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CBCT and Cephalometric Analysis of Condylar Morphology in Patients with Hyperdivergent Growth Pattern

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CBCT, Lateral cephalogram, TMJ, Growth pattern

ABSTRACT:

Introduction: The correlation between form and function suggests that the shape of the Temporomandibular joint (TMJ) may be influenced by functional forces. Since the mandible and the TMJ experience varying loads in individuals with different dentofacial morphologies, it is possible that the condyle and the fossa may vary in shape among people with different malocclusions.

Objectives: (1) To study 3D mandibular condylar morphology in vertically growing facial pattern with cone beam computed tomography.(2) To compare the 3D mandibular condylar morphological variation between vertically growing facial pattern individuals with normodivergent patients.

Methods: Total 30 lateral cephalogram & Cone Beam Computed Tomography were obtained retrospectively. The mean age was 22 to 28 years including 15 female and 15 male samples with class I and class II malocclusion. Various cephalometric parameters and CBCT parameters were taken and measurements were done.

Results: A significant inter-group difference was noted in the Gonial angle, SN-MP angle, FMA angle, LFH, Y-AXIS angle. With no correlation found between PL-Occlusal angle and MP-Occlusal angle. Comparison of condylar radius at different angle in axial plane suggest that there is definite significant difference noted in long axis length, radius at 150˚,radius at 210˚,radius at 240˚,radius at 270˚,radius at 300˚and radius 330˚between groups.

Conclusions: Mandibular condylar morphology shows variation in structural characteristics when compared between vertical growth pattern individuals with normodivergent individuals. In vertical growth pattern patient’s condylar size is different at lateral and posterior radius of the condyle. In normodivergent pattern individuals, condylar shape is well defined anatomically with more rounded form which allows better force distribution in TMJ and good functional capacity.

Introduction

Studying facial morphology aims to explore how dental occlusion and facial profile can be affected by growth. As the jaw grows, it shifts and carries the teeth along with it. If both jaws move the same amount in the same direction, the dental occlusion may remain unchanged. However, if growth is uneven, the jaws will develop a new relationship with each other. Typically, any change in jaw relationship is partially or completely hidden at the dental occlusion due to compensatory tooth movement in one or both jaws. When tooth movement cannot fully compensate for jaw growth, a change in dental occlusion occurs.

The correlation between form and function suggests that the shape of the Temporomandibular joint (TMJ) may be influenced by functional forces. Since the mandible and the TMJ experience varying loads in individuals with different dentofacial morphologies,[1] it is possible that the condyle and the fossa may vary in shape among people with different malocclusions.

The condylar heads' bone formation leads to the upward and backward growth of the mandibular ramus, resulting in the displacement of the entire mandible in a downward and forward direction. The narrowed condylar neck is attributed to bone resorption near the condylar head. Functional forces involved in this stage of mandibular growth include the attachment of the lateral pterygoid muscle to the neck, as well as the growth and action of the tongue and masticatory muscles.

Cephalometric analysis has been used to take morphological measurements for a long time; however, conventional cephalometrics is constrained by a number of factors, including the x-ray beam geometry that magnifies the image, the differences between the left and right sides, and the position of the head.[2] The image produced by lateral cephalograms is severely constrained by the physics, which may reflect a magnification error.[3]

CBCT has been viewed as the assessment of decision in many examples, since it gives high-goal imaging, symptomatic dependability, and chance advantage evaluation. In orthodontics, it is recommended for impacted teeth, evaluations of the temporomandibular joint, 3D views of the upper airways, assessment of maxillofacial growth and development, and estimation of dental age. Biomechanical simulations, models of bone remodeling, orthodontic surgical planning simulations, and measurements taken by digitizing points in 3D coordinates all demonstrate the validity of CBCT. In view of these benefits and conceivable outcomes in orthodontic appraisal, treatment, and follow-up, and its generally minimal expense, numerous orthodontists use CBCT regularly for all patients. When compared to multi-slice CT CBCT delivers a significantly lower radiation dose to the patient.[5,6]

So, we have tried to find out possible correlation of mandibular condylar morphology in vertical growth pattern individuals with the use of CBCT. Study of condylar radius at different angle also done. Such analysis can explore more ideas to diagnose and to plan treatment in high angle cases.

Materials and method

Total 30 lateral cephalogram & Cone Beam Computed Tomography were obtained retrospectively. The mean age was 22 to 28 years including 15 female and 15 male samples with class I and class II malocclusion. Adult cases were taken to eliminate consideration of mandibular condyle growth.

