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Tc99m-MDP SPECT-CT bone scintigraphy in the diagnosis of unilateral condylar hyperplasia

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ABSTRACT

Background: Condylar hyperplasia (CH) is excessive growth of either mandibular condyle leading to facial asymmetry. The aim of this study was to access the condylar growth by ^{99m}Tc-methylene-diphosphonate (MDP) single photon emission computed tomography (SPECT)-computed tomography (CT) bone scan, and compared the results with age matched control groups.

Methods: 57 patients aged 10-30 years were enrolled, 26/57 were diseased with CH, and 31/57 belonged to the control group. Both groups were divided into group A (10-20 years) and group B (21-30 years). All underwent ^{99m}Tc-MDP SPECT-CT bone scan of the head region. The condyle to L4 vertebra ratio on planer and condyle to clivus ratio on summed SPECT images were measured. The mandibular deviation was measured in the diseased group on the coronal view of 3D CT reconstruction image of the head.

Results: Both SPECT and planer parameters classified 17/26 patients as active CH. The mean condyle to clivus ratio and condyle to L4 vertebra ratio of active condyles is higher than control group, (p = <0.005). The mean condyle to L4 ratio and condyle to clivus ratio among the control group A and B showed significant differences among age decade groups (p-value <0.05) with moderate negative correlation with age. The amount of mandibular deviation among the active and inactive cases showed no significant difference.

Conclusion: Both planer and SPECT images showed comparable results with higher mean condylar ratios in active cases compared to age-matched control groups. The condylar ratios decrease with increasing age in the control group, and are found to be significantly different among two age decade groups. The amount of mandibular deviation is not predictive of active or inactive cases of CH.

Keywords: Condylar hyperplasia, bone scan, SPECT-CT, condyle to clivus ratio.

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Introduction

Condylar hyperplasia (CH) is a rare non-neoplastic idiopathic jaw condition, characterized by excessive growth of mandibular condyle which leads to facial asymmetry, mandibular deviation, malocclusion, and articular dysfunction [1,2]. Among all the patients evaluated for facial asymmetry, approximately 30% presented active CH [3]. CH is most common in 11-30 years of age and affects men and women equally [4] with female predominance in some studies [5]. There has been a lot of variation amongst populations. Although the etiopathogenesis is unknown, several explanations have been proposed, including trauma, hormone imbalance, infection, arthrosis, hypervascularity, and a possible hereditary component [6]. The most common complaint of CH patients is facial asymmetry and patients frequently present with chin deviation to the opposite side away from the afflicted side [7], however, about one-third of patients reported swelling, discomfort, and dysfunction on the contralateral side [8]. Extraoral and intraoral clinical examination, as well as radiographic and tomographic data, are used to diagnose CH [9]. Plain radiography and panoramic tomography are important, but more thorough anatomical and functional imaging is required for appropriate management. Plain X-ray is a 2D technique and is not much reliable due to superposition of structures and magnification errors resulting from varying distances between the film and the X-ray [10]. Computed tomography (CT) scans can be reconstructed into 3-dimensional pictures and give extensive anatomical information, thereby helpful in differentiating unilateral CHs from other causes of facial asymmetry [11]. It, on the other hand, is unable to discern between active and inactive condyles. Soft tissue abnormalities in the region of temporomandibular joint (TMJ) are best evaluated using magnetic resonance imaging (MRI), however the MRI cannot depict growth activity in hyperplastic condyle [12]. Planar bone scintigraphy and single photon emission computed tomography (SPECT) employing 99mTc methylene-diphosphonate (MDP) provides a quicker way to compare the activity differences between normal and pathological condyles, which indicates the relative growth rates at the time of the examination.

Increased radionuclide uptake in the hyperplastic condylar region, can constitute an evidence of continued abnormal growth and assist in management by making appropriate decisions [13,14]. SPECT/CT may be utilized to assess the active and inactive states of the CH as well as the underlying bone alterations to confirm degenerative changes and rule out other plausible causes of higher uptake, such as a tumour or trauma through its CT component. The variability in normal right and left mandibular condyle uptake is less than 10% as observed in various studies done on normal population undergoing skeletal scintigraphy for a range of diseases. The difference of 10% or more in bilateral condylar uptake is considered indicative of active hyperplasia, according to previous clinical data [15]. Mandibular asymmetry is mostly treated surgically, with or without orthodontics, and involves two types of interventions, depending on condylar activity. During the active phase of CH, a high condylectomy on the afflicted side is recommended to prevent increasing asymmetry. To rectify any remaining occlusal and facial asymmetry, secondary treatment with mandibular or maxillary osteotomies or both (orthognathic surgery) is recommended. If orthognathic surgery is performed while condylar activity continues, more asymmetry may emerge. As a result, a precise assessment of the condyle's cessation of growth activity is required [16]. Once the hyperplasia is no longer active (due to condylar surgery or the disease's self-limiting course), remaining asymmetry can be rectified using normal orthognathic principles. The goal is to restore a symmetrical and balanced face profile as well as optimal temporomandibular function.

