5.29	.041*	25	56.2	18	54.39	1.81	0.497

A p-value of >0.05 Non-significant; *<0.05 Just significant; **<0.01 Moderately significant; *<0.001 Highly significant.**

Table – 2(c): Comparison of the Left side variables of Fossa, Condyle and Mandible between Group I, Group II and Group III

LEFT SIDE																			
S.N	**Variables**	**Group I**		**Group II**		**Mean Difference**	**p-value (paired t test)**	**Group I**		**Group III**		**Mean Difference**	**p-value (paired t test)**	**Group II**		**Group III**		**Mean Difference**	**p-value (paired t test)**
		Mean	**SD**	**Mean**	**SD**			**Mean**	**SD**	**Mean**	**SD**			**Mean**	**SD**	**Mean**	**SD**		
A .LINEAR MEASUREMENTS: (in mm)																			
I	**Wt-Md.Fossa**	20.67	1.25	21.2	2.44	-0.528	0.34	20.67	1.25	22.34	2.94	-1.667	**.015***	21.2	2.44	22.34	2.94	-1.1389	0.173
II	**Hi-Md.Fossa**	8.07	0.94	7.7	0.86	0.364	0.159	8.07	0.94	7.84	0.87	0.224	0.432	7.7	0.86	7.84	0.87	-0.1404	0.602
III	**An-J.Space**	2.01	0.57	1.86	0.4	0.152	0.277	2.01	0.57	1.88	0.42	0.129	0.42	1.86	0.4	1.88	0.42	-0.0233	0.853
IV	**Su-J.Space**	3.02	0.66	2.97	0.88	0.052	0.814	3.02	0.66	2.31	0.64	0.709	**.001****	2.97	0.88	2.31	0.64	0.65689	**.010***
V	**Po-J.Space**	2.08	0.58	2.88	1.59	-0.792	**0.023***	2.08	0.58	2.27	0.83	-0.188	0.385	2.88	1.59	2.27	0.83	0.60378	0.149
VI	**AP-Md.Cond.Pro**	7.86	0.79	7.9	0.82	-0.04	0.861	7.86	0.79	7.77	0.91	0.084	0.749	7.9	0.82	7.77	0.91	0.12378	0.643
VII	**ML-Md.Cond.Pro**	17.5	2.49	16.89	2.2	0.612	0.361	17.5	2.49	17.33	3.04	0.171	0.841	16.89	2.2	17.33	3.04	-0.4413	0.583
VIII	**C.Co-MS Plane**	47.23	2.84	46.01	2.81	1.22	0.133	47.23	2.84	46.49	3.74	0.739	0.465	46.01	2.81	46.49	3.74	-0.4809	0.632
IX	**Dif-R&L.Co.Center**	1.71	1.14	2.06	1.03	0.352	0.256	1.71	1.14	2.57	1.22	0.86	**0.023***	2.06	1.03	2.57	1.22	0.51	0.149
X	**Hi-Cond.**	5.54	0.83	6.24	0.86	-0.708	**0.005****	5.54	0.83	6.43	0.83	-0.892	**0.001*****	6.24	0.86	6.43	0.83	-0.1838	0.487
XI	**Wt-Cond.**	9.51	0.8	9.38	1.14	0.124	0.659	9.51	0.8	9.22	0.94	0.291	0.281	9.38	1.14	9.22	0.94	0.16733	0.613
XII	**Hi-Pro.Cond.**	16.32	2.31	15.96	3.04	0.36	0.64	16.32	2.31	17.49	3.82	-1.169	0.218	15.96	3.04	17.49	3.82	-1.5289	0.152
XIII	**Md-R.Length**	54.55	6.33	49.41	4.94	5.14	**0.002****	54.55	6.33	53.88	6.74	0.674	0.739	49.41	4.94	53.88	6.74	-4.4658	**0.016***
XIV	**Md-B.Length**	108.13	7.96	100.19	7.16	7.944	**0.001*****	108.13	7.96	110.69	10.08	-2.562	0.357	100.19	7.16	110.69	10.08	-10.506	**0.001*****
XV	**Total Md-Length**	70.55	7.54	67.07	5.23	3.476	0.064	70.55	7.54	72.76	7.25	-2.213	0.34	67.07	5.23	72.76	7.25	-5.6891	**0.005****

