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Original Research

Evaluation of the correlation between chronological age, dental and skeletal maturation in the age group 8-13 years old north Indian population

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ABSTRACT:

Aim and Objectives: The aim of the study was to evaluate the correlation between chronological age, dental and skeletal maturation in the age group 8-13 years old north Indian population. **Materials and Methods:** A retrospective study in which total of 70 good quality cephalometric and panoramic radiographs (OPG) of children in the age group of 8-13 years were collected. Chronologic age of the patient was recorded from the OPD records and calculated by the difference of time between date of birth and the day for the procurement of radiograph. Dental age calculated with the help of Demirjian's tooth developmental stage chart. Skeletal age determined by Baccetti cervical maturation stage chart skeletal age. Statistical analysis was determined by normality of the data was assessed using Shapiro Wilkinson test. Inferential statistics to find out the difference between and within the groups was done using STUDENT T TEST and ONE WAY ANOVA and TUKEYS POST HOC TEST. **Conclusion:** Although various methods of age assessment have been used, the applicability can vary due to the ethnic, racial & geographical variations between individuals and populations. Hence, the maturity standards should be based on studies made on the same population.

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INTRODUCTION

Growth can be one of the most uncertain variation, but understanding the same is very important for diagnosis and treatment planning. It is essential to learn the normal human growth and maturity to recognize abnormal or pathological growth in orthodontic and dentofacialorthopaedic treatment planning. Therefore, even though we have different methods to determine growth, assessment of skeletal age and dental age have been used most widely to determine a child's developmental age.[1]

Various skeletal maturity indicators exist to evaluate degree of ossification of bony markers such as epiphysis- diaphysis fusion, hand- wrist bone ossification, cervical vertebra maturation, sternoclavicular bones, changes in pubic symphysis and fusion of cranial sutures.[2]But presently, cervical vertebrae maturation (CVMS) is used to evaluate skeletal maturity due to its simplicity, reproducibility and that no extra radiation exposure is required since lateral cephalometric radiograph is routinely required for orthodontic diagnosis and treatment planning.[3]

Another measure of assessing physiologic maturation is dental maturity. It is used to estimate the physiological maturity due to ease of recognition of dental developmental stages, together with the availability of periapical or panoramic radiographs in most orthodontic practices.[4]

However, the most widely used method for dental age estimation is given by Demirjian's et al. which attempts to classify tooth mineralization by maturation changes in tooth development.[5] This method has been tested in various populations as an age estimation technique. In 2001, Willems et al., evaluated the accuracy of Demirjian method in Belgian Caucasian population and modify the scoring system when a significant overestimation can be recorded.[6]

Although various methods for age estimation exist but no universal system has yet been achieved due to

the variation in different ethnic population groups and also little information exists regarding the correlation between chronological age, skeletal maturation and stages of dental development.

MATERIALS AND METHODS

The study was conducted in the Department of Paedodontics and Preventive Dentistry, with the aim to correlate the chronological age with dental age and skeletal age in the age group of 8-13 years. A total of 70 good quality cephalometric and panoramic radiographs (OPG) of children in the age group of 8-13 years from North Indian population, were selected from the Department of Oral Medicine and Radiology. The data was obtained from the pre-treatment records of children who fulfilled the inclusion criteria.

The selection criteria included subjects with:

Inclusion Criteria	Exclusion Criteria
• Cephalogram and OPG of subjects between 8-13 years of age.	• Cephalogram and OPG of subjects below 8 years or above 13 years of age
• Radiograph showing no congenital anomalies of 2nd, 3rd, 4th cervical vertebra such as fusion between cervical vertebra or presence of secondary ossicles were included.	• Patient with any congenital anomalies of 2^{nd} 3^{rd} 4^{th} cervical vertebra such as fusion between cervical vertebra or presence of secondary ossicles were eliminated
• No history of any type of orthodontic treatment.	• History of any type of orthodontic treatment
• No missing tooth or anomalies in dentition.	• Any missing tooth or anomalies in the dentition