Although there is substantial data supporting the use of bone SPECT for identifying active mandibular CH, some factors have hampered its extensive clinical application. Those include the determination of the relative metabolic activity of one condyle versus the contralateral condyle and unavailability of a solid reference database of normal condylar activity and age-related decline in normal condylar activity [17].

Material and Methods

This study was conducted at the Nuclear Medicine department of Punjab Institute of Nuclear Medicine (PINUM), Faisalabad. Cases of CH presenting at PINUM from 2018 onwards and cases coming for bone scan aged between 10 and 30 years for other pathology were included in this study.

Table 1. *Demographic characteristics of the population.*

Sr. #	Category	Number	Age range (years)	Gender	
				Male	Female
1	Diseased group	26	10-30	14	12
2	Control group	31	10-30	15	16

A total of 57 patients were selected for the study who underwent ^{99m}Tc-MDP bone scan along with SPECT-CT of head region. They were divided into two groups, i.e., the diseased group (n = 26) and the control group (n = 31). The population characteristics of all were shown in Table 1.

Diseased group includes the patients with signs and symptoms, raising the suspicion of unilateral CH and referred from maxillofacial department for categorization of active and inactive CH. All patients having history of trauma or surgical intervention of mandible were excluded from the study. Control group consist of patients who underwent ^{99m}Tc- MDP bone scan for other indications, and have no previous history of growth or developmental abnormality, or any pathological condition or surgery involving the maxillofacial region.

The control group was further subdivided into two subgroups in order to create age matched controls, i.e., control group A (10-20 years) and control group B (21-30 years). All the bone scans were evaluated using two different quantitative parameters for classifying the patients as active and inactive CH, i.e., Condyle to L4 vertebra ratio on planner scan and condyle to clivus ratio on SPECT-CT images.

For the calculation of condylar to L4 vertebra uptake ratio on planner scan, Fixed-size regions of interest were drawn around each mandibular condyle, identified as a localized area of prominent uptake on right and left anterior oblique views of head and neck region in hyperextended neck position. To ensure that the left-sided and right-sided region of interest (ROI) were of comparable size, the ROI was copied to the contralateral condylar region. The average counts of L4 vertebra were calculated by drawing rectangular ROI over L4 vertebra and a background ROI in the adjoining abdominal area. The ROIs drawn on bone scan were shown in Figure 1. The condylar to L4 vertebra uptake ratio of each condyle was then calculated using equation 1 and the relative percent uptake was then calculated form the uptake ratio obtained.

$$\text{Condyle to L4 vertebra uptake ratio} = \frac{\text{Condyle ROI counts - Background}}{\text{L4 ROI counts - Background}} \tag{1}$$

For the calculation of Condyle to clivus ratio, the SPECT study was evaluated by reconstructing the SPECT data into axial, coronal, and sagittal planes and summing up the relevant transaxial images. Fixed-size regions of interest were drawn on summated images around each mandibular condyle, which was identified as a localized area of prominent uptake.

The quantitative analysis was done using clivus. The clivus was selected for internal validation because this bony structure is within the field of view containing the condyles and could be identified easily on the ^{99m}Tc-MDP SPECT slices. The ROIs drawn on composite image were shown in Figure 2 and condyle to clivus ratio was calculated using equation 2. All images were evaluated independently and the relative percent uptake was then calculated from the uptake ratio obtained.

$$\text{Condylar to clivus ratio} = \frac{\text{Average condylar counts}}{\text{Average Clivus counts}} \quad (2)$$

