Journal of Chemical Health Risks

www.jchr.org

JCHR (2024) 14(5), 1685-1692 | ISSN:2251-6727

Evaluation of Condylar Volume and Surface Area of Skeletal Class I Subjects with and without Anterior Open Bite - A Cross-Sectional CBCT Study

Neha Dechamma[1], Roshan Sagarkar[2], Prashantha G.S[3], Sharanya Sabrish[2], Nirajita Bhaduri[4], Sathyashree. K[4]

1;Post Graduate Student, Faculty of Dental Sciences, Ramaiah University of Applied Sciences, Bangalore, India

2; Associate Professor, Faculty of Dental Sciences, Ramaiah University of Applied Sciences, Bangalore, India

3; Professor, Faculty of Dental Sciences, Ramaiah University of Applied Sciences, Bangalore, India

4; Assistant Professor, Faculty of Dental Sciences, Ramaiah University of Applied Sciences, Bangalore, India

(Received: 11 June 2024 Revised: 16 July 2024 Accepted: 10 August 2024)

KEYWORDS

Condylar volume

Condylar surface area

Skeletal Class I

Anterior open bite

CBCT

ABSTRACT:

Introduction: As the mandibular condyle plays a crucial role in the development of the cranio-facial complex, evaluation of the condylar volume and surface area is important for a comprehensive understanding about cranio-facial development. Thus, the aim of the study was to evaluate the condylar volume and surface area in subjects having skeletal Class I with anterior open bite using Cone-Beam Computed Tomography (CBCT).

Objectives: the aim of this study was to evaluate and compare mandibular condylar volume and surface area in subjects with skeletal Class I and skeletal Class I with an anterior open bite using CBCT imaging techniques.

Methods: Thirty-eight CBCT scans were obtained, including 19 subjects with skeletal Class I malocclusion and 19 subjects with skeletal Class I malocclusion and anterior open bite. Selection criteria were based on the ANB angle, N-ANS linear measurement, and mandibular plane angle. The TMJ on both the right and left sides of each subject was evaluated independently using CBCT scans. Evaluation parameters included condylar volume and condylar surface area, analyzed using 3D Slicer 5.2.1 software. Parametric tests were employed to compare condylar volume and surface area between the two groups.

Results: Subjects with skeletal Class I malocclusion exhibited significantly higher condylar volume and surface area compared to those with skeletal Class I malocclusion and anterior open bite. Males within both groups demonstrated significantly higher right condylar volume compared to females. In skeletal Class I malocclusion with anterior open bite, males showed significantly higher left condylar volume and surface area compared to females.

Conclusions: Individuals with skeletal Class I malocclusion displayed greater condylar volume and surface area compared to those with skeletal Class I malocclusion and anterior open bite. Males generally exhibited higher condylar volume and surface area than females, particularly in specific conditions like skeletal Class I malocclusion with anterior open bite.

1. Introduction

The condyle is a crucial site of growth in the mandible, and its ultimate shape and volume are linked to the relationship between the maxillary and mandibular bases.[1,2,3] Growth of the condyle contributes not only to the increasing size of the mandible but also to the forward and downward displacement of the mandible.[4] Anatomical knowledge of the mandibular condyle is essential in clinical practice in orthodontics. Since the condyle is regarded as the primary growth center of the mandible, the amount of vertical growth of the condyle must correspond to the vertical dentoalveolar growth, or else it could lead to mandibular rotation, subsequently affecting the vertical skeletal relationship. As the mandibular condyle plays a predominant role in the development of the craniofacial complex, evaluation of the condylar volume and surface area is important for a

Journal of Chemical Health Risks

www.jchr.org

JCHR (2024) 14(5), 1685-1692 | ISSN:2251-6727

comprehensive understanding of craniofacial development.[2]

The use of cone-beam computed tomography (CBCT) has become an important milestone in imaging processes in orthodontics, aiding in the complete assessment and diagnosis of various structures three-dimensionally. Since dentofacial structures change three-dimensionally during growth and treatment processes, evaluating all these structures through CBCT provides an accurate measure of those changes. In a study conducted by Gribel et al.[5], it was suggested that CBCT measurements were as accurate as direct craniometric measurements taken on dry skull specimens. Since CBCT is considered one of the most comprehensive imaging modalities for bone imaging, it is used for detecting changes in condylar morphology.