B. ANGULAR MEASUREMENTS: (in degrees)																			
XVI	**Angle Md.Co.Pro-MS Plane**	68.64	5.54	66.28	6.45	2.36	0.172	68.64	5.54	70.06	6.93	-1.416	0.461	66.28	6.45	70.06	6.93	-3.7756	0.074
XVII	**Tub-Art Angle**	58.92	6.73	53.72	9.1	5.2	**0.026***	58.92	6.73	56.94	11.57	1.976	0.484	53.72	9.1	56.94	11.57	-3.2244	0.312

A p-value of >0.05 Non-significant; *<0.05 Just significant; **<0.01 Moderately significant; *<0.001 Highly significant.**

Table 3:- Group I, Group II, Group III Comparison and Correlations of Concentric positioning of condyles.

	Side	S.N	Variables (in mm)	Mean Difference (right-left)	p-value (paired t test)	Pearson correlation (r)
GROUP I	Right side	III	An-J.Space	-0.16	0.339	-0.303
		V	Po-J.Space			
	Left side	III	An-J.Space	-0.07	0.679	-0.124
		V	Po-J.Space			
GROUP II	Right side	III	An-J.Space	-0.81	**0.039 ***	-0.057
		V	Po-J.Space			
	Left side	III	An-J.Space	-1.02	**0.004 ***	0.173
		V	Po-J.Space			
GROUP III	Right side	III	An-J.Space	-0.18	0.518	-0.488
		V	Po-J.Space			
	Left side	III	An-J.Space	-0.39	0.077	0.140
		V	Po-J.Space			

A p-value of >0.05 Non-significant; *<0.05 Just significant; **<0.01 Moderately significant; *<0.001 Highly significant.**

Results:-

On Comparison between the variables of Right side and Left sides of Fossa, Condyle and Mandible, (Angle Md.Co.Pro-MS Plane, p=0.007**) in Group I and(C.Co-MS Plane, p=0.047*)in Group II were statistically significant **[Table 2(a)].**

While comparing the Right side variables of Fossa, Condyle and Mandible between Group I and Group II, (Hi-Cond., p<0.001***), (Md-B.Length, p<0.001***), (Md-R.Length, p=0.002**), (Hi-Md.Fossa, p=0.36*) had significant differences. Between Group I and Group III, (Su-J.Space, p=0.002**), (Hi-Cond., p=0.005**), (Tub-Art Angle, p=0.041*) and (Wt-Md.Fossa, p=0.013*)were significant. Between Group II and Group III, (Md-B.Length, p=0.001***),(Total Md-Length, p=0.003**), (Su-J.Space, p=0.038*) and (Md-R.Length, p=0.013*)were significant **[Table 2(b)].**

While comparing of the Left side variables of Fossa, Condyle and Mandible between Group I and Group II, (Md-B.Length, p=0.001***), (Hi-Cond., p=0.005**),(Md-R.Length, p=0.002**), (Po-J.Space, -0.792 mm, p=0.023*) and (Tub-Art Angle, p=0.026*) were significant. Between Group I and Group III, (Su-J.Space, p=0.001), (Hi-Cond., p=0.001***), (Wt-Md.Fossa, p=0.015*) and (Dif-R&L.Co.Center, p=0.023*) were significant. Between Group II and Group III, (Md-B.Length, p=0.001***),(Total Md-Length, p=0.005**), (Su-J.Space, p=0.010*) and Mandibular ramus length (Md-R.Length, p=.016*) were significant **[Table 2(c)].**