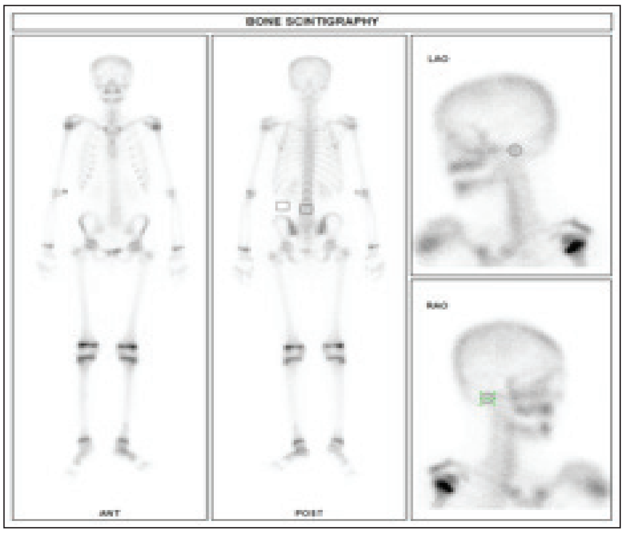


Figure 1. *ROIs were drawn on bone scan, over both condyles, L4 vertebra and background for the calculation of condyle to L4 vertebra uptake ratio.*

Diagnosis of active CH was based on the difference of condylar uptake parameters calculated on both planner and ^{99m}Tc MDP SPECT-CT scintigraphy.

On planner images, the condyles were classified as active if the ≥10% difference was observed in the values of condylar to L4 vertebra uptake ratio, with increased uptake in the hyperplastic condyle.

On SPECT/CT, the condyles were classified as active if there was more than a 10% difference in condylar to clivus uptake ratio along with enlargement of condyle with sclerosis and ground glassy haziness on CT images. However, if CT showed fracture, tumor, or sclerosis of the TMJ, it was considered negative even in the presence of increased uptake.

The Mann-Whitney test was used to evaluate the differences in the ratio between CH and age matched control groups. Pearson correlation was done to establish the correlation between age and condylar ratios calculated on planner and summed SPECT images. IBM SPSS version 26 is used for statistical analysis.

Results

Bone scan analysis in the diseased group showed that both SPECT and planner parameters classified 17 out of 26 patients as active CH. The difference of mean percentage uptake among the active condyles is 18.78% ± 7.8% on Planner and 19.14% ± 6.36% on SPECT images and among the inactive condyles is 4.57% ± 3.18% on Planner and 3.46% ± 2.66% on SPECT images.

The difference of mean percentage uptake of both condyles on planner images in the first age decade (10-20 years) of control group A is 4.33% ± 2.64% and among the second age decade (21-30 years) of control group B is 4.24% ± 3.01%. The mean of difference in percentage uptake on SPECT images among the first age decade (10-20 years) of control group A is 2.26% ± 2.17% and 5.35% ± 2.47% among the second age decade (21-30 years) of control group B.

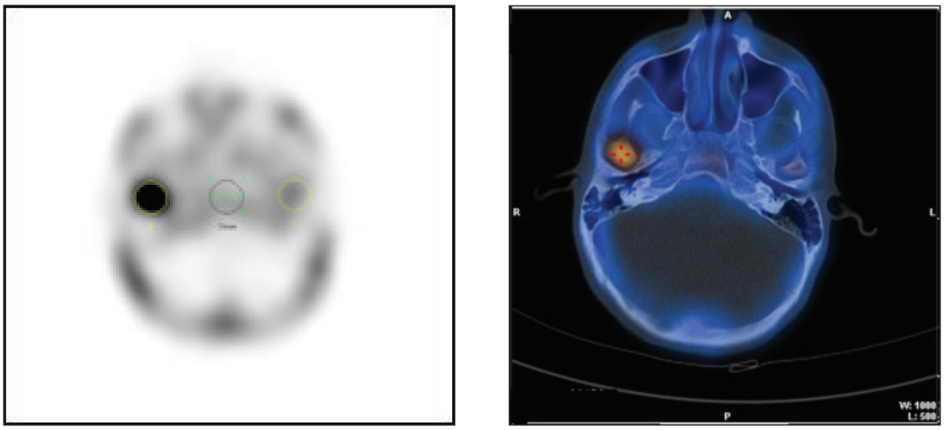
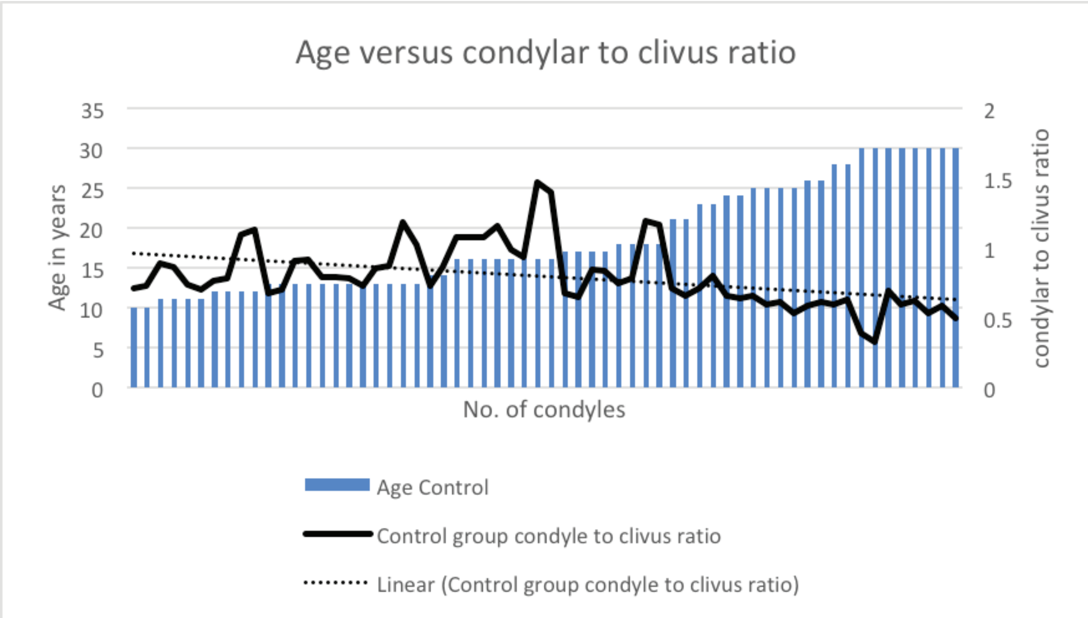