Figure-i; Demirjian tooth calcification stages A to H

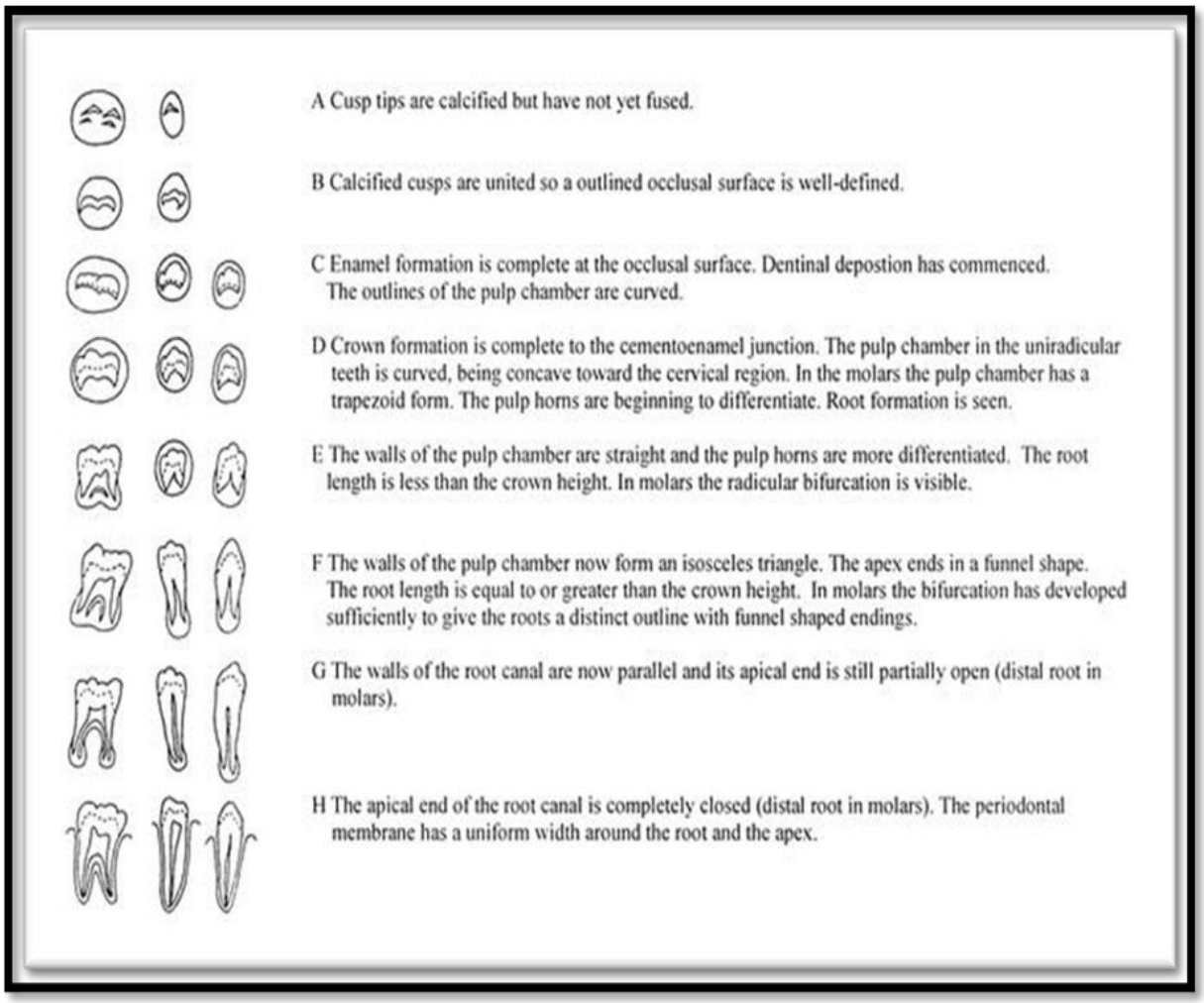


Figure-ii; Demirjian's score tables based on developmental stage of tooth

Tooth	Stage								
	0	A	B	C	D	E	F	G	H
Boys									
M2	0.0	2.1	3.5	5.9	10.1	12.5	13.2	13.6	15.4
M1				0.0	8.0	9.6	12.3	17.0	19.3
PM2	0.0	1.7	3.1	5.4	9.7	12.0	12.8	13.2	14.4
PM1			0.0	3.4	7.0	11.0	12.3	12.7	13.5
C				0.0	3.5	7.9	10.0	11.0	11.9
I2				0.0	3.2	5.2	7.8	11.7	13.7
I1					0.0	1.9	4.1	8.2	11.8
Girls									
M2	0.0	2.7	3.9	6.9	11.1	13.5	14.2	14.5	15.6
M1				0.0	4.5	6.2	9.0	14.0	16.2
PM2	0.0	1.8	3.4	6.5	10.6	12.7	13.5	13.8	14.6
PM1			0.0	3.7	7.5	11.8	13.1	13.4	14.1
C				0.0	3.8	7.3	10.3	11.6	12.4
I2				0.0	3.2	5.6	8.0	12.2	14.2
I1					0.0	2.4	5.1	9.3	12.9

Stage 0 is no calcification.

ASSESSMENT OF CHRONOLOGICAL AGE

Chronologic age of the patient was recorded from the OPD records and calculated by the difference of time between date of birth and the day for the procurement of radiograph.