Exclusion Criteria:
Midline shift of the mandible relative to the ideal facial midline
Temporomandibular joint(TMJ) disorders
Craniofacial syndromes
It was felt these factors could significantly affect condylar morphology and/or the occlusion, which would in turn distort data gathered for the study.
Cephalometric tracing was done by one examiner on lateral cephalogram manually. 10 hard tissue cephalometric points were registered yielding 6 angular and 3 linear measurements. The subjects were divided into two equal groups based on the SN-MP plane angle (SN-MP) : vertical growth tendency (SN-MP $\geq 34.8^\circ$ degrees) with class I and class II malocclusion as test group, average growth pattern individuals with class I malocclusion with a normodivergent angle that served as the controls (SN-MP between 22.2°-34.8°).[13]
Cone beam CT scan with use of the CS 9000 3D Extraoral Imaging System by carestream (figure 1). Mandibular condyle morphology was assessed by CS 3D imaging software 3.2.9, Carestream health Inc. 3D dicom data were recorded with the patient in natural head position. Image reconstruction done for anatomical measurements. The exposure factors were 90 kV, 10 mA, and 11.26s. The imaging data were displayed on a PC monitor. Reconstructed slices were 1 mm thick. The condylar radius (the distance from the center of the long axis to the contours of the condyles) were measured by using analysis software. Left and right TMJs were evaluated independently for each patient. TMJ evaluation included the average radius of the right and

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left condyles were used for the statistical analysis. Condylar morphology is classified from the axial and frontal views. [8,14] (Figure 2)

Figure 1 : CBCT machine

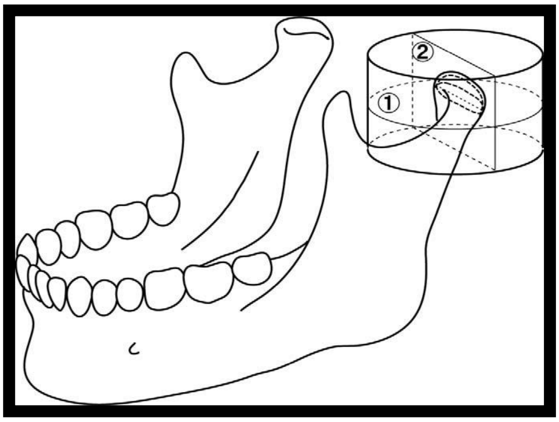

Figure 2: Axial and frontal view of condyle

Condylar morphology measurements

The standard planes for measurement.

Axial plane: The plane parallel to the FH and running along the midpoint of the medial and lateral poles of the mandibular condyle. (Figure 3)

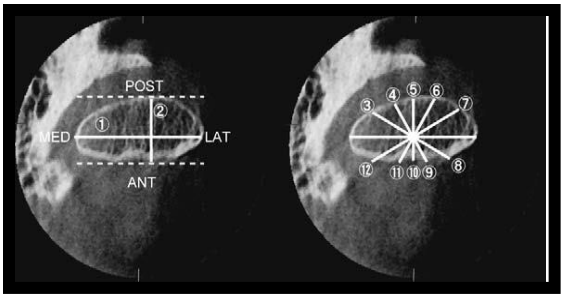

Figure 3: Axial Plane measurement of condyle

Frontal plane: The plane running along the long axis of the mandibular condyle and vertical to the FH. (Figure 4)

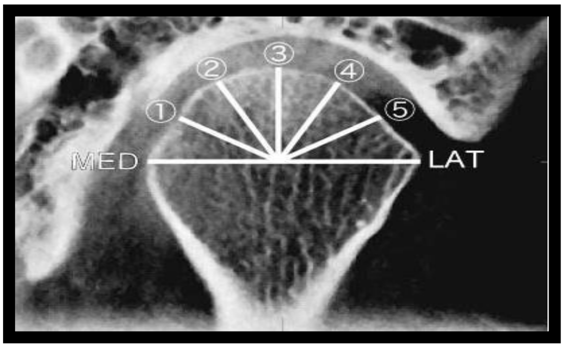

Figure 4: Frontal plane measurement of condyle

Long axis (Figure 3): The distance between the medial and lateral ends of the mandibular condyle.

Short axis (Figure 3): The distance between the two lines drawn parallel to the long axis and tangential to the outer margin of the condyle. The condylar radius was measured at 30° intervals from the center of the long axis to understand the topographic characteristic contours of the mandibular condyle.

Using the frontal image, the condylar radius was also assessed at 30° intervals from the center of the long axis (figure 4)

(a) Parameters measured for the axial plane of the condyle.

(1) Long axis (mm): Distance between the medial and lateral ends of the mandibular condyle. (Figure 5)

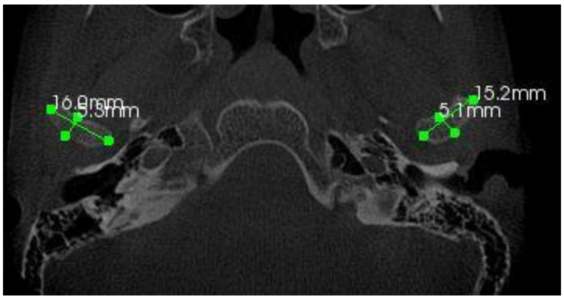

Figure 5: Long & short axis of condyle in axial plane

(2) Short axis (mm): Distance between the two lines drawn parallel to the long axis and tangential to the outer margin of the condyle. (Figure 5)