Figure 2. *ROI on the condyles and clivus (central ROI) on summed SPECT image (left) along with SPECT-CT image (right).*

Table 2. *Mean ratios among two age decades of control group.*

Sr #	Age groups	10-20 years	21-30 years	*p*-value
1	Condyle to clivus ratio			
	Mean ± S.D	0.905 ± 0.202	0.599 + 0.103	<0.0001
	Range	(0.643-1.473)	(0.328-0.8)	
2	Condyle to L4 vertebra ratio			
	Mean ± S.D	0.435 ± 0.190	0.248 + 0.120	0.00023
	Range	(0.151-0.989)	(0.1-0.516)	

The mean condyle to clivus ratio is 0.905 ± 0.202 (range: 0.643-1.473) among the control group A and 0.599 ± 0.103 (range: 0.328-0.8) among the control group B. The mean condyle to L4 ratio in control group A is 0.435 ± 0.190 (range: 0.151-0.989) and in control group B is 0.248 ± 0.120 (range: 0.1-0.516). The difference among the mean values of condyle to clivus and condyle to L4 vertebra ratio, is statistically significant ($p < 0.001$) in both age decades of control group, as shown in Table 2.



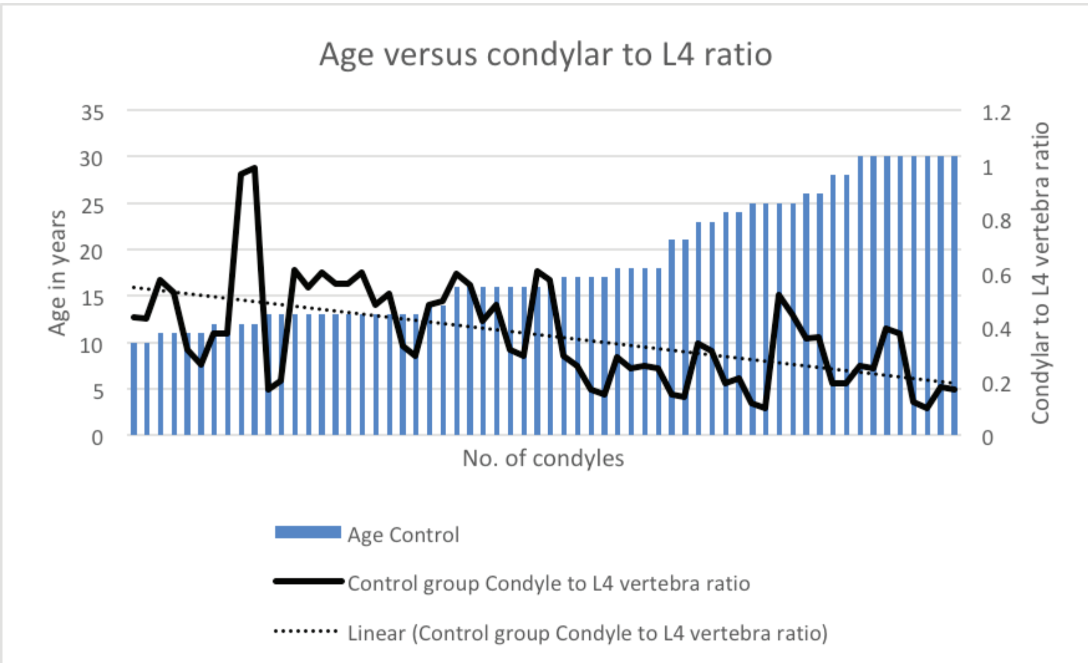


Figure 3. *(a) Distribution of condylar to clivus uptake ratios with increasing age among the control group. (b) Distribution of condylar to L4 vertebra uptake ratios with increasing age among the control group.*