ASSESSMENT OF DENTAL AGE

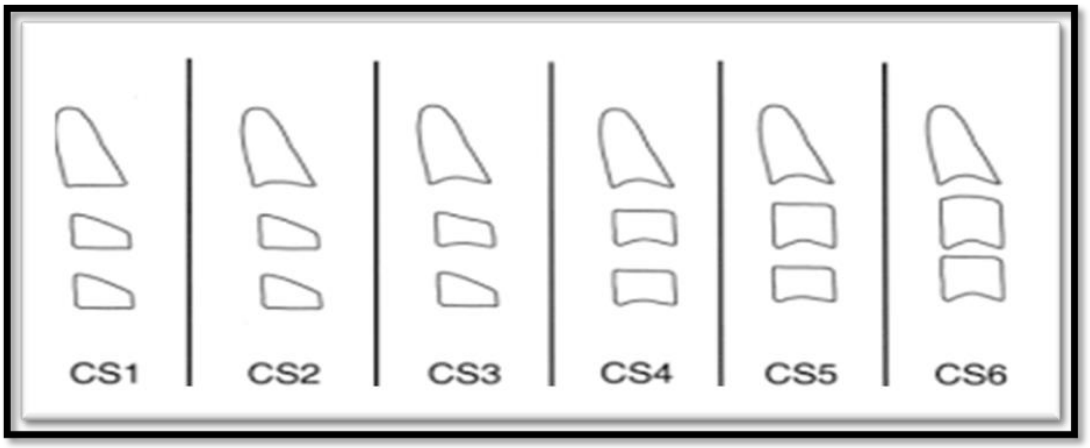
Dental age was assessed with the help of OPGs and skeletal maturation with the help of lateral cephalogram. The left mandibular central incisor, lateral incisor, canine, premolars, first molar and second molars were traced from the radiograph. Evaluation of the radiograph were done with the help of an X – ray viewer box.

Tooth calcification stages were scored according to the method described by Demirjian et al in which 8 stages (A to H) have been defined from the first appearance of calcified points to the closure of the apex. Each tooth included had an individual development stage (Fig.i) and thus assigned with a corresponding score, according to normal standards, which are gender dependent (Fig.ii). The maturity score sum was then converted into dental age by using the score table (fig.iii).

Figure- iii; Conversion of maturity score to dental age[2]

