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ASSESSMENT OF RELATIONSHIP BETWEEN SPHENOOCCIPITAL SYNCHONDROSIS AND CONDYLAR CORTICATION IN CHRONOLOGIC AGE DETERMINATION USING CBCT: A RETROSPECTIVE ANALYSIS

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ABSTRACT:

Background: Age estimation is of prime importance for personal identification during mass disasters and determination of legal age. Although many methods using other body parts are present, the whole body is not always available at the time of postmortem. Hence there is a constant demand for identifying newer methods to accurately determine age. Hence this study aims to evaluate the relationship between chronological age, sphenooccipital synchondrosis fusion and condylar cortication using CBCT.

Methodology: CBCT scans of 75 patients between 10 to 25 years were evaluated. The CBCT images were evaluated in sagittal sections for the fusion status of sphenooccipital synchondrosis using a four stage grading system and fusion status of both condyles using a three stage grading system. Statistical analysis was performed using IBM SPSS software version 16.

Results: In condylar cortication, the smallest mean age (14.73) was seen in type 1 and the largest mean age (21.50) was seen in type 3 which showed a statistically significant difference. However the left and right condyle did not show any difference in cortication. In SOS fusion stages, the mean age of 14.14, 16, 17.84 and 21.26 was found in stage 0, 1, 2 and 3 respectively. There was a steady increase in the stages with age which was highly significant.

Conclusion: There is a strong positive correlation between chronological age, degree of SOS fusion stage and condyle cortication type. Condyle cortication can be used as an efficient alternative if the skull base is not intact at the time of forensic examination.

Keywords: Sphenooccipital synchondrosis, condylar cortication, age determination, CBCT.

INTRODUCTION:

Estimation of age is of extreme importance in the field of forensic and medical sciences for identifiying the unidentified remains during a disaster period. In India, age determination is very crucial due to the increasing cases of child marriages and child labours, especially among the low socioeconomic group where people do not have their birth records often.

Among various methods used in determining the age of the individual, radiological evaluations are convenient, non-invasive and can be repeated many times on living individuals as well as on dead individuals. Radiography was first applied in forensics in 1896 to identify bullets in a victim's head [1]. Age estimation using bones are often employed and reliable, and is investigated by various methods like assessing ossification of hand and wrist bones, epiphysis-diaphysis fusion, closure of various sutures, evaluation of cervical vertebra, femoral head, iliac bone, clavicle, etc [2].

Age estimation using dental structures are very crucial as teeth is an indestructible post-mortem record even after many decades and centuries after an induvidual's death. The mandible and skull which holds the teeth also serves as a very effective tool in estimating the age. Measurement of the gonial angle [3], height of the alveolar ridge, position of the mental foramen, bone mineral density, trabecular pattern are various factors measured for this purpose. In the skull, union of various synchondrosis, sutures, fontanelles and area of skull bones may be calculated.

The spheno-occipital synchondrosis (SOS) is a cartilaginous fusion located between the occipital and sphenoid bones. It majorly contributes to the growth and development of the skull and is also responsible for the upward and forward growth of the maxilla. Previous studies reported the SOS closure completes between 17 and 20 years

in average in both males and females. It has also been established that the closure begins at 8 years and it is slightly earlier in females than in males irrespective of the population [4]. The sphenooccipital synchondrosis which is one among the three midline cranial synchondrosis is a very useful tool in age estimation of unidentified individuals or victims. It is practically not possible to assess its closure using the conventional two dimensional radiography. It can be either evaluated directly in cadavers or using three dimensional (3D) imaging modalities like Computed Tomography (CT) and Cone Beam Computed Tomography (CBCT).

The growth and development of mandible and condylar cortication always goes hand in hand. During the 12th week of intrauterine life secondary cartilage occurs on the osseous surface of the condyle. In the initial phases of life, the condyles are completely devoid of cortication and the condylar surface is rich in vasculature. Around the second decade, cortication begins in the superior pole which progresses to cover the articular surface completely. Until the 3rd decade condylar cartilage is not completely replaced by osseous tissue [5]. Once the cortication completes, the growth of condyle ceases. Thus the ossification of mandibular condyles might be of good use in age estimation of induviduals within the 3rd decade.

CBCT is a technology introduced specifically for volumetric imaging of the head and neck structures. It is widely used in dentistry as it gives three dimensional imaging with minimal distortion and superimposition and also minimizes the risk of higher radiation involved with CT. CBCT is used to study the condylar morphology and many cranial structures mainly due to its efficient 3D imaging capacity. It is of great use for calculation of volume or dimensions of various paranasal sinuses and foramina, for reconstruction of the destroyed area in the skull, for assessing the calcification or closure of sutures, etc. which favours the important three aspects in forensics – age determination, sex determination and personal identification [6].