(3) **The radius (in mm)** of the condyle was measured at 30° intervals from the center of the long axis: 3, radius at 30°; 4, radius at 60°; 5, radius at 90°; 6, radius at 120°; 7,

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radius at 150˚; 8, radius at 210˚; 9, radius at 240˚; 10, radius at 270˚; 11, radius at 300˚ 12, radius at 330˚. (Figure 6, 7, 8)

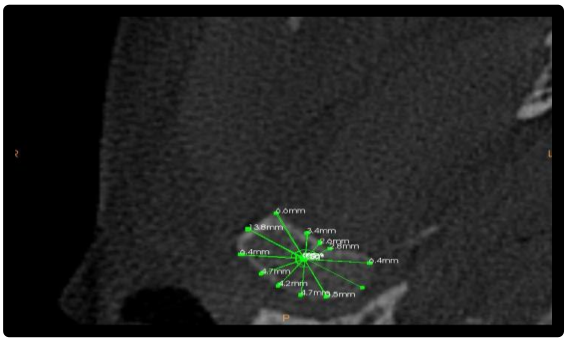

Figure 6: Axial plane measurements

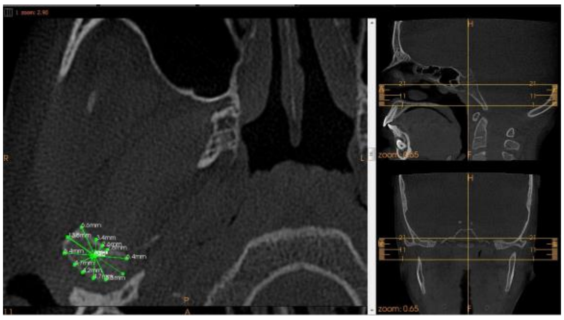

Figure: 7 Axial plane slice cut & measurements

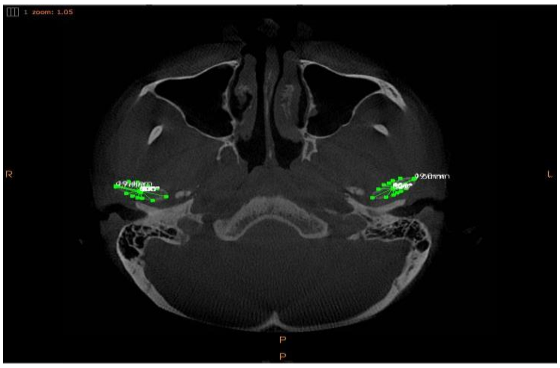

Figure 8: Axial plane measurements bilaterally

(b) Parameters measured for the frontal plane of the condyle

The radius (in mm) of the condyle was measured at 30˚ intervals from the center of the long axis: 1, radius at 30˚; 2, radius at 60˚; 3, radius at 90˚; 4, radius at 120˚; 5, radius at 150˚. (Figure 9, 10, 11)

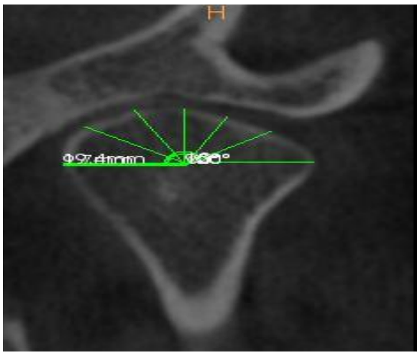

Figure 9:Frontal axis measurement of condyle(angle)

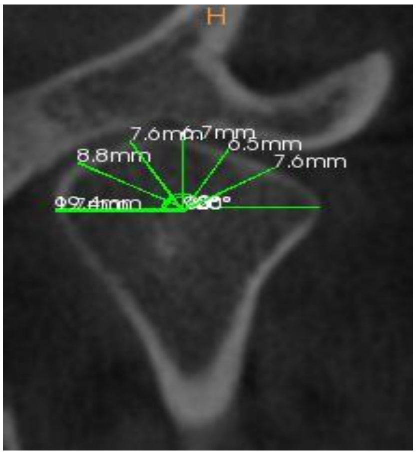

Figure 10: Frontal axis measurement of Condyle radius

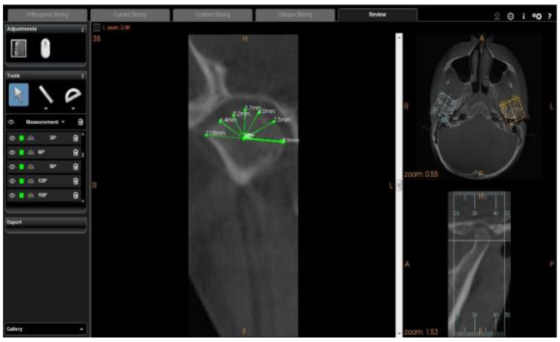

Figure: 11 Frontal plane slice and measurements of condyle

Results

Inter group comparison of cephalometric variable of vertical growth components

A significant inter-group difference was noted in the Gonial angle, SN-MP angle, FMA angle,
LFH, Y-AXIS angle. With no correlation found between PL-Occlusal angle and MP-Occlusal angle. (Table 1)