Previous literature suggests that condylar volume and surface area differ among genders[7,9], skeletal classes[6,7,8,9], and growth patterns[6,8] of individuals. However, to date, there are no studies on how condylar volume and surface area differ between skeletal Class I and skeletal Class I with an anterior open bite using CBCT.

Objectives

The aim of this study was to evaluate and compare mandibular condylar volume and surface area in subjects with skeletal Class I and skeletal Class I with an anterior open bite using CBCT imaging techniques.

2. Methods

Sample Collection:

The study protocol was approved by the ethics review committee. This cross-sectional study was conducted on full-skull Cone Beam Computed Tomography (CBCT) scans. Patients visiting the department for a general dental check-up and meeting the inclusion criteria were selected for the study.

The inclusion criteria for patients were:

a. Males and females between 15 and 30 years of age.

b. Skeletal Class I and Skeletal Class I with anterior open bite cases.

c. Patients without TMD.

The exclusion criteria for patients were:

a. Any pathology or developmental anomalies.

b. Orthodontically treated cases.

c. Any history of trauma.

d. Patients with unilateral or bilateral posterior crossbite (skeletal/dental).

The patient sample consisted of two groups (Table 1). Informed consent was obtained from the selected patients. CBCT scans of the 38 patients were taken in their natural head position, and all scans were performed using the same machine and Carestream software (Carestream 9300), with parameters of 6.3 mA, 90 kvp, 300 microns resolution, with a full field of view (FOV) of 17x13.5 cms, and an exposure time of 11.30 secs, to eliminate bias.

Skeletal Class I subjects with ANB angle 2^o- 4^o	19 subjects
Skeletal Class I with anterior open bite subjects with Nasion- Anterior nasal spine length (N-ANS) < 47mm and mandibular plane angle > 37^0, skeletal open bite cases have short N-ANS length and high mandibular plane angle	19 subjects

Table 1: The patient sample consisted of two groups.

The 38 CBCT scans of left and right TMJs were independently evaluated for each patient. TMJ evaluation included:

a. Calculation of condylar volume using 3D Slicer software (version 5.2.1).

b. Calculation of condylar surface area using 3D Slicer software (version 5.2.1).

Software used: 3D Slicer 5.2.1 - A software application for visualization and analysis of medical image computing datasets, which includes segmentation, registration, and various quantifications of CT/MRI images.

Journal of Chemical Health Risks

www.jchr.org

JCHR (2024) 14(5), 1685-1692 | ISSN:2251-6727

Volume and Surface Area Calculation:

Full skull CBCT scans were obtained using Carestream software. The segmentation of the mandibular condyle was based on 3D Digital Imaging and Communications in Medicine (DICOM), created with CT dataset, using the software 3D Slicer 5.2.1. Mandibular Condyle CT datasets were segmented with a dedicated 3D Slicer tool to construct a mask, which included the full skull as shown in Figure 1.

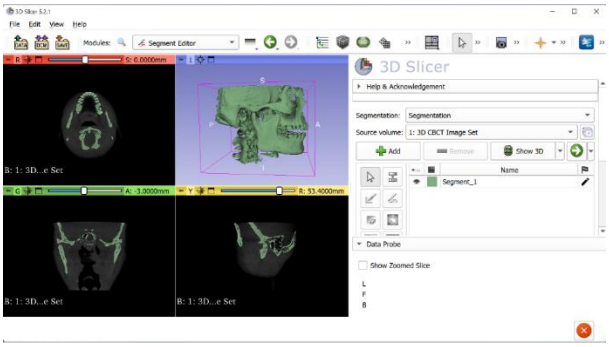

Figure 1: Mask obtained from 3D slicer

The Frankfort horizontal (FH) plane was constructed from the inferior orbital rim to the superior border of the external auditory meatus on the 3D model. An initial cut was made parallel to the FH plane just above the superior aspect of the condyle as shown in Figure 2.