On Comparison and Correlations of Concentric positioning of condyles, the mean differences in Group II was(p =0.039 *) on the Right side and (p = 0.004**) on the Left side were statistically significant while in Group I and III, the mean differences were not significant **[Table 3].**

Discussion:-

The interrelation between form and function affects the variation in condyle and glenoid fossa morphology in various skeletal malocclusion[13]. The final dimensions of the maxillary and mandibular arches plays a major part in the size and volume of condyles. The remodelling changes of TMJ depends on the mechanical and functional loads of its adjacent structures.Different skeletal malocclusions, jaw size, ramus height and position of condyles can affect the occlusion and teeth inclination. The optimal condylar position should also be considered in diagnosis and treatment planning for a suitable orthodontic treatment approach in different skeletal malocclusions and temporomandibular disorders and therefore, TMJ examination is mandatory for detecting its abnormalities before initiating Orthodontic treatment[14].

Ricketts[15] found major variations in TMJ of class II patients when he compared Class II and class III malocclusion with normal occlusion. **Thompson**[16], **Farrar and McCarty**[17]found posteriorly placed mandibular condyles in patients with increased overbite. **Arnett**[18]said that Class III malocclusions had large condyles which provided support for occlusal changes while small condyles were prevalent in Class II malocclusion.

Different imaging techniques have been used to study the condyle-fossa relationship in various malocclusion but the diagnostic precision with the conventional radiography was limited due to problems in point imaging, superimposition of the bony structures and structural distortion[19]. CBCT machines with their high resolution multi-planar images, low cost, reduced radiation dose and less time spent during image-acquisition allows TMJ examination without any distortion and superimposition

For assessing the symmetry between the right and left condyles in the anteroposterior and mediolateral planes, the Axial slice is ideal as it allows visualization of both condyles in the same picture and also identification of reference planes like median sagittal plane. For evaluating condyle-fossa relationship, analysing the anterior and posterior articular spaces for condylar concentricity, the Sagittal slice was ideal [6,7].

Age limit ranging from 14 to 25 years were used in this study because glenoid fossa reach their maximum size by the age of 8 years and also other skeletal structures rarely show growth beyond that age [21,22].

Linear measurements:

Width of mandibular fossa was significantly higher in Group III on both Right and Left side. Height of mandibular fossawas larger in Group III on the Right side and in Group II on the Left side but not significant. Our findings were in unison with the studies done by **Krisjaneet al** [10] and **Katsavriaset al** [2] in which the size of the mandibular fossa tends to be larger, wider and shallower in Class III malocclusion.

In our study**,** we found thatAnterior joint spacewas decreased in Group II on the Right side and Left side. On comparison of Concentric positioning of the condyles in Group II **(Table - 3),**the difference was significant on both sides which shows that there was non-concentric positioning of the condyles and were positioned more anteriorly in the mandibular fossa. Another study by **Krisjaneet al** [10]showed similar findings to our study in which there was decreased anterior joint space in Class II. Also, **Pullingeret al**[3] showed in class II division 1 malocclusion that anterior positioning of condyles were a classical feature. Concentric positioning of the condyles is regarded as an ideal association between the condyle and fossa in asymptomatic patients while non-concentric positioning of condyles in the fossa have been related with abnormal TMJ function and also in Class II and Class III skeletal malocclusions because of variable mandibular jaw sizes.Superior joint spacewas decreased significantly and the condyles were superiorly positioned in Group III on both sides as the mean differences were significanton intergroup comparison between Group I and Group III of the Right side and Left side, and between Group II and Group III of the Right side and Left side. In the study by **Rodrigues** [6,7]**,** superior joint space of Class III patients was increased but not significant. On intergroup comparison between Group I and Group II of the Left side, Posterior joint spacewas significantly decreased in Group I on the Left side as the mean difference was significant but the reason behind that is not clear.