A moderate negative correlation was found between the age and Condylar to L4 vertebra ratios (r = -0.522, $p < 0.05$) and between age and condylar to clivus ratio (r = -0.570, $p < 0.05$).

The graphical representation of the age versus condylar to clivus and condyle to L4 vertebra ratios showed a trend of decreasing uptake ratios, with increasing age among the control group, as shown in Figure 3a and b, respectively.

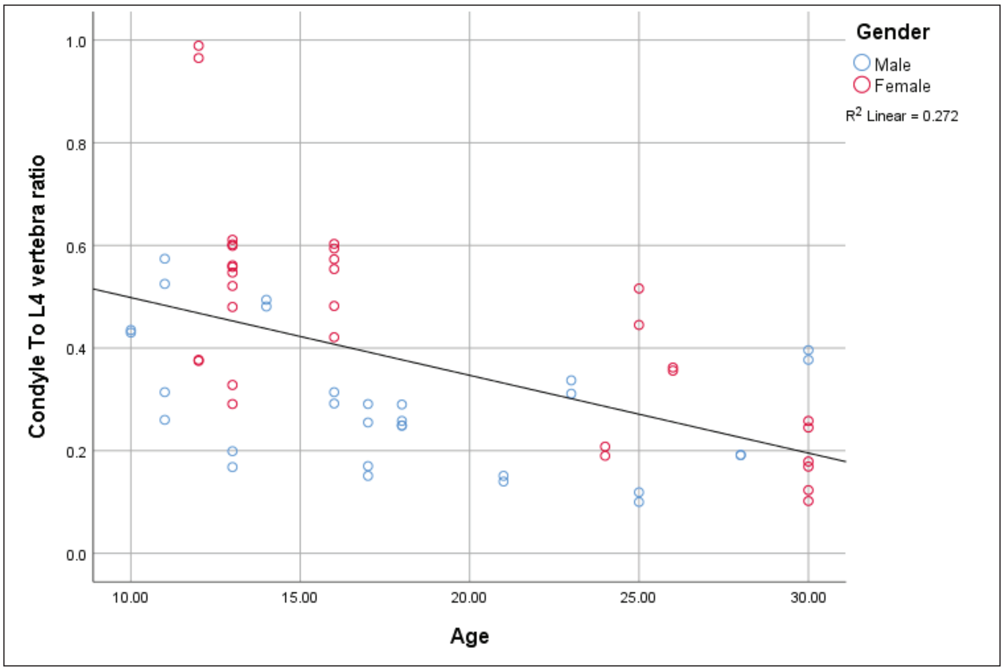
It was found that in condyle-by-condyle analysis in the control group (n = 62), males have low condylar to clivus and condylar to L4 vertebra ratio compared to females of the same age. It also showed a decreasing trend in both ratios with increasing age among the control group in both male and female populations, as shown in Figure 4a and b.

The quantitative parameters of condyles of the control group (n = 62) and in the diseased group (n = 52) were analyzed were summarized in Table 3.

It was found that the difference of both ratios between the control and those having active CH was found to be statistically significant ($p < 0.01$).

Median condyle to L4 ratio values and condyle to clivus ratio values in the control group and active CH patients are shown in Figure 5a and b, respectively.