Chronological age does not always reflect skeletal maturation exactly due to individual variation in growth spurts. According to studies worldwide, SOS fusion stage is an accepted and reliable indicator for the evaluation of growth, developmental pattern and skeletal maturation. But, in India, only a very few studies assessing age with SOS are available. Many more studies with the Indian population assessing the same, are required, in order to find out the differences in fusion pattern among our diverse population belonging to different climatic and environmental conditions.

Similarly a few studies have quoted the ability of age determination with condylar cortication. But only one study to the best of our knowledge have compared the accuracy of sphenooccipital synchondrosis and condylar cortication with respect to age determination. More studies are required to determine its sensitivity and specificity. If condylar cortication proves to have the same accuracy as of SOS, it can be of much use in mass disasters especially when the mandible is the only source of evidence. Therefore our study aimed to evaluate and assess the relationship between chronological age, sphenooccipital synchondrosis fusion and condylar cortication using CBCT.

MATERIALS AND METHODS:

It is a retrospective study where a total of 75 CBCT images were selected belonging to both male and female patients aged between 10 to 25 years. Image selection was performed at random, i.e., regardless of ethnicity, gender or presence/absence of teeth, following the inclusion and exclusion criteria.

The study was performed on CBCT images of patients who underwent pre-operative CBCT imaging for the purpose of third molar extraction, dental implant placement, orthodontic treatment and other surgical treatment planning purposes at a private scan center in Chennai using MyRay Sky View 3D CBCT machine with 9 x 6 inches field of view and thickness slice of 1mm.

Inclusion criteria:

- Full skull CBCT images presenting both the condyles and the Sphenooccipital synchondrosis (SOS) in their field of view.
- CBCT data retrieved from the patient database which were taken for other dental purposes or treatment planning.
- CBCT of patients between 10 – 25 yrs of age

Exclusion criteria:

CBCT data of patients with Temporomandibular joint (TMJ) disorders, patients with any bone mineral metabolism disorder, congenital or developmental craniofacial and skeletal deformities, endocrine system diseases that affect bone metabolism, trauma history, and pathologic situations which affected the area of interest.

- CBCT data of patients above 25 years of age

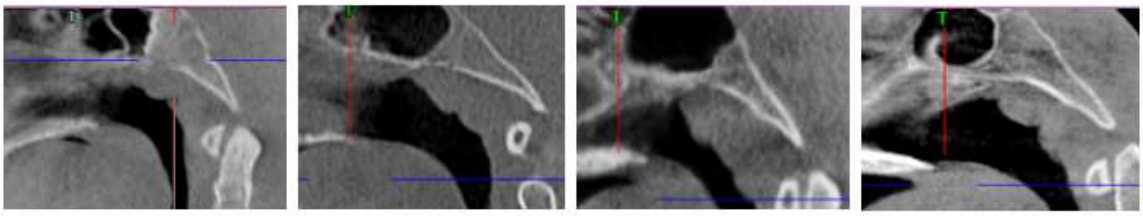
Study procedure:

The selected samples from the CBCT data were stored in an external hard disk. They were then transferred to a Myray software for further processing. The images were reformatted using NNT iRYS viewer software. The NNT iRYS viewer software allows viewing of axial, cross-sectional, Panoramic and 3D visualization of the jaw on the same screen.

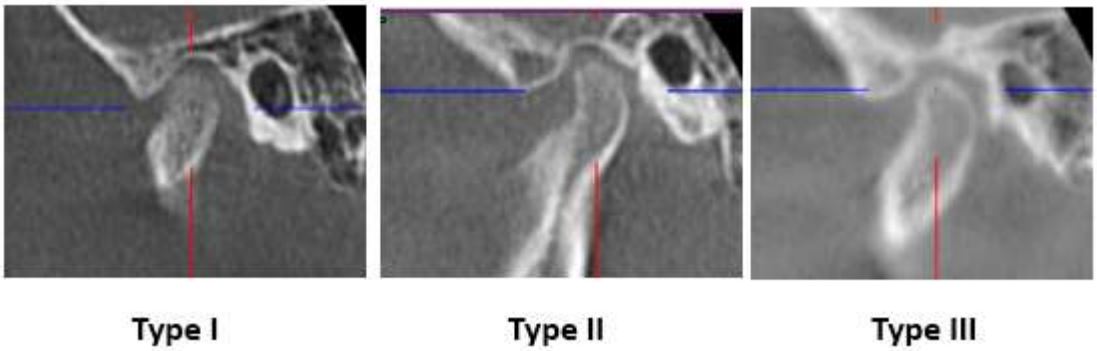
Evaluation of sphenooccipital synchondrosis:

Sagittal view of the sphenooccipital synchondrosis was captured and evaluated. The density and contrast of the images were adjusted to improve the visibility of SOS fusion status.