On various intragroup and intergroup comparisons, the greatest anteroposterior diameter of mandibular condylar processes, the greatest mediolateral diameter of mandibular condylar processes were not significantly different. The distance between the geometric centers of condylar processes and midsagittal plane was significantly higher in Group II on the Right side as the mean difference was significant on intragroup comparison between Right side and Left side of Group II. Our findings were similar to study by **Rodrigues** [6,7]in whichmean difference was comparatively higher in Class II malocclusion but not statistically significant. In our study,the anteroposterior difference between the geometric center of right and left condylar processeswas significantly higher in Group III on the Left side as the mean difference was significant on intergroup comparison between Group I and Group III of the Left side.

Height of condylewas significantly higher in Group III on both sides as the mean difference was significant on intergroup comparison between Group I and Group III of the Right side and Left side, it may be because of the larger size of mandible in Skeletal Class III malocclusion. On various intragroup and intergroup comparisons, Width of condylewas not significantly different. Height of ProcessusCondylarisvalues in Class III was higher but not significantly different on both the sides when compared with other malocclusions. But, in a study by **Katsavrias**[2] and **Krisjane et al**[10]**,** they found thatheight of condyle was significantly higher in Class III malocclusion during growth due to increased vertical development of mandibular ramus.

Mandibular ramus lengthwas significantly shorter in Group II on both sides as the mean difference was significant on intergroup comparison between Group I and Group II of the Right side and Left side; and between Group II and Group III of the Right side and Left side. Similarly, Mandibular body lengthsignificantly shorter in Group II on both sides and Total mandibular lengthwas significantly shorter in Group II only on the Right side. In a study by **Gupta**[23]**,** it was found that Ramus height was decreased significantly in Class II.

Angular measurements:
When we measured the angle between the long axis of the mandibular condylar process and the midsagittal plane, it was significantly increased in Group I on the Right side as the mean difference was significant on intragroup comparison between Right side and Left side of the Group I. Tuberculum articulareanglewas significantly increased in Group I on both sidesas the mean differencewas significant on intergroup comparison between Group I and Group III of the Right side and between Group I and Group II of the Left side. But in a similar study by **Krisjaneet al** [10]there was no significant differences between Class II and Class III malocclusion.

In our study, the position of condyle associated significantly with sagittal skeletal malocclusions keeping the vertical growth pattern as normodivergent. This significant correlation may be because of inconsistent functional loads being exerted on the temporomandibular joints of patients with distinct sagittal skeletal malocclusions which might be accountable for bringing a change in the condylar position. Further studies and researches are necessary to place an emphasis on the 3D evaluation of the TMJ and its surrounding structures. More attention should be given to increase the sample size, to include the age changes and gender correlation, differences in vertical skeletal growth patterns, three dimensional volume, condyle angulation and shape estimation parameters in the future.

Conclusion:-

1. The height of mandibular fossa was larger on the right side and Tuberculum articulare angle was increased on both the sides in skeletal class I. The width and height of condyle was higher on the left side.
2. In skeletal class II, the size of condyle was increased on left side, and was placed more anteriorly and angularly in the fossa since anterior joint space was significantly decreased.
3. In skeletal class III, the width of mandibular fossa was larger on both the sides. Both condyles were placed anteriorly and superiorly as superior joint space was significantly decreased and left condyle was longer and angular than right side.
4. Non-concentric positioning of the Right and Left side condyles was present in all Skeletal Class I, II and III malocclusion and the condyles were asymmetrical. The condyles were anteriorly placed in all skeletal malocclusions but the greatest difference was present in Class II.
5. When right side of skeletal class I is compared with other malocclusions, the height of condyle was larger in skeletal class II than in skeletal class III while no other differences were found when compared between skeletal class II and skeletal class III.
6. When left side skeletal class I malocclusion is compared with other malocclusions, the height of condyle was larger in skeletal class III than in skeletal class II while no other differences were found when compared between skeletal class II and skeletal class III.
7. The mandibular body length and total mandibular length was decreased in Class II, and both were inversely proportional to ramus length.

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