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Table 1: Inter group comparison of cephalometric variable of vertical growth components

	GROUP	N	Mean	p Value	Mann-Whitney Test
Ar-Go-Me	TEST CONTROL	15 15	133.50 124.47	0.014	S
PFH	TEST CONTROL	15 15	72.43 77.10	0.004	S
AFH	TEST CONTROL	15 15	118.43 112.17	0.081	NS
SN-MP	TEST CONTROL	15 15	39.57 27.37	0.004	S
FMA	TEST CONTROL	15 15	33.83 22.97	<0.0001	S
LFH	TEST CONTROL	15 15	69.37 60.90	<0.0001	S
PL-Occ	TEST CONTROL	15 15	10.10 9.00	0.430	NS
MP-Occ	TEST CONTROL	15 15	22.13 14.73	0.442	NS
Y-AXIS	TEST CONTROL	15 15	66.29 61.01	0.003	S

Inter group comparison of condylar morphology at different radius in axial plane

Comparison of condylar radius at different angle in axial plane suggest that there is definite significant difference noted in long axis length, radius at 150˚,radius at 210˚,radius at 240˚,radius at 270˚,radius at 300˚and radius 330˚between groups. The radius of medial side and anterior part like radius at 30˚, radius at 60˚, radius at 90˚, radius at 120˚ do not show any statistical difference between two groups. (Table 2)

Table 2: Inter group comparison of condylar morphology at different radius in axial plan

	GROUP	N	Mean	p Value	Mann-Whitney Test
Long axis axial plane	TEST	15	17.25	0.036	S
	CONTROL	15	16.33		
Short axis axial plane	TEST	15	6.29	0.245	NS

	CONTROL	15	6.67		
Radius at 30˚axial plane	TEST	15	6.10	0.787	NS
	CONTROL	15	5.89		
Radius at 60˚axial plane	TEST	15	3.61	0.934	NS
	CONTROL	15	3.63		
Radius at 90˚axial plane	TEST	15	3.09	0.819	NS
	CONTROL	15	3.09		
Radius at 120˚axial plane	TEST	15	3.96	0.983	NS
	CONTROL	15	3.91		
Radius at 150˚axial plane	TEST	15	5.76	0.026	S
	CONTROL	15	6.14		
Radius at 210˚axial plane	TEST	15	5.84	0.547	NS
	CONTROL	15	6.01		
Radius at 240˚axial plane	TEST	15	4.17	0.008	S
	CONTROL	15	4.50		
Radius at 270˚axial plane	TEST	15	3.72	0.041	S
	CONTROL	15	4.22		
Radius at 300˚axial plane	TEST	15	4.22	0.029	S
	CONTROL	15	4.52		
Radius at 330˚axial plane	TEST	15	6.05	0.017	S
	CONTROL	15	6.47		

Inter group comparison of condylar morphology at different radius in frontal plane

Comparison of condylar radius at different angle in frontal plane suggest that there is definite significant difference noted in radius at 150˚with no significant difference in radius at 30˚,radius at 60˚,radius at 90˚,radius at 120˚. Results show that the linear measurement of lateral side of the condyle has definite size difference between the two groups. (Table 3)

Table 3: Inter group comparison of condylar morphology at different radius in frontal plane

	GROUP	N	Mean	p Value	Mann-Whitney Test
Frontal plane long axis	TEST	15	18.09	0.534	NS
	CONTROL	15	17.28		
Radius at 30˚frontal plane	TEST	15	7.77	0.967	NS

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	CONTROL	15	7.68		
Radius at 60˚frontal plane	TEST	15	6.28	0.724	NS
	CONTROL	15	6.25		
Radius at 90˚frontal plane	TEST	15	5.75	0.709	NS
	CONTROL	15	5.88		
Radius at 120˚frontal plane	TEST	15	6.11	0.068	NS
	CONTROL	15	6.70		
Radius at 150˚frontal plane	TEST	15	7.04	0.041	S
	CONTROL	15	7.31		

Correlation between Size of the Mandibular Condyle and Maxillofacial Morphology-TEST GROUP

The long axis length is correlated with SN-MP angle, FMA angle, LFH, Y-AXIS angle. Condylar radius at 90˚ was correlated with SN-MP angle, FMA angle, LFH. Condylar radius at 150˚in axial plane & frontal plane was correlated with SN-MP, FMA. Condylar radius at 240˚, 270˚and 300˚in axial plane and condylar radius at 90˚in frontal plane were correlated with Gonial angle, SN-MP angle, and FMA angle. Condylar radius at 30˚in frontal plane Gonial angle. Condylar radius at 120˚in frontal plane SN-MP angle, FMA angle. PL-Occ plane angle and MP-Occ plane angle does not correlate with any with any of the condylar radius.(Table.4,5, 6, 7)