Age	Points		Age	Points		Age	Points		Age	Points	
y	♂	♀	y	♂	♀	y	♂	♀	y	♂	♀
3.0	12.4	13.7	6.3	36.9	41.3	9.6	87.2	90.2	12.9	95.4	97.2
.1	12.9	14.4	.4	36.9	41.3	.7	87.7	90.7			
.2	13.5	15.1	.5	39.2	43.9	.8	88.2	91.1	13.0	95.6	97.3
.3	14.0	15.8	.6	40.6	45.2	.9	88.6	91.4	.1	95.7	97.4
.4	14.5	16.6	.7	42.0	46.7				.2	95.8	97.5
.5	15.0	17.3	.8	43.6	48.0	10.0	89.0	91.8	.3	95.9	97.6
.6	15.6	18.0	.9	45.1	49.5	.1	89.3	92.3	.4	96.0	97.7
.7	16.2	18.8				.2	89.7	92.3	.5	96.1	97.8
.8	17.0	19.5	7.0	46.7	51.0	.3	90.0	92.6	.6	96.2	98.0
.9	17.6	20.3	.1	48.3	52.9	.4	90.3	92.9	.7	96.3	98.1
			.2	50.0	55.5	.5	90.6	93.2	.8	96.4	98.2
4.0	18.2	21.0	.3	52.0	57.8	.6	91.0	93.5	.9	96.5	98.3
.1	18.9	21.8	.4	54.3	61.0	.7	91.3	93.7			
.2	19.7	22.5	.5	56.8	65.0	.8	91.6	94.0	14.0	96.6	98.3
.3	20.4	23.2	.6	59.6	68.0	.9	91.8	94.2	.1	96.7	98.4
.4	21.0	24.0	.7	62.5	71.8				.2	96.8	98.5
.5	21.7	24.8	.8	66.0	75.0	11.0	92.0	94.5	.3	96.9	98.6
.6	22.4	25.6	.9	69.0	77.0	.1	92.2	94.7	.4	97.0	99.5
.7	23.1	26.4				.2	92.5	94.9	.5	97.1	98.8
.8	23.8	27.2	8.0	71.6	78.8	.3	92.7	95.1	.6	97.2	98.9
.9	24.6	28.0	.1	73.5	80.2	.4	92.9	95.3	.7	97.3	99.0
			.2	75.1	81.2	.5	93.1	95.4	.8	97.4	99.1
5.0	25.4	28.9	.3	76.4	82.2	.6	93.3	95.6	.9	97.5	99.1
.1	26.2	29.7	.4	77.7	83.1	.7	93.5	95.8			
.2	27.0	20.5	.5	79.0	84.0	.8	93.7	96.0	15.0	97.6	99.2
.3	27.8	31.3	.3	80.2	84.8	.9	93.9	96.2	.1	97.7	99.3
.4	28.6	32.1	.7	81.2	85.3				.2	97.8	99.4
.5	29.5	33.0	.8	82.0	86.1	12.0	94.0	96.3	.3	97.8	99.5
.6	30.3	34.0	.9	82.8	86.7	.1	94.2	96.4	.4	97.9	99.5
.7	31.1	35.0				.2	94.4	96.5	.5	98.0	99.6
.8	31.8	36.0	9.0	83.6	87.2	.3	94.5	96.6	.6	98.1	99.6
.9	32.6	37.0	.1	84.3	87.8	.4	94.6	96.7	.7	98.2	99.7
			.2	85.0	88.3	.5	94.8	96.8	.8	98.2	99.8
6.0	33.6	38.0	.3	85.6	88.8	.6	95.0	96.9	.9	98.3	99.9
.1	34.7	39.1	.4	86.2	89.3	.7	95.1	97.0			
.2	35.8	40.2	.5	86.7	89.8	.8	95.2	97.1	16.0	98.4	100.0

Figure-iv; Modified Baccetti cervical vertebral developmental stages (2005)[7]



ASSESSMENT OF SKELETAL AGE

In order to determine the skeletal maturation stage, cervical vertebrae (C2, C3, and C4) outlines traced from the lateral cephalometric radiographs were analysed using the CVM method (Baccetti et al., 2005) (fig.iv). The presence or absence of concavity at the lower border of C2–C4 as well as the shape of the vertebral bodies of C3 and C4 (trapezoidal, horizontal, square, and vertical) were analysed. Six developmental stages are described—from cervical stage (CS)1 to CS6 (Table – i).

