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Evaluation of TMJ morphology in various growth patterns in North Indian population: A CBCT study

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***Abstract*---**Introduction: Temporomandibular joint plays an important role in maintaining a balance between structures of oral-facial complex. And morphology of Condyle is an essential part of temporomandibular joint that response to functional load, masticatory muscle activity constantly even after completion of the growth. Therefore, its morphology directs the adaptations to these functional forces. Aim: To evaluate the TMJ morphology characteristics in various growth patterns using CBCT. Materials and Methods: The present study was conducted to evaluate and compare morphology of TMJ in different vertical growth pattern individuals in North Indian population using CBCT. Pretreatment cone-beam computed tomography (CBCT) images of 10 Hypodivergent, 10 Normodivergent

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and 9 Hyperdivergent subjects were analyzed using SN- mandibular plane angle. Morphological parameters of TMJ such as anterior, superior, posterior joint space, condylar axial angle, mandibular fossa depth, intercondylar distance, medio-lateral and anterio-posterior width were measured and statistical analysis were done using One Way ANOVA and Post hoc Tukey test. Results: A statistically significant difference was noted in the superior joint space among Group I(4.04±0.10), Group II(3.73±0.36) and Group III(3.06±0.22)with p=0.00 and significantly correlated to facial morphology. Conclusion: TMJ morphology varies according to different growth patterns. Patient with hyperdivergent growth pattern have decreased superior joint space, decreased mandibular fossa depth, decreased condylar head angle and condylar widths in comparison of hypodivergent and normodivergent facial patterns. The knowledge of TMJ morphological variations associated with different vertical skeletal patterns helps the clinician in understanding the TMJ pathology and planning the TMJ oriented orthodontic treatment for stable results.

***Keywords*---**TMJ, Group I-Hypodivergent, Group II -Normodivergent, Group III-Hyperdivergent, CBCT.

Introduction

Temporomandibular joint (TMJ) plays an important role in maintaining a balance between structures of oral-facial and maxillomandibular system. Condyle is an essential part of temporomandibular joint that response to functional load, masticatory muscle activity constantly even after completion of the growth. Therefore, its morphology directs the adaptations to these functional forces [1-2]. Condylar morphology is an important feature for temporomandibular joint (TMJ)-focused orthodontic treatment planning. Orthodontic diagnosis, treatment planning, and treatment outcomes are also affected by skeletal pattern [3-4]. Opdebeeck et al., defined hypodivergent or reduced vertical facial type as “short face”. Patients having short face have a maxillary deficiency in vertical dimension, severe counter-clockwise rotation of mandibular and low mandibular angle with skeletal deep-bite.

Schendel et al., described excessive vertical growth of face as “long face” syndrome and patient having long face have following features such as clockwise rotation of mandibular, high mandibular angle, adenoid faces and vertical maxillary excess. These extreme growth patterns not only affect the skeletal features but also affect the TMJ joint morphology. As the form and function are interrelated, due to which there is a strong correlation between condylar morphology and craniofacial morphology [5]. The condyles are very adaptative to external forces and the presence of cartilaginous tissue favours the ability of condylar remodelling in reaction to external stimuli [6]. Therefore, the condyles are not the main site of orofacial orthopaedics but also considered as important site for determining the facial pattern of orofacial complex [7-8].

Kikuchi et al., [9] used CT scans and cephalograms to study the relationship between skeletal morphology and condylar position. They concluded in their study that the condyle was more posteriorly positioned in the glenoid fossa when the mandible shows a clockwise rotation, indicating that the vertical dimension of the facial phenotype showed a close association with TMJ morphology. Cohlmia et al., [10] stated that the patients having skeletal Class III malocclusion have a tendency of more anteriorly positioned condyles when compared to skeletal Class I malocclusion, but no difference was found in condylar position between Class I and Class II malocclusions.

In this study condylar and TMJ morphology was studied in all three groups using using CBCT. The multidimensional nature of CBCT imaging and 3D reconstruction provided by CBCT allow a wholesome visualization of the complex structures such as TM joint and ensures precise and highly accurate measurements of these anatomic structures. Therefore the aim of the present study is to study and compare the morphology of TM joint in 29 preorthodontic patients from North Indian population using CBCT scans of different dentofacial phenotype.