Table 4: Correlation between Size of the Mandibular Condyle and Maxillofacial Morphology-TEST GROUP

		Ar-Go-Me	PFH	AFH	SN-MP	FMA	LFH	PL-Occ	MP-Occ	Y-AXIS
Long axis axial plane	Pearson Correlation	0.088	-0.119	-0.196	-0.189*	-0.324*	-0.337	0.130	-0.001	-0.493
	Sig. (2-tailed)	0.754	0.674	0.485	0.004	0.024	0.022	0.643	0.996	0.021
Short axis axial plane	Pearson Correlation	-0.566	0.343	-0.087	-0.605	-0.364	0.153	-0.079	-0.273	0.177
	Sig. (2-tailed)	0.028	0.211	0.757	0.017	0.183	0.585	0.781	0.324	0.529
Radius at 30˚axial plane	Pearson Correlation	-0.259	0.393	0.366	-0.204	-0.087	0.107	0.010	-0.242	0.347
	Sig. (2-tailed)	0.352	0.148	0.180	0.465	0.759	0.704	0.971	0.385	0.205
Radius at 60˚axial plane	Pearson Correlation	-0.616	0.209	-0.165	-0.425	-0.200	-0.106	-0.134	-0.093	0.259
	Sig. (2-tailed)	0.014	0.454	0.558	0.115	0.475	0.706	0.633	0.741	0.350
Radius at 90˚axial plane	Pearson Correlation	-0.504	0.278	-0.194	-0.352*	-0.259*	-0.059*	-0.186	0.019	0.219
	Sig. (2-tailed)	0.055	0.317	0.488	0.020	0.035	0.034	0.506	0.946	0.434
Radius at 120˚axial plane	Pearson Correlation	-0.468	0.031	-0.339	-0.365	-0.245	0.028	-0.069	0.111	0.155
	Sig. (2-tailed)	0.079	0.914	0.216	0.180	0.379	0.922	0.807	0.695	0.582

Radius at 150˚axial plane	Pearson Correlation	-0.294	0.160	-0.065	-0.280*	-0.202*	0.279	0.182	0.102	-0.190
	Sig. (2-tailed)	0.287	0.568	0.818	0.031	0.047	0.313	0.517	0.718	0.497
Radius at 210˚axial plane	Pearson Correlation	-0.407	0.054	-0.068	-0.400	-0.337	0.519	0.102	0.035	-0.361
	Sig. (2-tailed)	0.132	0.849	0.810	0.140	0.219	0.047	0.718	0.901	0.186
Radius at 240˚axial plane	Pearson Correlation	-0.554	-0.051	-0.248	-0.584*	-0.518*	0.544	0.159	-0.127	-0.177
	Sig. (2-tailed)	0.032	0.856	0.373	0.022	0.048	0.036	0.572	0.653	0.528
Radius at 270˚axial plane	Pearson Correlation	-0.217	-0.184	-0.336	-0.417*	-0.445*	0.161	0.305	-0.052	-0.357
	Sig. (2-tailed)	0.437	0.511	0.220	0.012	0.013	0.566	0.269	0.853	0.192
Radius at 300˚axial plane	Pearson Correlation	-0.123	-0.016	-0.104	-0.533*	-0.288*	0.347	0.099	-0.036	-0.146
	Sig. (2-tailed)	0.664	0.954	0.712	0.041	0.030	0.205	0.726	0.900	0.603
Radius at 330˚axial plane	Pearson Correlation	-0.013	-0.099	-0.080	-0.549	-0.333	0.486	0.106	-0.161	-0.093
	Sig. (2-tailed)	0.965	0.724	0.778	0.034	0.226	0.066	0.708	0.567	0.743

Correlation between Size of the Mandibular Condyle and Maxillofacial Morphology-CONTROL GROUP

The long axis length is correlated with Gonial angle, SN-MP angle, FMA angle, LFH, Y-AXIS angle. Condylar radius at 90˚correlated with SN-MP angle,FMA angle. Condylar radius at 150˚in axial plane & frontal plane were correlated with SN-MP angle, FMA angle Condylar radius at 240˚, 270˚and 300˚in axial plane and condylar radius at 90˚in frontal plane were correlated with Gonial angle, SN-MP angle, and FMA angle. Condylar radius at 30˚in frontal plane show correlation with Gonial angle. Condylar radius at 120˚in frontal plane, SN-MP angle, FMA angle. PL-Occ plane angle and MP-Occ plane angle does not correlated with any with any of the condylar radius. (Table 5)

Table 5: Correlation between Size of the Mandibular Condyle and Maxillofacial Morphology- CONTROL GROUP