SOS fusion stages were assessed on the mid-sagittal plane of CBCT images which was clearly visible separately for each individual.
SOS fusion scoring were assessed with four stages which was described by Franklin and Flavel [7]. It is shown in Fig 1.
Stage 0 (unfused): completely open with no evidence of fusion between the basilar portion of the occipital bone and the sphenoidal bone, no bone present in the gap
Stage 1 (fusing endocranially): no more than half the length of the synchondrosis is fused proceeding endo—to ectocranially
Stage 2 (fusing ectocranially): greater than half the length of the synchondrosis is fused—the ectocranial (inferior) border remains unfused
Stage 3 (Complete fusion): completely fused with the appearance of normal bone throughout—a fusion scar may be present
Fig 1: Stages of Sphenooccipital synchondrosis fusion



Evaluation of condylar cortication:
Condyle cortication was evaluated on the sagittal section of CBCT images for both left and right sides separately, where the condyle is completely and clearly visible and the cortication is most intense.
The density and contrast of the images were adjusted to improve the visibility of condyles.
Cortication of condyle is determined with the density difference between cortical bone adjacent to condyle and the other areas around the condyle. It consists of three types based on the classification of Bayrak et al [8], which is shown in Fig 2
Type I: No cortication observed on the condyle
Type II: The bone on the condylar surface appears at a lower density than the structures around the condyle
Type III: The surface of the condyle appears at a higher or similar density than the surrounding cortical areas.
Fig 2: Types of condylar cortication



SOS fusion scoring and condylar cortication scoring for both sides were assessed and assigned individually for all patients by two examiners and was tabulated in Microsoft spreadsheet. The second examiner was blind to the demographic details of all patients.
Later, 20 CBCT images were selected randomly after 2 weeks and assessed by both examiners for intra-examiner and inter-examiner variability.
All tabulated scoring were presented for statistical analysis.
Statistical analysis:
The data were entered into the computer database. The response of frequencies were calculated and analyzed by using SPSS version 16.0 IBM, U.S. The probability value $p<0.05$ considered as significant, and $p<0.001$ were considered as highly significant. Statistical analysis of relationship between sphenooccipital synchondrosis and condylar cortication in chronologic age determination using CBCT was carried out to find the significant difference.
Descriptive analysis was used to find the distribution of each variable, ANOVA was used to find the association between each variable and Pearson correlation was used to find the relationship between two variables. The statistical tests used for the analysis of the result were:
1. Mean

2. Standard Deviation
3. One-way ANOVA.
4. Post-hoc Tukey test
5. Chi-square test.
6. Pearson's chi-squared test

RESULTS:

The study group consisted of 75 patients aged between 10 and 25 years. Table 1 shows the study contains 21(27.6%) members from 10 -15 years of age group, 31 (40.8%) members from 16-20 years of age and 22 (28.9%) members from 21- 25 years of age, with mean age of 18 ± 1.79.

Table 1: Descriptive values of chronologic age

Age	Frequency	Percentage	Mean	SD
10-15	21	27.6	18.01	1.79
16-20	31	40.8		
21-25	22	28.9		

Table 2: Descriptive values of Gender

Gender	Number of participants	Percentage	Mean	SD
Male	38	51.3	1.49	0.503
Female	37	48.7		

The demographic characteristics of the study group is described in Table 2, which contains 38 (51.3%) males (aged from 10 to 22) and 37 (48.7%) females (aged from 10 to 25), with mean ages of 1.49 ± 0.50.

Table 3: Descriptive values of stages of Spheno occipital synchondrosis (SOS)

Spheno occipital synchondrosis (SOS) fusion stage	Number of participants	Percentage	Mean	SD
0	14	18.4	1.79	1.13
1	15	19.7		
2	19	25		
3	25	35.5		

Table 3 shows distribution of patients according to Sphenooccipital synchondrosis, which shows 14 (18.4%) belongs to stage 0, 15 (19.7%) belongs to stage 1, 19 (25%) belongs to stage 2 and 25 (35.5%) belongs to stage 3. More patients are there in stage 3 SOS and with least in stage 0 SOS.

Table 4: Descriptive values of stages of Condylar cortication on both sides

	Types of Condylar cortication	Number of participants	Percentage	Mean	SD
Right	I	26	34.2	1.95	0.804
	II	25	35.5		
	III	22	28.9		
Left	I	23	30.3	2.03	0.805
	II	25	35.5		
	III	25	32.9		

Descriptive distribution of Condylar cortication is given in table 4, number of patients with type I condylar cortication is 26 (34.2%), type II condylar cortication is 25 (35.5%) and type III condylar cortication is 22 (28.9%) on the right side. Number of patients with type I condylar cortication is 23 (30.3%), type II condylar cortication is 25 (35.5%) and type III condylar cortication is 25 (32.9%) on the left side with more amount of distribution in type I on the right side and type II & III on the left side.