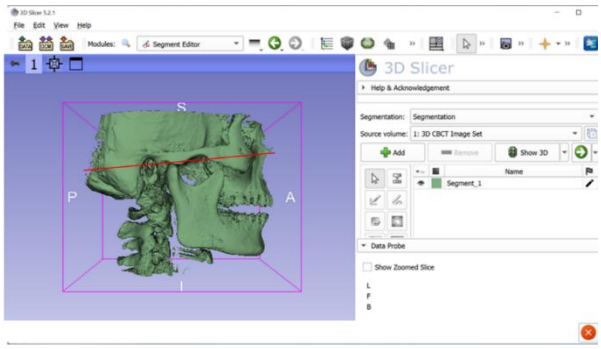

Figure 2: **Frankfort horizontal (FH) plane constructed on 3D model obtained from 3D slicer.**

Then the upper, lower, and lateral walls of the condyle along with the mandible were cropped out from the full skull using various cropping tools in the 3D slicer software as shown in Figure 3.

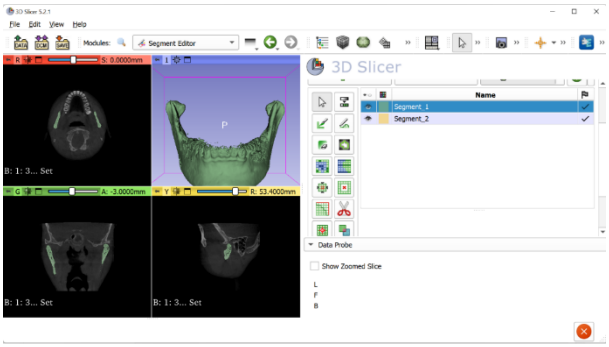

Figure 3: 3D model of the mandible obtained after cropping.

The condyle was enlarged. The cuts were made on the coronal views; the upper, the lower, and the side limits of the condyle were standardized as shown in Figure 4.

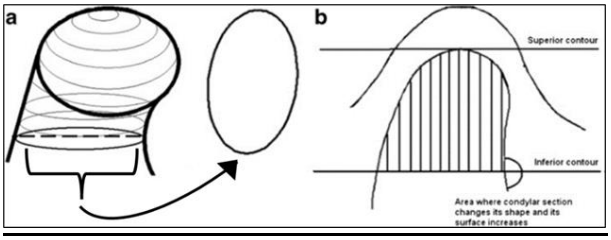

Figure 4: (a) Scheme of condyle; (b) Upper and lower limits of condyle.

Contours of the side walls of the condyle were defined by considering the density of cortical bone. The upper limit of the condyle was defined where the first radiopaque area was viewed in the area of synovia, then for the lower sections, for each section, the condyle was isolated through the visualization of cortical bone. The lower limit of condyle was traced when the section left the ellipsoidal shape (due to the presence of the anterior crest) and became circular (suggesting the level of the condylar neck) as shown in Figure 4.

After the isolation, using a 3D Slicer segment statistics module which is a quantification tool, where the values are computed from the binary label map representation of the segment, was used to obtain automatic volumetric and surface area measurements for each condyle (left and right side) as shown in Figure 5.

Journal of Chemical Health Risks

www.jchr.org

JCHR (2024) 14(5), 1685-1692 | ISSN:2251-6727

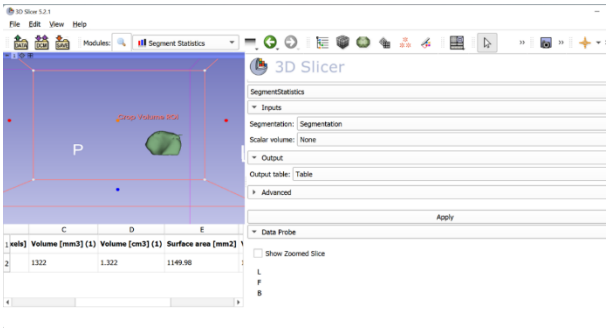

Figure 5: Volumetric and surface area measurements obtained for each condyle using segment statics module.