Table – i Cervical vertebral maturation stages given by Baccetti et al, (2005)[8]

Stages	Features
CVMS I	The lower borders of all the three vertebrae are flat, with the possible exception of a concavity at the lower border of C2 in almost half of the case.The bodies of both C3 and C4 are trapezoid in shape (the superior border of the vertebral body is tapered from posterior to anterior)
CVMS II	Concavities at the lower border of both C2 and C3 are present The bodies of C3 and C4 may be either trapezoid or rectangular horizontal in shape
CVMS III	Concavities at the lower borders of C2, C3 and C4 now are present. The bodies of both C3 and C4 are rectangular horizontal in shape
CVMS IV	The concavities at the lower borders of C2, C3 and C4 still are present. At least one of the bodies of C3 and C4 is squared in shape. If not squared, the body of the other cervical vertebra still is rectangular horizontal
CVMS V	The concavities at the lower borders of C2, C3 and C4 still are evident. At least one of the bodies of C3 and C4 is rectangular vertical in shape. If not rectangular vertical, the body of the other cervical vertebra is squared
CVMS VI	The concavities at the lower borders of C2, C3 and C4 still are evident. At least one of the bodies of C3 and C4 is rectangular vertical in shape. If not rectangular vertical, the body of the other cervical vertebra is squared. The peak in mandibular growth has ended at least two years before this stage.

CVMS: Cervical vertebrae maturation stage

STATISTICAL ANALYSIS

Data was analyzed using the statistical package SPSS 22.0 (SPSS Inc., Chicago, IL) and level of significance was set at $p<0.05$. Descriptive statistics was performed to assess the mean and standard deviation of the respective groups. Normality of the data was assessed using Shapiro Wilkinson test. Inferential statistics to find out the difference between and within the groups was done using STUDENT T TEST and ONE WAY ANOVA andTUKEYS POST HOC TEST. Correlation analysis was done using spearman rho rank correlation.

RESULTS

Table ii: Out of the total 70 children ,maximum number of child patients were males (n=36) with the mean age of 11.69, while female (n= 34) with mean age of 12.03

Table iii: Person correlation analysis shows strong correlation among males with respect to CA vs DA(r=0.56) , CA vs SA(r=0.49).Similar strong correlation was also observed among males regarding SA vs DA.(r=-0.74).All the correlation were found to be statistically significant($p<0.05$)

Whereas among the females also shows strong correlation with respect to CA vs DA(r=0.55), CA vs SA(r=0.71).Similar, strong correlation was also

observed among females regarding SA vs DA.(r=0.66) All the correlation was found to be statistically significant($p<0.05$).

Pearson correlation analysis shows strong correlation among total participants with respect to CA vs DA(r=0.72) , CA vs SA(r=0.59) and SA vs DA.(r=-0.71).All the correlation were found to be statistically significant($p<0.05$)

Table iv: Pearson correlation analysis shows strong significant correlation among 8-9 age group with respect to CA vs DA (r=0.39). Similar strong correlation was not observed regarding CA vs SA (r= 0.17) & SA vs DA (r=0.24).

Pearson correlation analysis shows strong significant correlation among 10-11 age group with respect to CA vs DA(r=0.42) , SA vs DA(r=0.44).Similar strong correlation was not observed regarding CA vs SA.(r=-0.16).

Pearson correlation analysis shows strong significant correlation among 12-13 age group with respect to SA vs DA(r=0.59) , Similar strong correlation was not observed regarding CA vs SA.(r=-0.14) & CA vs DA(r=0.18).

Table v: Significant difference observed in total and female gender with respect to the age categories. Post hoc analysis shows the significance with in the "total group" was between chronological and dental age ($p<0.05$). Male category did not show any significant difference. Among the female category, significant difference was observed between chronological and dental age($p<0.05$)

Table vi: Strong correlation was observed between Calcification in Different Teeth and Cervical Maturation Stages with respect to all the teeth.

Table no.ii- Mean age of the study participants

	MEAN	SD
Male	11.69	1.13
Female	12.03	1.29
Total	11.84	1.38

Table no.iii-Correlation between chronological, Dental and Skeletal age(spearman rank correlation test) with respect to gender

	Comparison	r value	p value
Male	CA vs DA	0.56	0.002*
	CA vs SA	0.49	0.002*
	SA vs DA	0.74	0.001*
female	CA vs DA	0.55	0.002*
	CA vs SA	0.71	0.001*
	SA vs DA	0.66	0.001*
Total	CA vs DA	0.72	0.001*
	CA vs SA	0.59	0.002*
	SA vs DA	0.71	0.002*