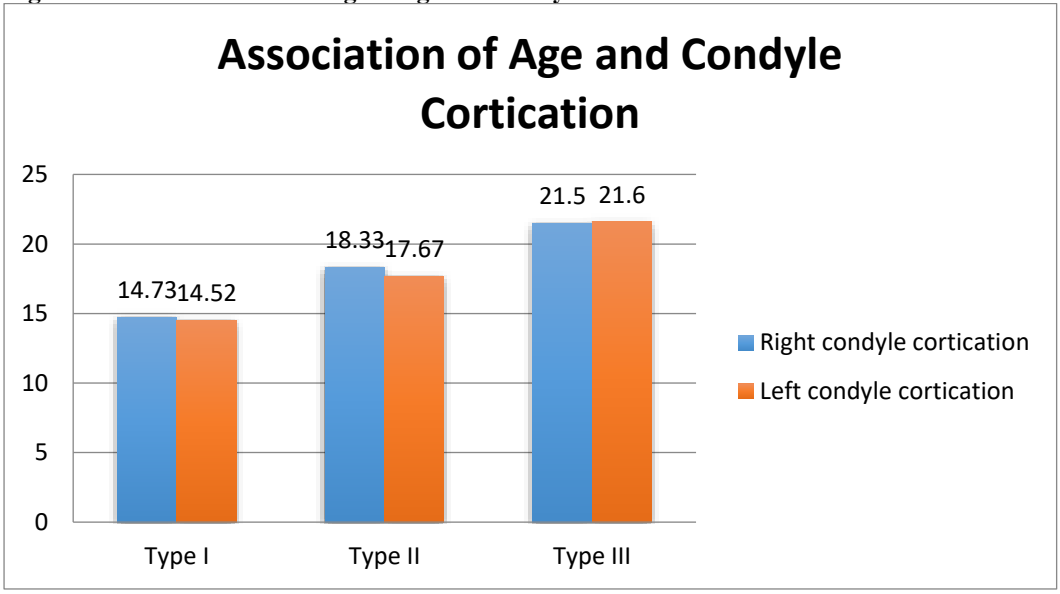
Table 5: Association of chronologic age according to the types of the condyle cortication

Condyle cortication		Number of participants	Mean age	Minimum	Maximum	SD	p Value
Right	Type I	26	14.73	10	20	2.850	0.000*
	Type II	27	18.33	11	22	2.828	

	Type III	22	21.50	16	25	2.988	
Left	Type I	23	14.52	10	20	2.858	0.000*
	Type II	27	17.67	11	22	2.660	
	Type III	25	21.60	15	25	2.739	

*p value is significant if it is less than 0.05

Fig 3: Association of chronological age and condylar cortication



As shown in Table 5, 26 subjects had Condyle cortication of Type I cortication, 27 subjects had Type II cortication, and 22 subjects had Type III cortication on the right side. We see that the average age of Type I is the smallest (14.73) and that of Type III is the highest (21.50), and a **statistically significant difference was found between mean age of the three types (p = 0.000)** as seen in Fig 3**.** While considering left condyle Type I shows smallest value (14.52) and Type III is the highest (21.60) with statistical difference of p value lesser than 0.05. **Left and right condyle did not show any difference in condyle cortication.**

Table 6: Association of chronologic age according to the Spheno occipital synchondrosis (SOS)

SOS	Number of participants	Mean age	Minimum	Maximum	SD	p Value
Stage 0	14	14.14	10	21	3.57	0.000*
Stage 1	15	16	11	20	2.80	
Stage 2	19	17.84	14	25	2.83	
Stage 3	27	21.26	16	25	2.58	

*p value is significant if it is less than 0.05

Table 6 and Fig 4, shows the association of chronologic age distribution in the SOS fusion stages of all patients. SOS fusion stage 0 was found to be at mean age of 14.14 ±3.57, stage 1 at 16 ± 2.80 mean age, stage 2 at 17.84 ± 2.83 mean age and stage 3 at 21.26 ± 2.58 mean age. **It shows statistical significance between SOS and chronologic age. Sphenooccipital synchondrosis (SOS) fusion occurs as age increases.**