Mandibular deviation analysis was done by obtaining the measurements on 3D bone tissue reconstruction CT



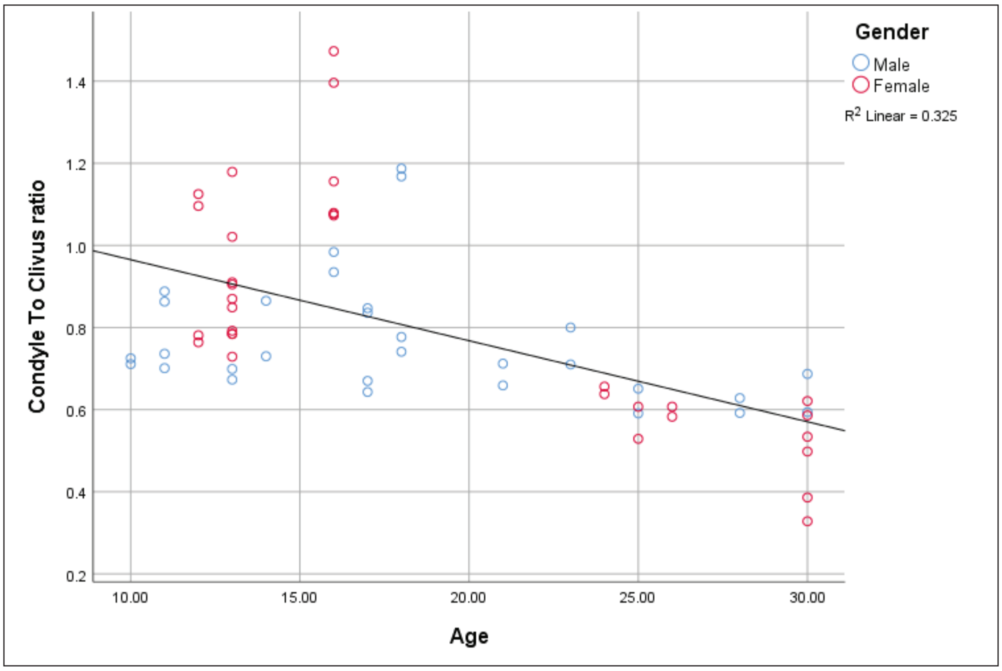
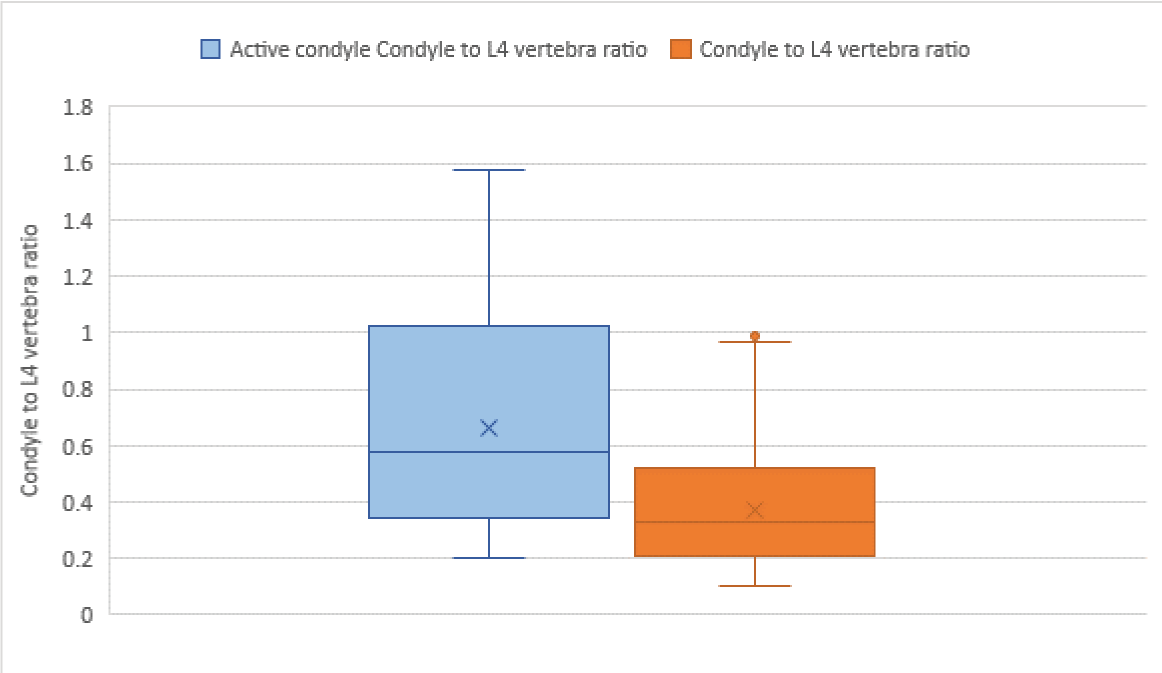


Figure 4. *(a) Normal condyle to L4 vertebra ratio, adjusted for sex and age. (b) Normal condyle to clivus ratio values, adjusted for sex and age.*

Table 3. Condylar ratios for control group and patients with active and inactive CH.