Table iv- Correlation between chronological, Dental and Skeletal age.(spearman rank correlation test) with respect to age categories

	comparison	r value	p value
8-9	CA vs DA	0.39	0.001*
	CA vs SA	0.17	0.159
	SA vs DA	0.24	0.04*
10-11	CA vs DA	0.42	0.038*
	CA vs SA	0.16	0.546
	SA vs DA	0.44	0.027*
12-13	CA vs DA	0.14	0.678
	CA vs SA	0.18	0.512
	SA vs DA	0.59	0.021*

Table no. v –Comparison of chronological age, dental age and skeletal age

	AGE	N	MEAN	SD	SEM	P value	ANOVA
TOTAL	Chronological age	70	11.84	1.38	0.21	0.02*	C VS D=0.02*
	Dental age	70	12.49	1.50	0.29		C VS S=0.64
	Skeletal age	70	12.06	1.49	0.22		D VS S=0.19
MALE	Chronological age	36	11.80	1.19	0.15	0.07	C VS D=0.15
	Dental age	36	12.20	1.34	0.19		C VS S=0.98
	Skeletal age	36	11.76	1.27	0.14		D VS S=0.10
FEMALE	Chronological age	34	11.94	1.08	0.21	0.002*	C VS D=0.002*
	Dental age	34	12.78	1.29	0.23		C VS S=0.10
	Skeletal age	34	12.35	1.19	0.13		D VS S=0.08

Table no. vi- Correlation and Associations Between Calcification in Different Teeth and Cervical Maturation Stages

NUMBER	SPEARMAN VALUE	P value
CI	0.68	0.011*
LI	0.79	0.001*
CANINE	0.72	0.001*
PM 1	0.68	0.011*
PM 2	0.56	0.018*
M1	0.16	0.14
M2	0.39	0.023*

DISCUSSION

Growth and development are two important parameters of human life. Growth is the base from which development emerges. It is generally accepted that a strong relationship exists between skeletal, sexual and somatic maturation, but contributions to the correlation between dental age and skeletal maturity are inconclusive.

In somatic growth and development, it is already an accepted fact that girls are advanced than boys, up to the preadolescent years. During the growing years, it is observed that girls are usually 1 to 6 months ahead of boys.[18] Three fundamental ways exist to assess dental age; determination according to clinical emergence of teeth is the oldest technique. Gingival emergence may be influenced by local factors: ankylosis, early or delayed extraction of the deciduous tooth, impaction and crowding of the permanent teeth.Insufficient root development is characteristic of premature eruption (i.e. during the intraoral eruption stage root has one-third of its final length).[9]

Bone maturation is evaluated by means of different biological indicators such as height, weight, chronological age, dental age, carpal x-rays or cervical vertebrae.

Lamparski was the first to use cervical vertebrae as indicators for skeletal maturation. Skeletal maturation assessed by cervical vertebral maturation stage (CVMS) assessment is mostly accepted now as it is performed on lateral cephalograms, a radiograph often used in ortho-diagnosis and also does not require extra radiation. The method proposed by Baccetti et al. was used in this study as this method has a comparable high reliability and validity. It anticipates the occurrence of mandibular growth peak which happens between stages two and three.[7] The CVM method comprised of six maturational stages, with the peak in mandibular growth occurring between CS3 and CS4. The pubertal peak has not been reached without the attainment of both CS1 and CS2.[10] These cervical vertebrae (C2, C3 & C4) can be visualized when the patient wears a protective radiation collar.[11]

The orthopantomography radiographs (OPG) were used to evaluate dental maturity because of the easy availability in clinics and mandibular region is clearly visible. The Demirjian et al. method was chosen to determine the tooth calcification stage.[12]This method consists of distinct details based on tooth shape and the ratio of root length to crown height rather than on the absolute length, so that foreshortened or elongated projections of developing teeth will not influence the reliability of assessment. This method uses tooth calcification rather than tooth eruption.[13] Dental age estimation was conducted on seven teeth of left quadrant of mandible since these teeth represent the age range of commencement to completion of root calcification close to the age range of the patients selected for the study. The maxillary posterior teeth were omitted from the study because superimposition of calcified structures in this area resulting in inaccurate assessment of the stage of development.[14]

Various studies have shown that there is some secure correlation between skeletal, sexual and somatic maturation; but on the other hand, few studies have also found this inconclusive.