Materials and Methods

The study was conducted in Department of Orthodontics and Dentofacial Orthopaedics, Shree Guru Gobind Tricentenary Dental College, Gurugram after the approval from Ethical committee (SGTU/Exam/SCY/11929). The total sample for the study was consisted of 29 patients. All the CBCT scans of participants for this study were taken from data bank of Department Of Orthodontics and Dentofacial Orthopaedics. The sample for the study constituted North Indian population.

Inclusion criteria

The preorthodontic scans were selected in the age range of 15-35 years with permanent dentition.

Exclusion criteria

Patient with previous orthodontic treatment, Congenital skeletal deformity such as cleft lip and palate, History of trauma or general condition affecting the TMJ and Systemic disorder related to bone.

The Pretreatment CBCT scans were acquired by Planmeca 3D Mid ProFace CBCT scanner (Planmeca, Helsinki, Finland), operated at 90 kV and 14 mA, with a field of view (FOV) of 200mmx160mm.The voxel size of the scans is 150 µm. The slice thickness is 0.200mm and patient was seated with the natural head position and teeth are in maximum intercuspation.

The DICOM (Digital Imaging And Communications In Medicine) images obtained were then analyzed using Planmeca Romexis software version 5.0.0 (Planmeca, Helsinki, Finland) in a partially darkened room.

Study Groups

The Study was conducted over 29 subjects which were classified into 3 groups using mandibular plane angle SN-GoGn as a criteria to differentiate the type of growth pattern.

GROUP 1- Hypo-divergent [SN-GoGn angle equal to less than 25°] includes 10 CBCT scans.

GROUP2- Normo-divergent [SN-GoGn angle equal to 25°-32°] includes 10 CBCT scans.

GROUP 3-Hyper-divergent [SN-GoGn angle equal to or greater than 32°] includes 9 CBCT scans.

The CBCT scan images were then reoriented on volume rendered view using Frankfort plans as horizontal plane as poroin, right orbital, left orbital for standardization of all scans. After the skulls were orientation bilaterally in all 3 planes the digital lateral cephalograms were generated by CBCT scans in form of DICOM image and the SN- mandibular plane angle was measured to categorize images into three groups according to types of growth patterns.

Condyle and glenoid fossa (TMJ) measurements:

Image Orientation

For the condyle and glenoid fossa measurement, x-axis was scrolled on sagittal section to be placed at the point where inferior limit of condyle or sigmoid notch just appeared on the axial section, the y-axis was set tangent through pterygoid vertical. Then the z-axis was moved and adjusted to lie along center of sigmoid notch on the axial section [Fig-1]. The procedure was followed for both right and left condyles.

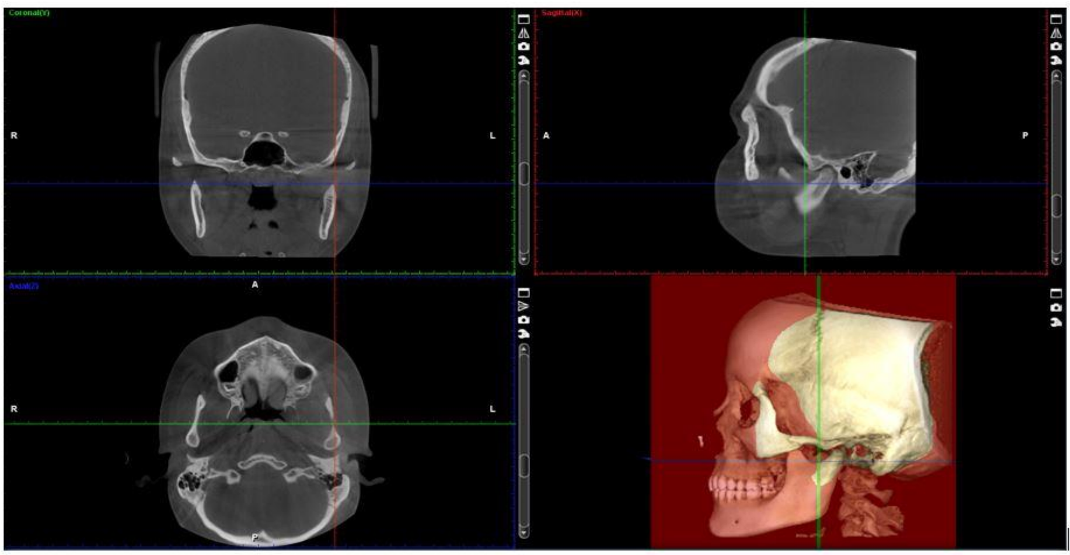

Fig-1: TMJ Joint orientation on MPR views and volume rendered view

Following measurements were then taken on sagittal section to determine the position of condyle.
Linear and angular condylar measurements wered done [Table 1].