Sr #	Study group	Parameters	Condyle to clivus ratio	Condyle to L4 vertebra ratio
1	Disease group with active CH (*n* = 17)	Mean ± SD	1.026 ± 0.367	0.665 ± 0.392
		Median (range)	0.918 (0.608-1.94)	0.576 (0.202-1.576)
		CV %	35.77783	59.02905
2	Disease group with inactive CH (*n* = 18)	Mean ± SD	0.982 ± 0.421	0.325 ± 0.210
		Median (range)	0.745 (0.596-2.061)	0.3055 (0.065-0.761)
		CV %	42.89007	64.7906
3	Control group (*n* = 62)	Mean ± SD	0.797 ± 0.227	0.369 ± 0.190
		Median (range)	0.738 (0.328-1.473)	0.3325 (0.1-0.989)
		CV %	28.5244	51.69297



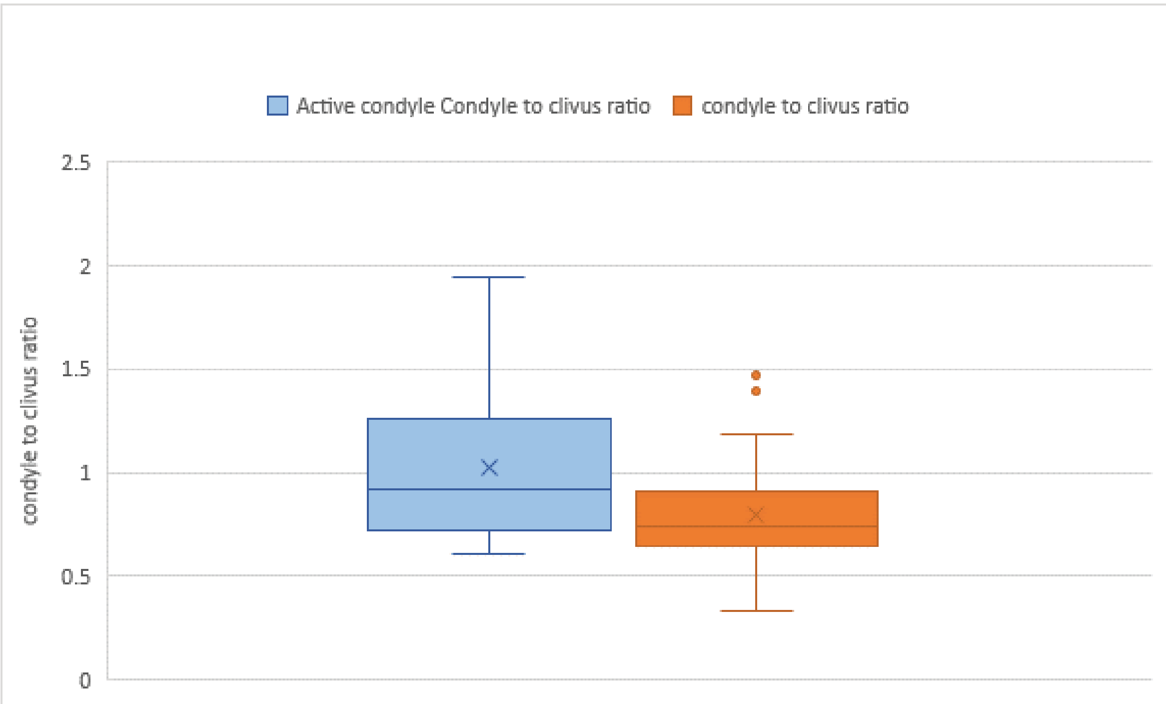


Figure 5. *(a) Median condyle to L4 ratio values in control group and active CH patients. (b) Median condyle to clivus ratio values in control group and active CH patients.*

images of the diseased patients to determine its relation with the active or inactive state of unilateral CH. The results showed no statistically significant difference in the amount of mandibular deviation, which was 20.56 ± 15.02 mm in active cases of unilateral CH and 18.26 ± 9.04 mm in inactive cases ($p = 0.96$).

Discussion

We in our study enrolled 26 patients who presented with a suspicion of Unilateral CH (10-30 years age). All of them underwent ^{99m}Tc-MDP bone scan and hybrid SPECT/CT to categorize the patients as having active or inactive CH. We determined condyle to L4 ratio on planner images and condyle to clivus ration on summed SPECT images. We found comparable results of both planner and SPECT scintigraphy as both categorize 17 patients as having active CH and 09 having inactive CH. The results obtained in our study are contrary to the results obtained by Lopez et al. [18] and Agarwal et al. [19] whose study showed that SPECT is more accurate than planner for evaluation of CH. We in our study has calculated the condyle to L4 ratio on the right and left anterior oblique views compared to Lopez et al. [18], who draw ROI on lateral values and also calculated relative uptake values rather than condyle to L4 ratio. We took anterior oblique views of the skull in our study instead of lateral views to minimize the superimposition of counts from overlapping structures.