In the present study, the age group (i.e. 8 to 13 year) was considered as it corresponds with the Baccetti et al. (2005) skeletal maturation stages - the CS1 stage which is parallel to the chronological age of 104.67 months (approximately 8 ½ years); while the study included the children till 13 years in accordance to the Dental council of India amendments of pediatric age group.

On the basis of general demographic data collected, it was assessed that majority of children who participated in the study were males (n=36) while the females were only 34 in number (Table ii). Similar studies were conducted by **Gupta S et al (2015)[15] and Nanda M et al (2017)[16]** who also reported that the majority of the children were males rather than females.

On finding the correlation between skeletal age and dental age particularly in males, the 'r' value was found to be 0.74 which depicts the strong correlation (Table iii). The results of the present study are in correspondence with the **Dzemidzic V et al (2016)[17]**study where a strong correlation was found between skeletal and dental age for males. On relating the results of the study for females' participants, a strong correlation was found between the skeletal age and dental age with the r value of 0.66 and for chronological age with dental age, it was 0.55; chronological age with skeletal age, r value was 0.71 (Table iii). The results were consistent with the study conducted by **Ramírez-Velásquez M et al (2018)[18]** while on the contrary, study conducted by **Kumar V et al (2013)[19]**, showed statistically insignificant correlation of chronological and dental age (r = 0.034) in case of females.

On assessing the correlation between the CA/DA, CA/SA and SA/DA for all the subject collectively; it was found that the r value for chronological age with dental age was 0.72 depicting the strong correlation(Table iii). The findings are consistent with the studies conducted by **Różyło-Kalinowska I et al (2011)[20]**, **Bedoya et al (2016)[21]** who also reported the high positive correlation between chronological age and dental age.

On assessing the correlation between chronological, dental and skeletal age with respect to age categories, spearman rank correlation analysis showed the strongest correlation with respect to chronological age and dental age (r = 0.39) for 8-9 years of age group while the correlation of skeletal age with dental age was less than the above (r=0.24), among 10- 11 years of age group, skeletal and dental age exhibited the maximum correlation (r = 0.44); chronological

age with dental age revealed the r value of 0.42 which showed the decreased amount of correlation. For 12 – 13 year of age category, skeletal and dental age revealed the highest correlativity with r value of 0.59 and all the results were statistically significant with the p value less than 0.05 (Table iv). This could be explained by the reason that maximum variation in maturation of cervical vertebrae occurs during the growth period.The study results conducted by **Shilpa PH et al (2013)**[22] are in concordance with the current study which showed the significant accuracy for CA/DA for the age group of 8 -11 years.

A significant difference was observed in total and female gender with respect to age categories during comparison of chronological age, dental age and skeletal age (Table v). The significance is more for females as compared to males. This was in accordance with the studies conducted by **Alkhal et al. (2008)**[3] and **Uyal et al. (2004).**[23]

In our study, result showed the strongest correlation between calcification stage and CVM stage of lateral incisor and canine with the r value of 0.79 & 0.72 respectively and r = 0.68 for both central incisor and first premolar (Table vi). **Perinetti et al.** evaluated the association between dental calcification and skeletal maturation categorizing the skeletal maturation into three categories: pre – pubertal, Pubertal, and post- pubertal periods, indicating that the dental calcification was only useful for diagnosing pre- pubertal growth phase. **Kalinowska et al (2011)**[20]investigated the relationship between Demirjian's method and cervical vertebrae maturation (CVM) method.

CONCLUSION

Following conclusions were drawn from the study:

- The statistically significant correlation between dental and skeletal age suggests that the dental age can be used to predict the skeletal age for orthodontic intervention.
- When compared for sexes, it was found that the correlation between chronological and skeletal age was more for females as compared to males whereas chronological age and dental age was found to be approximately equal for both. But the correlation between dental age and skeletal age was found to be slightly more in male which was statistically significant.

It can be concluded that although various methods of age assessment have been used, the applicability can vary due to the ethnic, racial & geographical variations between individuals and populations. Hence, the maturity standards should be based on studies made on the same population.

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