Table 1: Definition of linear and angular condylar measurement

S.NO.	MEASURMENTS	DEFINITION
1.	Anterior joint space(mm)	Linear distance from anterior point on condyle to a point on articular eminence
2.	Superior joint space(mm)	Linear distance between the most superior point of the mandibular fossa and the most superior point of the condylar head
3.	Posterior joint space(mm)	Linear distance from posterior point on condyle to posterior surface of fossa
4.	Depth of mandibular fossa (mm)	Linear distance between the most superior point of the mandibular fossa and the plane formed by the most inferior points of the articular tubercle and the postglenoid process
5.	Condylar axis angle (°)	Angle between medio-lateral plane of condyle and the midsagittal plane.
6.	Medio-lateral condylar width(mm)	The linear distance measured from medial point on condylar process to lateral point on condylar process
7.	Antero-posterior condylar width(mm)	The linear distance measured from anterior point on condylar process to posterior point on condylar process
8.	Intercondylar medial distance(mm)	The linear distance measured from mesial point of right condylar process to the mesial point on left condylar process
9.	Intercondylar lateral distance(mm)	The linear distance measured from distal point of right condylar process to the distal point on left condylar process

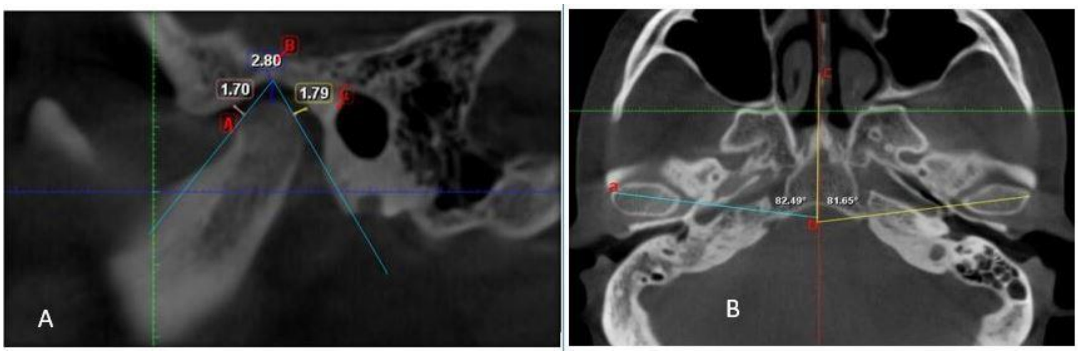

Fig-2 A : A-Anterior joint space (AJS), B-Superior joint space (SJS), C-Posterior joint space (PJS), Fig 2 B: D- Condylar axis angle (abc)

Fig-3 A: A-Antero-posterior condylar width, B- Mediolateral condylar width, Fig 3 B : F-Intercondylar lateral distance, E-Intercondylar medial distance