Fig 4: Association of chronological age and Sphenooccipital synchondrosis

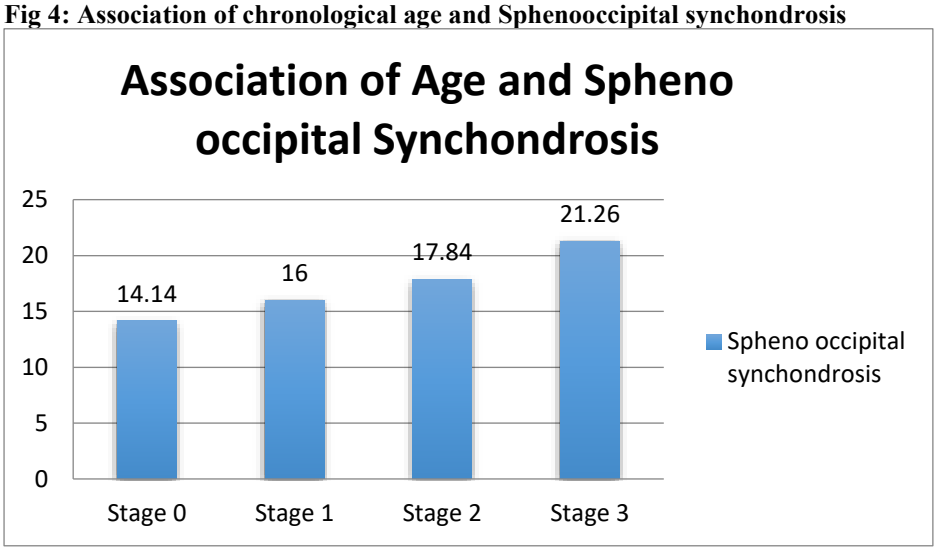


Table 7: Relationship between Types of condyle cortication, Age and Spheno occipital synchondrosis (SOS)

Condyle cortication		SOS	Number of participants	Mean	Minimum	Maximum	SD	p Value
Right	Type I	0	13	13.30	1	2	0.48	
		1	9	15.44	1	2	0.52	
		2	3	16.66	1	2	0.57	
		3	1	17.00	2	2	0	
	Type II	0	1	15.00	3	3	0	
		1	6	16.50	1	2	0.54	
		2	12	17.91	1	3	0.66	
		3	8	20.62	2	3	0.51	
	Type III	0	0	0	0	0	0	
		1	0	0	0	0	0	
		2	4	19.25	2	3	0.50	
		3	17	21.76	2	3	0.43	
Left	Type I	0	11	12.18	1	2	0.40	
		1	8	16.50	1	2	0.53	
		2	4	16.75	1	2	0.50	0.000*
		3	0	0	0	0	0	
	Type II	0	2	15.50	2	2	0	
		1	7	16.42	1	2	0.53	
		2	9	17.88	1	3	0.60	
		3	9	19.33	2	3	0.50	
	Type III	0	1	21	3	3	0	
		1	0	0	0	0	0	
		2	6	19.16	1	3	0.75	
		3	17	22.88	2	3	0.33	

*p value is significant if it is less than 0.05

The distribution of the study population according to age, cortication types, and SOS fusion stages is presented in Table 7. As seen in Fig 5 and 6, in patient with right type I cortication most (13) of them belongs to SOS stage 0. In Right type II cortication most of them (12) belongs to SOS stage 2, in right type III cortication most (17) of them belongs to SOS stage 3. **This shows condyle cortication and SOS moves on the same plane and increase as age increases and there is a statistical significance between these groups.** Patients with right type III cortication only SOS stages of 2 and 3 were seen. In Patient with left type I cortication most (11) of them belongs to SOS stage 0, in left type II cortication most of them (9) belongs to SOS stage 2 and 3 , in left type III cortication most of them belongs to SOS stage 3 and **there is a statistical significance between these groups**.

Fig 5: Distribution of study population in various stages of condylar cortication according to SOS staging on the right side

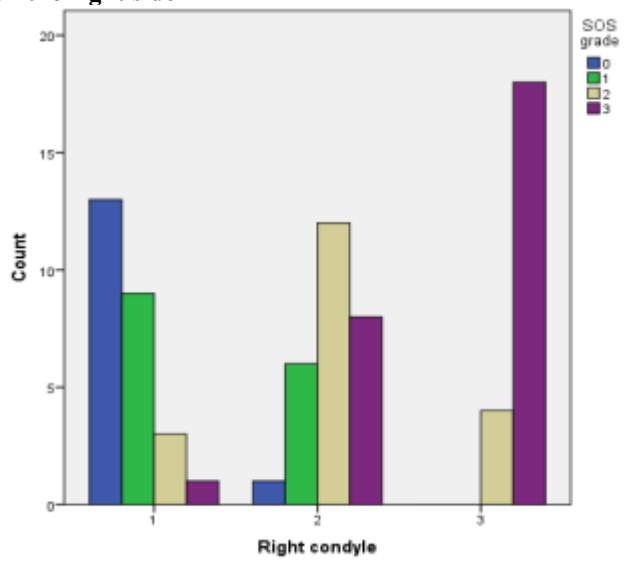


Fig 6: Distribution of study population in various stages of condylar cortication according to SOS staging on the left side