		Ar-Go-Me	PFH	AFH	SN-MP	FMA	LFH	PL-Occ	MP-Occ	Y-AXIS
Long axis axial plane	Pearson Correlation	-0.300*	-0.132	-0.012	-0.589*	-0.135*	0.102	-0.131	0.364	-0.154
	Sig. (2-tailed)	0.015	0.639	0.966	0.021	0.030	0.717	0.642	0.183	0.035
Short axis axial plane	Pearson Correlation	0.010	-0.265	-0.215	0.047	-0.231	-0.042	-0.201	0.157	-0.084
	Sig. (2-tailed)	0.972	0.340	0.441	0.869	0.407	0.882	0.473	0.577	0.766
Radius at 30˚ axial plane	Pearson Correlation	-0.094	0.104	-0.030	-0.078	-0.333	-0.075	-0.191	0.068	-0.035
	Sig. (2-tailed)	0.740	0.712	0.916	0.783	0.226	0.791	0.494	0.808	0.901
Radius at 60˚ axial plane	Pearson Correlation	-0.226	-0.026	-0.232	-0.209	-0.329	-0.318	-0.010	0.099	-0.213
	Sig. (2-tailed)	0.419	0.926	0.405	0.455	0.232	0.249	0.971	0.724	0.445
Radius at	Pearson Correlation	-0.237	0.022	-0.146	-0.222*	-0.307*	-0.332	0.012	0.084	-0.147

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90°axial plane	Sig. (2-tailed)	0.396	0.938	0.605	0.043	0.027	0.227	0.967	0.766	0.602
Radius at 120° axial plane	Pearson Correlation	-0.282	-0.010	-0.198	-0.191	-0.312	-0.438	0.082	0.129	-0.144
	Sig. (2-tailed)	0.308	0.972	0.480	0.495	0.258	0.103	0.772	0.646	0.609
Radius at 150° axial plane	Pearson Correlation	0.228	-0.072	0.003	-0.344*	-0.371*	-0.268	0.034	0.455	-0.083
	Sig. (2-tailed)	0.414	0.799	0.991	0.021	0.010	0.335	0.903	0.089	0.770
Radius at 210° axial plane	Pearson Correlation	0.191	-0.340	-0.030	0.706	0.078	-0.038	0.011	0.385	0.033
	Sig. (2-tailed)	0.494	0.215	0.916	0.003	0.781	0.893	0.968	0.156	0.906
Radius at 240° axial plane	Pearson Correlation	-0.322	-0.373	-0.064	-0.504*	-0.134*	-0.095	-0.019	0.347	-0.072
	Sig. (2-tailed)	0.024	0.170	0.820	0.029	0.035	0.738	0.947	0.206	0.800
Radius at 270° axial plane	Pearson Correlation	-0.211	-0.502	-0.263	-0.390*	-0.271*	0.204	-0.321	0.058	0.060
	Sig. (2-tailed)	0.019	0.056	0.343	0.042	0.024	0.467	0.244	0.837	0.833
Radius at 300° axial plane	Pearson Correlation	-0.151	-0.307	-0.067	-0.389*	-0.462*	0.216	-0.286	0.080	0.156
	Sig. (2-tailed)	0.014	0.265	0.813	0.015	0.020	0.439	0.301	0.776	0.578
Radius at 330° axial plane	Pearson Correlation	0.157	-0.420	-0.152	0.300	-0.059	0.291	-0.344	0.067	-0.120
	Sig. (2-tailed)	0.576	0.119	0.589	0.277	0.835	0.293	0.210	0.813	0.670

Table 6: Correlation Co-efficients Between Condylar Radii and Cephalometric Measurements-TEST group

		Ar-Go-Me	PFH	AFH	SN-MP	FMA	LFH	PL-Occ	MP-Occ	Y-AXIS
Frontal plane long axis	Pearson Correlation	0.031	0.018	-0.034	-0.174	-0.311	0.377	0.158	-0.105	-0.524
	Sig. (2-tailed)	0.912	0.949	0.903	0.535	0.260	0.166	0.574	0.710	0.045
	N	15	15	15	15	15	15	15	15	15
Radius at 30° frontal plane	Pearson Correlation	-0.206	0.320	0.088	-0.277	-0.361	0.450	0.014	-0.092	-0.386
	Sig. (2-tailed)	0.460	0.244	0.754	0.318	0.187	0.093	0.962	0.746	0.156
	N	15	15	15	15	15	15	15	15	15
Radius at 60°frontal plane	Pearson Correlation	-0.097	0.337	0.059	-0.364	-0.458	0.470	-0.124	0.088	-0.299
	Sig. (2-tailed)	0.730	0.220	0.834	0.183	0.086	0.077	0.659	0.754	0.280

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	N	15	15	15	15	15	15	15	15	15
Radius at 90°frontal plane	Pearson Correlation	-0.178	0.042	-0.240	-0.458*	-0.557*	0.387	-0.191	0.176	-0.190
	Sig. (2-tailed)	0.525	0.883	0.389	0.046	0.031	0.154	0.496	0.530	0.498
	N	15	15	15	15	15	15	15	15	15
Radius at 120° frontal plane	Pearson Correlation	-0.199	-0.178	-0.374	-0.442	-0.601	0.380	-0.101	0.041	-0.195
	Sig. (2-tailed)	0.478	0.525	0.169	0.099	0.018	0.163	0.721	0.885	0.486
	N	15	15	15	15	15	15	15	15	15
Radius at 150° frontal plane	Pearson Correlation	-0.045	-0.344	-0.271	-0.888*	-0.272*	0.211	0.077	0.056	-0.455
	Sig. (2-tailed)	0.873	0.209	0.329	0.003	0.033	0.449	0.786	0.842	0.088
	N	15	15	15	15	15	15	15	15	15