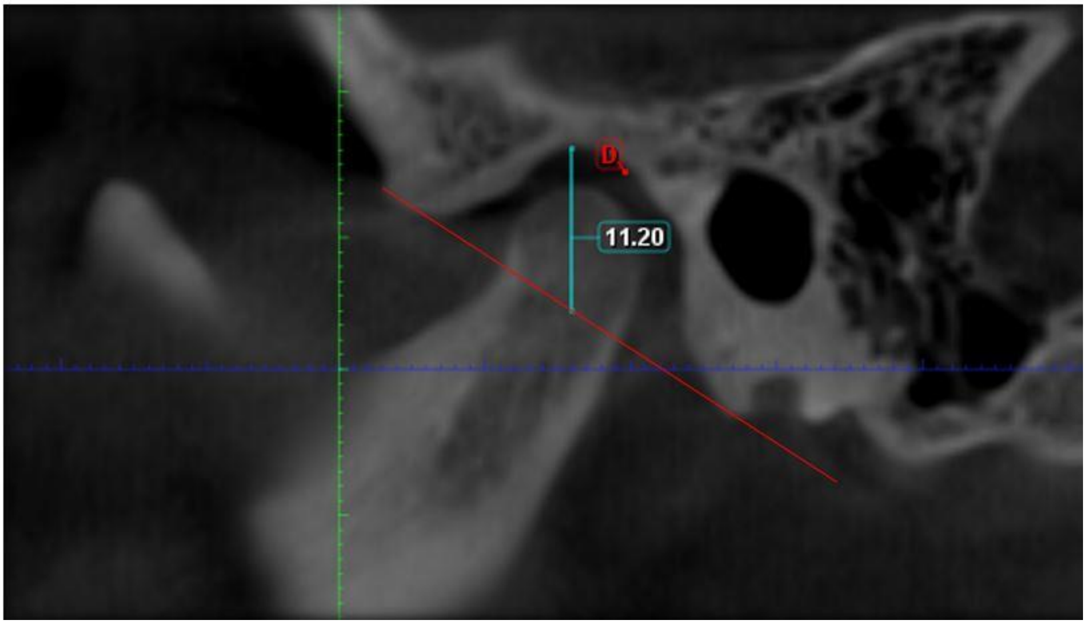

Fig-4 Depth of Mandibular fossa

Statistical analysis

To determine accuracy of the method, 7 randomly chosen CBCTS were reoriented and remeasured at the interval of 15 days by one investigator using the same landmarks and variables included in the study. Measurements were calculated using paired t-test and they showed high reliability with p value 0.027. One-way analysis of variance (ANOVA) and Tukey post-hoc test was used to compare mean values between three groups. The results were analyzed by using SPSS Statistics software version 24.0. The data was entered in the software and evaluated for required analysis. Continuous variables of data were presented as mean ± SD.

Results

On comparison of mean values of right and left side of TMJ morphology parameters of Hypodivergent (Group I), Normodivergent (Group II), Hyperdivergent (Group III) using One Way ANOVA test, statistically significant increase of superior joint space from Hyperdivergent (Group III) to Hypodivergent group (Group I) from 3.06mm to 4.04mm with p=0.00 while comparing Hyperdivergent Group, Normodivergent Group and Hypodivergent Group indicating that condyle is superiorly positioned in hyperdivergent when compaired to hypodivergent and normodivergent. There was difference in other parameters, but they were not significant [Table 2].

Table 2: shows the value of TMJ morphology variables with mean, SD and comparison with One-Way ANOVA Test in Hypodivergent (Group I), Normodivergent (Group II), Hyperdivergent (Group III)

Variable	Group I N=10		Group II N=10		Group III N=9		One Way ANOVA
	Mean	SD (±)	Mean	SD (±)	Mean	SD (±)	p-value
Anterior joint space(mm)	2.02	0.37	2.15	0.88	1.80	0.27	0.396
Superior joint space(mm)	4.04	0.10	3.73	0.36	3.06	0.22	0.00***
Posterior joint space(mm)	2.53	0.75	2.26	0.27	2.43	0.34	0.506
Mandibular fossa depth(mm)	11.58	1.23	11.58	0.84	11.14	1.43	0.646
A-P condylar width(mm)	6.90	0.74	6.64	0.71	6.83	1.13	0.801
M-L condylar width(mm)	15.65	2.17	17.09	1.94	16.79	2.22	0.297
Condylar axial angle (°)	68.79	6.38	66.96	5.69	66.97	4.44	0.711
Intercondylar medial distance(mm)	83.82	4.19	86.57	5.16	91.62	7.96	0.026*
Inter condylar lateral distance(mm)	102.71	9.11	102.88	6.32	108.11	6.68	0.229

#Measurements are average of both right and left side of TMJ parameters. Significant (*) $p \leq 0.05$; Highly Significant (**) $p \leq 0.01$; Very Highly Significant (***) $p \leq 0.001$

On intergroup comparison of mean values of right and left side of TMJ morphology parameters of Hypodivergent (Group I), Normodivergent (Group II), Hyperdivergent (Group III) using One Way ANOVA test and Post hoc Tukey test, statistically significant increase of superior joint space from Hyperdivergent (Group III) to Hypodivergent group (Group I) from 3.06mm to 4.04mm, while comparing Hypodivergent Group and Normodivergent Group the result was significant with p value 0.027, while comparing the Hypodivergent Group to hyperdivergent group and normodivergent group to hyperdivergent group results of superior joint space were statistically highly significant with p value 0.00 among. All the parameters were increasing from hyperdivergent to hypodivergent with there was no significant difference was found among three groups [Table 3].