The mean age of diseased group patients is 19.33 ± 5.88 years (range: 10-30 years), which is consistent with prior studies that unilateral CH mostly affects teens and young adults aged 10-30 years [6,20].

Our study showed a female-to-male ratio of 1:1.16 among the CH patients; however, Lopez et al. [18] and Wen et al. [21] showed contrary results with female dominance, and Hodder et al. [22] showed equal prevalence.

Previous studies have reported a difference in uptake values of less than 10% among the left and right condyles in the normal population [17,23,24]. Similar results were found in our study with a 4.30% mean percentage difference among the condylar ratios in left and right condyle on planner images and 3.36% on SPECT/CT. In both age decades of the control group, the difference between the mean values of condyle to clivus and condyle to L4 vertebra ratio is statistically significant ($p < 0.001$).

The range of condyle to clivus ratio in control group A (10-20 years) was 0.643-1.473 and 0.328-0.8 in control group B (21-30 years). This was comparable with the results of Rodriguez et al. [25] who found the range observed for ratios to the clivus in normal patients for the summed image was 0.30-1.28 in a population aged between 10 and 60 years.

We found a moderate negative correlation between condyle ratios and age among both age-decade groups. It was found that there was a moderate negative correlation, i.e., $r = -0.522$, $p < 0.05$ between age and condylar to L4 ratio and also between age and condylar to Clivus ratio, $r = -0.570$, $p < 0.05$. Cisneros and Kaban [26] also found a perfect correlation between age and condylar uptake ratio. The mean values of condyle to clivus and condyle to L4 vertebra ratio showed statistically significant difference among both age decade control groups (p-value: <0.001) strengthening the fact that that condylar growth activity tends to decrease with age [27].

Our study revealed a pattern of the ratios decreasing continuously with age, with females having much greater values than men. In both genders, the condylar to clivus and condylar to L4 vertebra ratios were calculated and the difference in mean values of both ratios was found to be statistically significant ($p < 0.0001$).

The mean condyle to L4 vertebra ratio and condyle to clivus ratios were analyzed in the control group and disease group with active CH. The difference of ratios between the control group and those with active CH was found to be statistically significant ($p < 0.01$).

Using a two-tailed Mann-Whitney test, statistical analysis of the quantified SPECT data, i.e., Condyle to clivus ratio and quantified planner data, i.e., condyle to L4 vertebra ratio of both diseased and control groups, yields a significant p-value of <0.01 among both age decade groups (i.e., 10-20 and 21-30 years). The results were in accordance with the results of Rodriguez et al. [25].

A comprehensive facial and intraoral clinical examination of the patient, as well as radiographic and/or tomographic pictures, are used to diagnose CH. However, determining therapy choices in individuals who come with CH requires a precise evaluation of growth activity [19]. Clinical workup and radiological investigations alone are not enough to detect the growth activity of CH. A combination of clinical follow-up and bone scintigraphy should be employed to categorize the patients of CH as active and inactive cases [28].

In an attempt to develop an independent method rather than opting for the approach of relative metabolic activity of one condyle versus another, we reported condylar to clivus ratio on summed SPECT images and condyle to L4 vertebra ratio on planner images for 62 normal condyles of patients without CH. We utilized the ROIs over the summed images since they produced the least varied results according to earlier studies [24,29]. A graphical representation model (Figure 3a and b) showing the range of normal values for ratios of condyle to clivus and condyle to L4 vertebra with decreasing trend in both ratios with increasing age should be further validated through longitudinal studies with improved sample size. This decreasing trend with age paved the way towards standardized approach of establishing the absolute values for age decade groups.

Acknowledgment

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List of Abbreviations

CH	Condylar hyperplasia
CT	Computed tomography
MRI	Magnetic resonance imaging
SPECT	Single photon emission computed tomography
MDP	Methylene-diphosphonate
ROI	Region of interest
TMJ	Temporo-mandibular joint

Conflict of interests

None.

Funding

None.

Consent to participate

Written informed consent was obtained from all individuals regarding the publication of this article in a medical journal.

Ethical approval

All procedures performed in this study were in accordance with the ethical standards of the institutional research committee. A formal Ethical approval is not applicable to this kind of study.

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