The condylar volume and surface area of all 38 samples (19 skeletal Class I & 19 Skeletal Class I with anterior open bite) were delineated and evaluated. The values were rechecked to ensure consistency among readings by the same observer at intervals of one week. The values obtained for condylar volume and surface area were assessed, tabulated, and statistical analysis was carried out.

Statistical analysis

The Statistical software SPSS 19.0 was used for the analysis of the data and Microsoft Word and Excel was used to generate graphs and tables. Descriptive and Inferential statistical analyses has been carried out in the present study. Results on continuous measurements are presented as the mean and standard deviation. Un paired t-tests and paired t-tests were applied to compare mean of different variables across groups.

3. Results

Among the 38 samples, the mean condylar volume and surface area of skeletal Class I subjects were found to be significantly higher when compared to the mean condylar volume and surface area of skeletal Class I with anterior open bite subjects ($p < 0.0001$), as shown in Table 2.

When the right and left condylar volumes were compared between males and females, it was found that the right condylar volume was significantly higher in males for both skeletal Class I and skeletal Class I with anterior open bite subjects ($p < 0.0001$), whereas the left condylar volume of males was significantly higher in skeletal Class I with anterior open bite subjects, as shown in Table 3.

When the right and left condylar surface areas were compared between males and females, it was found that the left condylar surface area was significantly higher in males having skeletal Class I with anterior open bite ($p < 0.0001$). No statistically significant difference was found when the left condylar volume was compared between skeletal Class I males and females. In addition, no statistically significant difference was found when the mean right condylar surface area was compared between males and females in both skeletal Class I and skeletal Class I with anterior open bite patterns.

		N	MEAN	SD	T	P
Mean condylar volume (right and left side)	Skeletal Class I	19	1383.7	127.9	7.7	0.0001
	Skeletal Class I with anterior open bite	19	1056.8	132.4		
Mean condylar surface area	Skeletal Class I	19	1003.02	69.1	8.5	0.0001
	Skeletal Class I with anterior open bite	19	805.5	73.4		

Table 2: Comparison of mean condylar volume and surface area between skeletal Class I and skeletal Class I with anterior open bite.

Journal of Chemical Health Risks

www.jchr.org

JCHR (2024) 14(5), 1685-1692 | ISSN:2251-6727

			N	MEAN	SD	T	P
Right condylar volume	Skeletal Class I	Male	11	1459.1	72	4.3	0.0001
		female	8	1278.4	108.4		
	Skeletal Class I with anterior open bite	Male	8	1203.8	149.8	4.6	0.0001
		female	11	961.8	72.14		
Left condylar volume	Skeletal Class I	Male	11	1419.3	130.3	1.6	0.1
		Female	8	1336.1	211.5		
	Skeletal Class I with anterior open bite	Male	8	1148.1	151.9	3.57	0.0001*
		Female	11	978.4	40.9		
Right condylar surface area	Skeletal Class I	Male	11	1048.4	64.09	1.8	0.04*
		Female	8	987.8	79.16		
	Skeletal Class I with anterior open bite	Male	8	847.9	65.57	0.5	0.2
		Female	11	779.2	111.03		
		Male	11	992.07	82.55		

Journal of Chemical Health Risks
www.jchr.org
JCHR (2024) 14(5), 1685-1692 | ISSN:2251-6727

Left condylar surface area	Skeletal Class I	Female	8	970.8	83.71	0.5	0.2
	Skeletal Class I with anterior open bite	Male	8	862.6	65.58	3.5	0.0001*
		Female	11	759.4	61.29		

Table 3: Comparison of right and left condylar volume and surface area between males and females in skeletal Class I and skeletal Class I with anterior open bite

4. Discussion

Facial growth tends to proceed along a vector composed of variable amounts of transverse, horizontal and vertical growth, as an outcome of osseous development at facial sutures, mandibular condyles, alveolar processes, and tooth eruption. As the mandible articulates with the cranium, it is important that consistent growth is achieved between anterior and posterior facial heights or excessive clockwise or counter-clockwise rotation of the mandible might occur. Malocclusions with extreme growth patterns are not only challenging for an orthodontist to treat, but can also have a profound functional, aesthetic, and psychological effect on an individual. This has led to a pursuit to discover and understand the relationship between the craniofacial growth pattern and the dentofacial morphologic characteristics.11 Therefore, the purpose of the current study was to evaluate the condylar volume and surface area in skeletal Class I and skeletal Class I with anterior open bite individuals and compare the two groups.