Variable	Group I		Group II		Group III		One Way ANOVA	Group I VS Group II	Group I VS Group III	Group II VS Group III
	N=10		N=10		N=9					
	Mean	SD (±)	Mean	SD (±)	Mean	SD (±)	p-value	p-value	p-value	p-value
Anterior joint space (mm	2.02	0.37	0.396	0.88	1.80	0.27	2.15	0.868	0.689	0.369
Superior joint space(mm)	4.04	0.10	3.73	0.36	3.06	0.22	0.00***	0.00***	0.00***	0.270
Posterior joint space(mm)	2.53	0.75	2.26	0.27	2.43	0.34	0.506	0.483	0.916	0.745
Mandibular fossa depth(mm)	11.58	1.23	11.58	0.84	11.14	1.43	0.646	1	0.704	0.694
A-P condylar width(mm)	6.90	0.74	6.64	0.71	6.83	1.13	0.801	0.801	0.985	0.878
M-L condylar width(mm)	15.65	2.17	17.09	1.94	16.79	2.22	0.297	0.951	0.479	0.3
Condylar axial angle (°)	68.79	6.38	66.96	5.69	66.97	4.44	0.711	0.748	0.763	1
Intercondylar medial distance(mm)	83.82	4.19	86.57	5.16	91.62	7.96	0.026	0.556	0.021	0.169
Inter condylar lateral distance(mm)	102.71	9.11	102.88	6.32	108.11	6.68	0.229	0.999	0.277	0.3

Fig-3 : shows intergroup comparison of TMJ variables among Hypodivergent (group I), Normodivergent (group II) and Hyperdivergent (group III). #Measurements are average of both right and left side of TMJ parameters. Significant (*) $p \leq 0.05$; Highly Significant (**) $p \leq 0.01$; Very Highly Significant (***) $p \leq 0.001$

Discussion

The position of condyle in mandibular fossa is determine by arrangement of the joint spaces, mandibular fossa depth and condylar axial angle. According to Pullinger et al., [11] joint space measurements are the best method to locate the condyle position in mandibular fossa. The results of this study showed that among joint spaces, superior joint space was highly significant with p-value ≤0.00. The mean value of superior joint space in hypodivergent group was 4.04 mm, in normodivergent group was 3.73 mm and in hyperdivergent group was 3.06 mm. The significantly smaller superior joint space in hyperdivergent group was suggestive of related more superiorly positioned condyles. The mean value of anterior joint space in hypodivergent was 1.80mm, 2.15mm in normodivergent and 2.02mm in hyperdivergent with p value 0.396 and posterior joint space was 2.53mm in hypodivergent group, 2.26mm in normodivergent group and 2.43mm in hyperdivergent group with p value 0.506. Moreover, no significant difference was observed in anterior and posterior joint spaces among three groups which indicate the absence of corelation between vertical dentofacial pattern and condylar position in antero-posterior dimension.

The depth of mandibular fossa in the present study the value of mandibular fossa depth was 11.58mm in both hypodivergent and normodivergent group and 11.14mm in hyperdivergent with p value 0.646. The result showed that mandibular fossa depth decrease in hyperdivergent group as condyle is more superiorly positioned in hyperdivergent group which in result the shallow mandibular fossa in hyperdivergent group as compaired to hypodivergent group. These finding were supported by Santander et al., [12] and Girardot et al., [3]. The condylar axial angle is a angle formed by the long axis of condyle to midsagittal plane which was 68.79° in hypodivergent and 66.97°was in hyperdivergent group with p value 0.711, shows that hyperdivergent group as the steep condylar axial angle when compaired to hypodivergent and normodivergent. As the condyle of hypodivergent placed more posteriorly when compaired to hypodivergent group and inclined more posteriorly. These finding were supported by Burke et al., [13] and Park et al., [14]

Superiorly placed condyle and posteriorly inclined condyles are the typical features of hyperdivergent growth patterns while studying the preadolescent subjects with skeletal Class II malocclusion as suggested by Burke et al., [13]. He also concluded that the hyperdivergent growth pattern have a tendency of reduced condylar tissue, results of which there is reduced growth potential of condylar, due to which there is increased in amount of anterior facial height during growth of the craniofacial complex this may lead to disbalance between anterior and posterior facial height, decreased ramal height and mandibular clockwise rotation which led to vertical dysplasia of face.