Table: 7 Correlation Coefficients Between Condylar Radii and Cephalometric Measurements-control group

		Ar-Go-Me	PFH	AFH	SN-MP	FMA	LFH	PL-Occ	MP-Occ	Y-AXIS
Frontal plane long axis	Pearson Correlation	-0.023	-0.233	-0.122	0.525	0.070	0.158	-0.117	0.228	0.063
	Sig. (2-tailed)	0.935	0.404	0.664	0.045	0.805	0.575	0.679	0.413	0.824
Radius at 30° frontal plane	Pearson Correlation	-0.381*	-0.168	0.019	0.637	0.198	0.188	-0.141	0.325	0.234
	Sig. (2-tailed)	0.028	0.550	0.947	0.011	0.479	0.501	0.617	0.238	0.402
Radius at 60° frontal plane	Pearson Correlation	0.176	-0.036	0.084	0.518	0.264	0.202	-0.202	0.231	0.337
	Sig. (2-tailed)	0.530	0.900	0.766	0.048	0.342	0.471	0.470	0.407	0.219
Radius at 90° frontal plane	Pearson Correlation	-0.265*	-0.033	0.114	-0.418*	-0.295*	0.181	-0.217	0.247	0.334
	Sig. (2-tailed)	0.014	0.906	0.685	0.012	0.029	0.519	0.437	0.375	0.224

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Radius at 120̊ frontal plane	Pearson Correlation	0.190	-0.316	-0.025	-0.518*	-0.256*	0.237	-0.138	0.191	0.096
	Sig. (2-tailed)	0.499	0.251	0.930	0.048	0.036	0.394	0.623	0.496	0.735
Radius at 150̊ frontal plane	Pearson Correlation	-0.119*	-0.231	-0.124	-0.419*	-0.105*	0.093	-0.104	0.208	0.135
	Sig. (2-tailed)	0.038	0.407	0.659	0.012	0.048	0.742	0.712	0.458	0.631

Discussion

In the present study the condylar morphological variations were analyzed and correlated with different growth pattern individuals and condylar growth is regulated not only by genetic factors but also by functional factors. In this study, the condyles of individuals with high occlusal force and average SN-MP angle were very well developed in terms of the long axis length; the radius at 60˚, 90˚, 120˚, 150˚, and 240˚,270˚,300˚, in the axial plane; and the radius at 150̊ in the frontal plane in control group. Whereas linear measurement of long axis length and condylar radius at , 150˚, 240˚,270˚,300˚, in the axial plane; and the radius at 90˚,150˚ in the frontal plane show deficient growth. These radius indicate the size of the lateral and posterior part of the condyle. The high-occlusal-force group and normodivergent individuals tend to have condyles with large, more rounded form at the lateral and posterior side than the vertical growth pattern individuals with low-occlusal-force group. A recent study showed that bilateral masseteric resection at the prepubertal stage in rats lead to impaired formation of the mandibular bone and condyle in adults[61]. A rat condyle transplanted into the subcutaneous dorsal site of a littermate changed in terms of shape, cellular kinetics, and collagen formation showed structural changes with functional alteration.[17]

Present study of condylar structural characteristic shows well developed anatomy in lateral and posterior radius area which also correlation with occlusal bite force. In this study condylar radius at 150̊ in frontal plane shows lateral surface which is well developed form in normodivergent pattern individuals and relatively less developed in condylar radius at 240̊, 270̊, 300̊ in axial plane in test group. This fact was supported by number of study which shows that compressive stress during clenching is localized at the lateral side of the mandibular condyles by the distribution of sulfated glycosaminoglycans in the surface layers of human TMJs.[18] On finite-element analysis of human TMJ, it was also reported that the largest stress is generated at the middle-to-lateral and superior to posterior areas of the condylar cartilage during jaw closure.[19] Mechanical compression induces chondrogenesis and condylar growth. Studies in which mandibular condyles were transplanted into a nonfunctional environment have shown that the progenitor cells of the proliferative zone differentiate into osteoblasts, and not chondroblasts in situ.[20,21] Under non-functional conditions, maturation and hypertrophy of the cartilage progress rapidly. Mature cartilage induces mesenchymal cells for the cessation of further cartilaginous growth.[11]

Study done by Stanely et al shows less correlation with various dental linear and angular cephalometric measurements like Y-Axis, MPA and LFH. But present study found definite correlation between cephalometric measurements like SN-MP, FH-MP, Y-Axis and LFH and also its correlation with CBCT analyzed condylar measurements which might attribute to more refined advanced technological methods with digital cephalometry machines and tomographic software analysis system.