Sexual dimorphism

When condylar volume and surface area was compared between males and females in both the groups, it was found that both condylar volume and surface area of males were higher than in females for both skeletal Class I and skeletal Class I with anterior open bite patterns. The present study was in accordance with study conducted by Tecco et al3, where they determined the condylar volume and surface area in young adult Caucasians through CBCT images and found that males had both a higher condylar volume and surface area compared to females and condylar volume and surface area of the right TMJ was higher compared to the left side. It was also in accordance with the study conducted by Al-koshab et al[1], where they conducted a retrospective study to determine the morphology and variations of the mandibular condyle and glenoid fossa. They concluded that mean condylar volume of the right TMJ was significantly higher compared to the left TMJ and males exhibited a larger condylar volume and size than females.

Differences related to skeletal Class I with and without anterior open bite

Open bite patients are considered to have a hyperdivergent growth pattern where the mandible is rotated in a clockwise direction. In the current study we found that subjects with a skeletal Class I with anterior open bite pattern had a lower condylar volume and surface area compared to skeletal Class I subjects. The present study was in accordance with the study conducted by Santander et al6, where they investigated the condylar volume by evaluating linear and angular measurements in the transverse, sagittal, and vertical dimensions in an adult population and concluded that vertically hyperdivergent subjects had smaller condyles with higher anteroposterior inclination angles than those of hypodivergent subjects. Our study was also in accordance with the study conducted by Saccucci et al.[2], Mostafavi et al.[7], and Hasebe et al.[8], where they concluded that the condylar volume and surface area was less in subjects with high mandibular plane angles when

Journal of Chemical Health Risks

www.jchr.org

JCHR (2024) 14(5), 1685-1692 | ISSN:2251-6727

compared to average and low mandibular plane angle subjects.

A study conducted by Park et al[12] on condylar position and morphology among different vertical skeletal patterns suggested that the hyperdivergent group had round shaped condyles, whereas the hypodivergent group usually had oval shaped condyles. Subjects with hyperdivergent facial morphology were associated with smaller antero-posterior and medio-lateral condyle widths as well as narrower condyle head angle, which was in accordance with the current study where lesser condylar volume was found in the skeletal Class I with anterior open bite group compared to skeletal Class I group.

One of the possible reasons for the condylar volume and surface area of skeletal Class I with anterior open bite to be lower compared to the skeletal Class I group is due to the difference in the occlusal forces. Occlusal force is one of the important factors influencing maxillomandibular development.[13] Clinically, it has been observed that weaker masticatory muscular force during the growth periods results in a skeletal pattern with larger mandibular plane, occlusal plane, and gonial angles with a short ramus, which corresponds to a hyperdivergent growth pattern.[13] The mandible is rotated downwards away from the rest of the facial skeleton, resulting in an increased anterior facial height, a posterior growth rotation of the mandible, excessive eruption of the posterior teeth and narrowing of the maxillary arch leading to anterior open bite.[14] It is also found that patients with an excessive lower vertical facial height and anterior open bite have weak muscular activity.

Hence, TMJs with large condyles are more resistant to displacement because of the tight fit of the fossa and condyle and they provide stable support for occlusal changes. Whereas, small condyles are easily displaced because of the condyle, fossa and capsule relationship and provide unreliable support for occlusal changes.[15]

Limitation of the study

Due to the limited incidence of patients with skeletal Class I with anterior open bite patterns the study was limited by a small sample size. It is suggested that further studies be directed to evaluate a larger sample size having skeletal Class I with anterior open bite.

Conclusion:

The following were the conclusions of the study:

•Mean condylar volume and surface area of subjects with skeletal Class I was found to be higher when compared to the condylar volume and surface area of skeletal Class I with anterior open bite subjects.

•Right condylar volume was higher in males for both skeletal Class I and skeletal Class I with anterior open bite subjects.

•Both the left condylar volume and surface area of males were higher in skeletal Class I with anterior open bite subjects.