Pullinger et al., [11] studied class II division 1 group and class I group. They concluded that condyle is more anteriorly inclined in class II group as compared to normodivergent or class I group and condyle is posteriorly inclined in hyperdivergent group when compared with hypodivergent. And in class III condyle had positioned posteriorly and more superiorly in mandibular fossa whereas Bacon et al., [15] found the condyle was in a more retrusive position in class II malocclusion. They also found that there is a strong corelation between condyle position and occlusion. The description for this result is assumed to be that a lack of stability of occlusion due to lack of intercuspation which cause mandibular shift and condylar displacement to overcome the occlusal instability.

The clinical implication of measuring joint space is of great value in orthodontics as the normal values of joint spaces are important in maintaining the position of condyle in mandibular fossa along it regulates the smooth movement of condyle in mandibular fossa with articular disc. The widening or narrowing of the joint space may lead to TMJ dysfunction or any pathology associated.

In present study antero-posterior condylar width and medio-lateral width were measured in all three groups. Antero-posterior condylar width was 6.83mm in hyperdivergent group, and 6.90 mm in hypodivergent group with p value 0.801, mediolateral condylar width was 15.69mm in hyperdivergent group,17mm in normodivergent and 15.67mm in hypodivergent with p value 0.297 and condylar neck width was 7.04mm in normodivergent, 7.34mm in hypodivergent and 6.97mm in hyperdivergent group with p-value 0.81, which shows statistically non-significant results. From the finding of this study, we can say that hyperdivergent have smaller condyles in comparison of hypodivergent and normodivergent. The result of present study was in accordance with the result of Santander et al., [12] who reported that condylar width increases from hyperdivergent to hypodivergent skeletal pattern as functional load such as biting force, masticatory muscle activity increases from hyperdivergent growth pattern to hypodivergent growth pattern. In past there were many studies which concluded that "short face" or hypodivergent craniofacial morphology was associated with stronger bite force and masticatory muscle activity as compared to "long face" or hyperdivergent skeletal growth pattern. [16]

Kurusu et al., [17] also stated that masticatory force played an important role in determining the morphology of maxillofacial complex and mandibular condyle. The condylar features of TMJ were affected by many factors as masticating strength, genetics and facial bio-type. Enomoto et al., [18] observed that the condylar width in mice that fed on hard diet were greater than the mice that fed on soft diet or vice-versa. It indicates alteration in biting force, affect the growth of condylar cartilage and result in different condylar morphology in different facial patterns.

In this study condylar morphology of right and left side of TM joint was studied separately as TM joint is a complex joint and no two joints are similar in morphology. This study induced that no significant difference was found between the left and right-side condylar morphology in patients having same vertical skeletal pattern. This indicate that condyles of the subjects were symmetrical in nature.

Moreover, the earlier studies proved that the condyle in a normodivergent subject occupied a symmetrical position in the glenoid fossa (Blaschke & Blaschke 1981., [19] and Williams 1983., [20]). In disparity, the subjects with TMD tend to had the asymmetric condylar position in comparison with normal subjects. (Rozencweig 1975) [21].

After so much of research work still there is a fundamental question persist that what should be the ideal position of condyle in TM joint at centric occlusion. As position of condyle in TM joint is not visible by naked eyes. So, many radiographic techniques were used to visualize the position such as Transcranial projection, Laminography, Tomopraphy, MRI and CBCT. Out of which CBCT, a recently developed imaging technology, has been used for 3-dimensional imaging of the TMJ. It has been shown that CBCT demarcate the joint structures with high accuracy and resolution. And the combined use of MRI and CBCT allows the accurate measurement of condylar position with disc status in TMJ.

Finally, the condylar morphology may be affected by various factors such as growth and development, functional forces, postural adaption, physiological and pathological remodelling of bone. So, by studying the affect to these factors during growth period we can modulate the resultant growth for improving the patient's treatment planning and treatment outcomes and by considering the condyle position and morphology in centric occlusion we can get better and stable treatment outcomes.

Limitation

The limitation of this study was the small sample size. So, further studies are required in this field.

Conclusion

This study provides that there is a correlation between TMJ morphology and skeletal patterns. Patient with hyperdivergent growth pattern have decreased superior joint space, decreased mandibular fossa depth, decreased condylar head angle and condylar widths in comparison of hypodivergent and normodivergent facial patterns. The knowledge of TMJ morphological variations associated with different vertical skeletal patterns helps the clinician in understanding the TMJ pathology and planning the TMJ oriented orthodontic treatment for stable results.

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