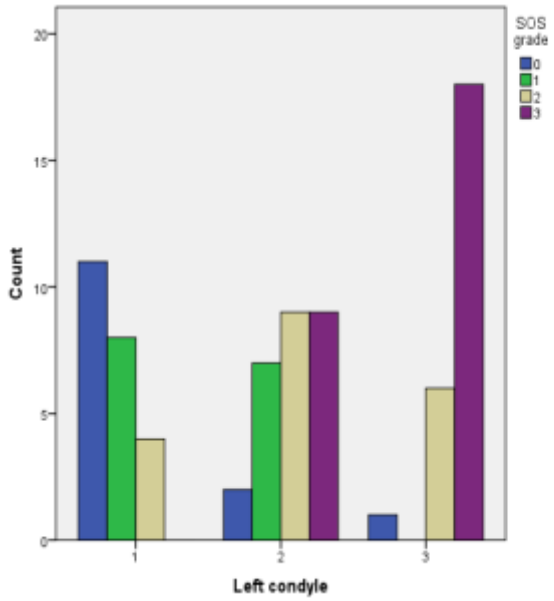


Table 8: Correlation coefficients between sphenooccipital synchondrosis and Right condyle cortication.

	Right Condyle cortication.				P value	Pearson correlation
		I	II	III		
sphenooccipital synchondrosis	0	13	1	0	0.000*	0.761*
	1	9	6	0		
	2	3	12	4		
	3	1	8	18		

*p value is significant if it is less than 0.05
* Correlation is significant at 0.01 level

Table 8 and Fig 7 shows that the correlation between sphenooccipital synchondrosis and right condyle cortication was evaluated using Pearson correlation. **There is a strong positive correlation (r= 0.761) between sphenooccipital synchondrosis and Right condyle cortication.**

Fig 7: Correlation graph between sphenooccipital synchondrosis

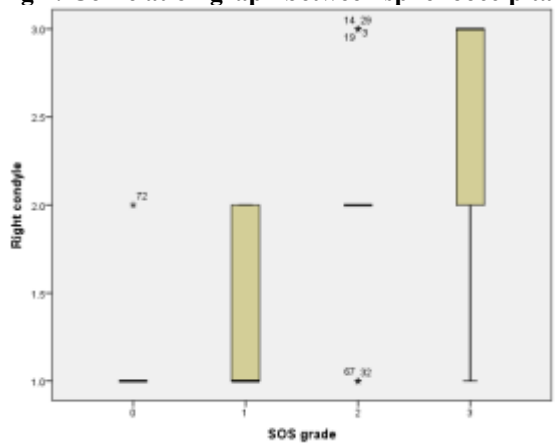


Table 9: Correlation coefficients between sphenooccipital synchondrosis and Left condyle cortication.

	Left Condyle cortication.				P value	Pearson correlation
		I	II	III		
sphenooccipital synchondrosis	0	11	2	1	0.000*	0.689*
	1	8	7	0		
	2	4	9	6		
	3	9	9	18		

*p value is significant if it is less than 0.05
* Correlation is significant at 0.01 level

Table 9 and Fig 8, shows correlation between sphenooccipital synchondrosis and left condyle cortication evaluated using Pearson correlation. **There is a strong positive correlation (r= 0.689) between sphenooccipital synchondrosis and left condyle cortication.**

Fig 8: Correlation graph between sphenooccipital synchondrosis and left condylar cortication

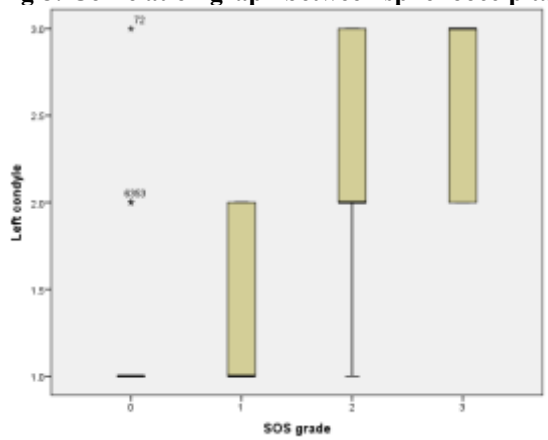


Table 10: Correlation coefficients between Age and Right condyle cortication.