The sites of stress on the surface of the mandibular condyles during occlusion were as previously reported, coinciding with sites in the current study at which differences in mandibular condyle morphology were observed as a result of the intensity of occlusal force. The low-occlusal-force patients had weak pressure on the surface of the mandibular condyles during mastication; therefore, a marked difference from the high-occlusal-force patients appeared particularly in the lateral and posterior directions. Mandibular condyle growth was inhibited at these sites, and differences in morphology were apparent. In addition, growth of mandibular condyle cartilage occurred laterally and posteriorly, leading to differences at these sites. Clinically, it has been observed that weaker masticatory muscular force during the growth periods results in a skeletal pattern in which the mandibular plane, occlusal plane, and gonial angles are large, and the ramus is short.[22,23]

Altered functional loading for 2-6 weeks caused significant reduction in the thickness of the condylar cartilage whereas; only at 4 weeks was there a significant decrease in the bone volume fraction and trabecular thickness of the subchondral bone. Gene expression analysis showed that altered functional loading for 4 weeks caused a significant reduction in the expression of SRY-box containing gene 9 (Sox9), Collagen type X (Col X), Indian hedgehog (Ihh), Collagen type II (Col II) and Vascular endothelial growth factor (Vegf) and altered loading for 6 weeks caused a significant decrease in the expression of Sox9, Col II, Vegf and Receptor activator of NF-kappaB ligand (Rankl) compared to the normal loading group.[24]

A previous biomechanical study showed that a mechanical disadvantage in the masseter may result from an increase in the gonial and mandibular plane angles.[10] Similarly, in the present study, a negative correlation was found between occlusal force and MP-FH; further, MP-FH, SN-MP, and S-Go, which are considered to be related to occlusal force, were closely correlated with the long axis length and the lateral and posterior radius of the condyles. These results clarified the relationships among occlusal force, mandibular condyle morphology, and maxillofacial morphology.

Vertical growth pattern individuals were noted with increased value of cephalometric norms like SN-MP, FH-MP, LFH, Y-Axis and Gonial angle as compared to normodivergent faces. The square jaw (relatively acute gonial angle) and short lower face height of the "powerful individual" are part of the usual caricature; demonstrate that occlusal forces are greater in individuals with this facial morphology. It is reported that a lengthening of facial dimensions in individuals with muscular weakness. Throckmorton et al.[10] have demonstrated that there is a greater mechanical advantage for the elevator muscles of the mandible if the ramus of the mandible is upright and the gonial angle is relatively acute. As the gonial angle increases, the mechanical advantage of the muscles decreases, and an equivalent effort by the muscle would produce less force at the dental occlusion.[30] This view implies that occlusal force might be another example of function reflecting form.[15]

Long face subjects have smaller maximum molar bite forces than do normal individuals. Van spronsen et al, also supported present study by their muscular system analysis which has been attributed both to differences in moment arms and size of the jaw muscles. A comparison was made between the mid-belly cross-sectional areas of the jaw muscles of 13 long face and 35 normal adults by means of serial MRI scans. The subjects were selected on the basis of anterior lower face height as a percentage of anterior total face height. In the long face group, the cross-sectional areas of the masseter, medial pterygoid, and anterior temporal muscles were, respectively, 30%, 22%, and 15% smaller than in the control group. By a discriminate analysis and a multivariate analysis of variance, these differences were found to be significant. Their study hint that differences in the sizes of the jaw muscles of long faced normal subjects might explain, in part, the observed differences in maximum molar bite force.[31] Less force directed at TMJ lead to reduced condylar dimension or restrict the growth in specific area of condyle like long axis ,lateral radius in axial plane and lateral condylar radius at 150˚.This was noted in our study which supports the previous study related to occlusal force and facial morphological correlation.

For future aspect according to Proffit study, it should be focused that it is possible to recognize this pattern in some children at an early age. Although not all individuals who will become long-face adults have this facial pattern prior to puberty, children who do have the pattern rarely, if ever, grow out of it. Another µCT analysis showed that the condylar width was significantly greater in the HD (hard diet) group than in the SD (soft diet) group after 1 week. After 4 weeks, mandibular length was significantly longer and ramus height was greater in the HSD (hard & soft diet) group than in the other two groups. Bone volume was significantly less in the SD group than in the other two groups after 4 weeks. These findings suggest that changes in mastication markedly affect mandibular condylar cartilage growth and mandibular morphology. It is considered that dietary education at an early age is

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important in order to prevent disruption of the development of the mandible which gives scope of future research in this area that proper diet related muscular exercise at early age may control vertical growth pattern to develop.[9]

Conclusion

Mandibular condylar morphology shows variation in structural characteristics when compared between vertical growth pattern individuals with normodivergent individuals.

In vertical growth pattern individuals' condylar size is different at lateral and posterior radius of the condyle.

In normodivergent pattern individuals, condylar shape is well defined anatomically with more rounded form which allows better force distribution in TMJ and good functional capacity.

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