These findings contribute to understanding craniofacial development and its implications for treatment planning in orthodontics, particularly in cases involving skeletal Class I malocclusion and anterior open bite.

References:

1. Al-koshab M, Nambiar P, John J. Assessment of condyle and glenoid fossa morphology using CBCT in South-East Asians. PloS one. 2015 Mar 24;10(3):e0121682.
2. Saccucci M, Polimeni A, Festa F, Tecco S. Do skeletal cephalometric characteristics correlate with condylar volume, surface and shape? A 3D analysis. Head & Face Medicine. 2012 Dec;8:1-8.
3. Tecco S, Saccucci M, Nucera R, Polimeni A, Pagnoni M, Cordasco G, Festa F, Iannetti G. Condylar volume and surface in Caucasian young adult subjects. BMC Medical Imaging. 2010 Dec;10:1-0.
4. Mizoguchi I, Toriya N, Nakao Y. Growth of the mandible and biological characteristics of the mandibular condylar cartilage. Japanese Dental Science Review. 2013 Nov 1;49(4):139-50.
5. Gribel BF, Gribel MN, Frazão DC, McNamara Jr JA, Manzi FR. Accuracy and reliability of craniometric measurements on lateral cephalometry and 3D measurements on CBCT scans. Angle Orthodontist. 2011 Jan;81(1):26-35.
6. Santander P, Quast A, Olbrisch C, Rose M, Moser N, Schliephake H, Meyer-Marcotty P. Comprehensive 3D analysis of condylar morphology in adults with different skeletal patterns–a cross-sectional study. Head & Face Medicine. 2020 Dec;16(1):1-0.

Journal of Chemical Health Risks

www.jchr.org

JCHR (2024) 14(5), 1685-1692 | ISSN:2251-6727

7. Mostafavi M, Vahdat AS, Javadian L, Ghaznavi A. Analysis of condylar volume in relation to craniofacial morphology using cone beam computed tomography. J Contemp Med Sci. 2018;4:202-6.
8. Hasebe A, Yamaguchi T, Nakawaki T, Hikita Y, Katayama K, Maki K. Comparison of condylar size among different anteroposterior and vertical skeletal patterns using cone-beam computed tomography. Angle Orthodontist. 2019 Mar;89(2):306-11.
9. Saccucci M, D'Attilio M, Rodolfino D, Festa F, Polimeni A, Tecco S. Condylar volume and condylar area in class I, class II and class III young adult subjects. Head & Face Medicine. 2012 Dec;8(1):1-8.
10. Fedorov A., Beichel R., Kalpathy-Cramer J., Finet J., Fillion-Robin J-C., Pujol S., Bauer C., Jennings D., Fennessy F.M., Sonka M., Buatti J., Aylward S.R., Miller J.V., Pieper S., Kikinis R. 3D Slicer as an Image Computing Platform for the Quantitative Imaging Network. Magnetic Resonance Imaging. 2012 Nov;30(9):1323-41.
11. Burke G, Major P, Glover K, Prasad N. Correlations between condylar characteristics and facial morphology in Class II preadolescent patients. American Journal of Orthodontics and Dentofacial Orthopedics. 1998 Sep 1;114(3):328-36.
12. Park IY, Kim JH, Park YH. Three-dimensional cone-beam computed tomography based comparison of condylar position and morphology according to the vertical skeletal pattern. Korean Journal of Orthodontics. 2015 Mar 1;45(2):66-73.
13. Kurusu A, Horiuchi M, Soma K. Relationship between occlusal force and mandibular condyle morphology: evaluated by limited cone-beam computed tomography. Angle Orthodontist. 2009 Nov;79(6):1063-9.
14. Burford D, Noar JH. The causes, diagnosis and treatment of anterior open bite. Dental Update. 2003 Jun 2;30(5):235-41.
15. Noh KJ, Baik HS, Han SS, Jang W, Choi YJ. Differences in mandibular condyle and glenoid fossa morphology in relation to vertical and sagittal skeletal patterns: A cone-beam computed tomography study. Korean Journal of Orthodontics. 2021 Mar 25;51(2):126-34.