	Right condyle cortication.				P value	Pearson correlation
		I	II	III		
Age	10-15	15	6	0	0.000*	0.649*
	16-20	11	13	7		
	21-25	0	8	14		

*p value is significant if it is less than 0.05
* Correlation is significant at 0.01 level

Table 10 and Fig 9, shows correlation between right condyle cortication and age evaluated using Pearson correlation. Chronologic age increased as the right condyle cortication increases from type I and type III. **There is a strong positive correlation (r= 0.649) between right condyle cortication and age.**

Fig 9: Correlation graph between age and right condylar cortication

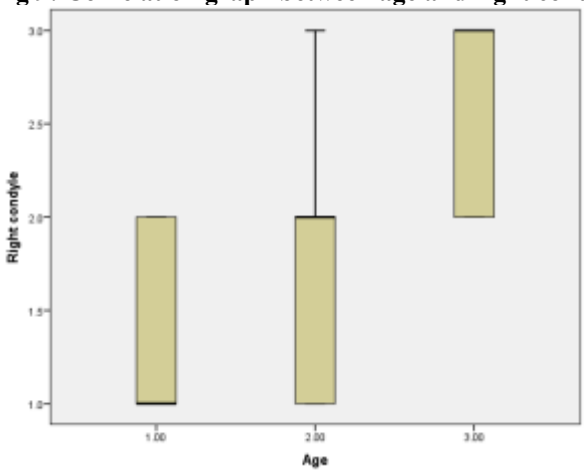


Table 11: Correlation coefficients between Age and Left condyle cortication

		Left condyle cortication.			P value	Pearson correlation
		I	II	III		
Age	10-15	14	6	1	0.000	0.689
	16-20	9	17	5		
	21-25	0	4	18		

Fig 10: Correlation graph between age and left condylar cortication

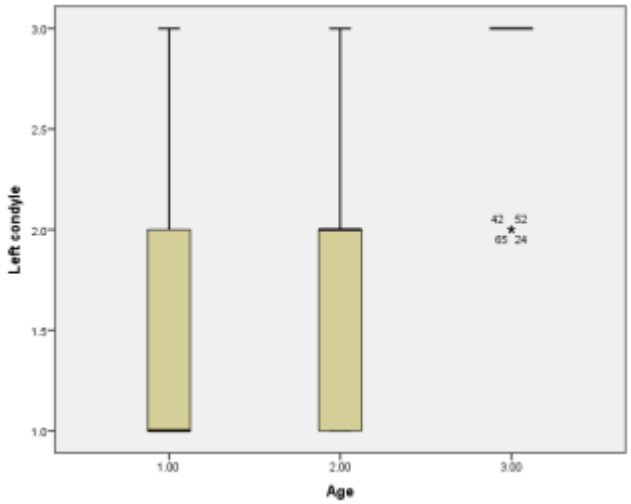


Table 11 and Fig 10, shows correlation between Left condyle cortication and age evaluated using Pearson correlation. Chronologic age increased as the left condyle cortication increases from type I and type III. **There is a strong positive correlation (r= 0.689) between left condyle cortication and age.**

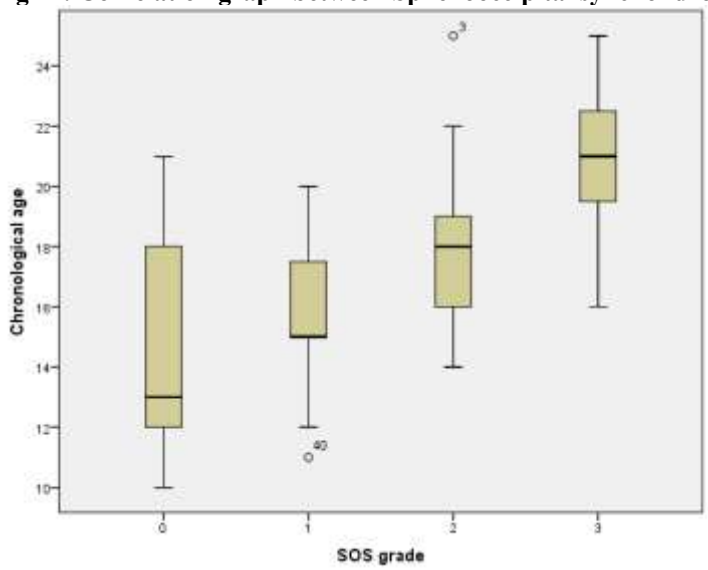
Table 12: Correlation coefficients between sphenooccipital synchondrosis fusion stage and age

	sphenooccipital synchondrosis fusion stage				P value	Pearson correlation
	0	1	2	3		
Age	10-15	9	8	4	0	0.000*	0.668*
	16-20	4	7	12	8		
	21-25	1	0	3	18		

*p value is significant if it is less than 0.05
* Correlation is significant at 0.01 level

Table 12 and Fig 11, shows correlation between sphenooccipital synchondrosis fusion stage and age evaluated using Pearson correlation. Chronologic age increased as the stages of the SOS fusion process increased from 0 to 3. **There is a strong positive correlation (r= 0.668) between sphenooccipital synchondrosis fusion stage and age.**

Fig 11: Correlation graph between Sphenooccipital synchondrosis and age



DISCUSSION:

The main goal of our study was to determine the chronological age of subjects with sphenooccipital synchondrosis and condylar cortication using CBCT. Literature has revealed various successful methods for age determination using skeletal methods like cervical vertebrae assessment, hand-wrist radiography, assessment of various sutures, etc., and dental methods like determining the tooth pulp ratio. We used CBCT for age estimation in our study, for its clarity and preciseness in three dimensional imaging. A study conducted by Wilma Pinchi et. al., in 2015 [9] to determine the age with the pulp cavity and hard tissues of the teeth for forensic purposes, indicated that CBCT is one of the most easiest and conservative techniques to help in accurate assessment of such cases by saving time. In our study also CBCT helped in accurate age determination and the same was said by Shakeel Kamzi et. al., in 2019 [10] and Haghanifar et. al., in 2019 [11] in their study for CBCT accuracy in age and sex determination.

Based on mean age in our sample, we found the closure of SOS attainment occurs at an age of 14.14 years for stage 0, 16 years for stage 1, 17.84 years for stage 2 and 21.26 for stage 3. These age are in accordance with mean age reported by Okamoto et.al., in 1996 [12] and Akhlaghi et. al in 2010 [13] who aimed to evaluate the growth and development of sphenooccipital synchondrosis from CT sections.

A study by Sharma et. al., in 2020 [14] also attempted to ascertain the possibility of age estimation in an Indian subpopulation by cone-beam computed tomographic (CBCT) analysis of SOS. According to them, the closure of SOS can be used to determine age in the adolescent-adult transition phase with more reliability.

In the present study association between Sphenooccipital synchrondrosis and age was evaluated. The results shows a **strong positive correlation between Spheno occipital synchrondrosis and age** which was compared with a study conducted by Pate et. al in 2018 [15], which showed a significant linear correlation between the age of an individual and spheno-occipital suture closure for both the sexes.

While seeing the condylar cortication, in this study it shows that as the age increases the cortication types also increases which was similar to a study conducted by Mathew et. al., in 2011 [16]**.** He tried to assess the condylar morphology and its relationship with age. They were divided into three groups according to age and analysed. It was concluded that condylar cortication increased with age.

Bayrak et.al., in 2018 [17] attempted to analyse and evaluate the relationship between mandibular condyle cortication and chronologic age with CBCT. Both sides condylar cortication were assessed on the sagittal plane separately for each individual that describes the cortication of the condyle. In accordance with this, we also evaluated condyles from both sides. The results stated that the type of cortication in the right and left condyle might be occasionally different for the same individual and that chronologic age increased as the stages of the cortication progressed from Type I to Type III in male and female individuals. **There was a strong positive correlation between condylar cortication and age.**

Seval Bayrak et.al., in 2019 [8] attempted to assess the relationship between chronologic age, mandibular condyle cortication, and SOS fusion. Cone Beam Computed Tomography data of 253 patients were retrospectively evaluated. Mandibular condyle cortication was divided into three classes as Types I, II, and III. SOS fusion grade was categorized using a four-stage system (0–3). These variables were evaluated in relation to age and sex. There was a significant positive relationship between age and condyle cortication, and between age and SOS fusion stage and between cortication type and SOS fusion stage which was similar to this study showing statistical significance between SOS, condylar cortication and chronological age. **Due to this positive correlation between**

the degree of SOS fusion stage, the condyle cortication type, and the chronological age, these indicators could be approved for the use of age estimation.

Yalcin et.al in 2019 [18] study tried to investigate mandibular condyle cortication (MCC), articular eminence cortication (AEC) and mandibular cortical index (MCI) according to age and gender on CBCT, and relationship between each other from CBCT scans of 520 patients retrospectively. The results concluded that the distribution of MCC, AEC, MCI were according to age and gender and all these cortications were correlated, which was observed in this study also.

LIMITATIONS:

The major limitation of this study would be a smaller sample size, as it was attempted more of a pilot study. In such case, it might not represent a huge and diverse population as seen in India.

Another limitation would be that, we did not eliminate the confounding factors involved in suture closure as in cases of syndromes or hormonal disturbances/influence or metabolic disorders. However it was not possible to eliminate these factors because it was a retrospective study.

CONCLUSION:

- CBCT demonstrated a detailed and clear evaluation of sphenooccipital synchondrosis and cortication of the condyle. Hence it can be implicated in future studies for the precise evaluation of age related changes in the head and neck region
- To the best of our knowledge this is the first study conducted in the South Indian population correlating both SOS and condylar cortication. Further studies are required involving a large sample size to establish the accuracy of the results and to generalize it to a greater population.
- Our results have concluded that there is a strong positive correlation between chronological age, degree of SOS fusion stage and condyle cortication type. This shows that condyle cortication can be used as an efficient alternative if the skull base is not intact at the time of forensic examination for age estimation

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