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Original Article

Dentistry Setion

Correlation between Maxillary Canine Calcification and Skeletal Maturation

SUSHIL KUMAR[1], ABHISHEK SINGHA ROY[2], ANKIT GARG[3], SAEED BIN HAMID[4], SUMIT TYAGI[5], ATISH KUMAR[6]

ABSTRACT

Introduction: Skeletal maturation assessment has a great role in many health professions especially in Orthodontics & Dentofacial Orthopedics. Functional appliances have proved to be more effective when used at the peak of mandibular growth, rather than before.

Aim: The aim of this study was to evaluate whether the calcification stages of permanent maxillary canine are useful to assess skeletal maturity.

Materials and Methods: In this cross-sectional study, samples were derived from panoramic radiographs and lateral cephalograms of 300 subjects (137 males and 163 females) with their age ranging from 9 to 18 years. Dental maturity {Demirjian Index (DI)} and skeletal maturity {Cervical Stages (CS)} were assessed from radiographs. The Pearson chi-square test (χ^2) and Sakoda adjusted Pearson contingency coefficient (C*) were calculated to determine the correlation between DI and CS.

Results: A highly significant association (C* = 0.851, *p*<.001for males and 0.879, *p*<.001 for females) was found between DI and CS. DI stage E coincided with CS2 (pre-peak of pubertal growth spurt) & DI stage F coincided with CS3 (peak of pubertal growth spurt) for all the subjects. DI stage H corresponded to CS5 and CS6 (end of peak of pubertal growth spurt).

Conclusion: A highly significant association was found between DI and CS. Maxillary canine DI stages could be useful to assess skeletal maturity.

Keywords: Calcification stages, Growth, Panoramic radiograph

INTRODUCTION

Skeletal age estimation has a key role in specialty of Orthodontics & Dentofacial Orthopedics, especially when treatment requires orthopedic correction. Growth modification using myofunctional appliances is more effective when used at the peak of mandibular growth, rather than before [1,2]. There are significant variations in development among children of the same age, so chronological age has restricted role in the evaluation of the skeletal maturation [3,4]. Therefore, the role of physiologic or biologic age in assessment of skeletal maturation came in picture. Most commonly used methods for growth evaluation are somatic that is based on the general body changes along with development of the secondary sexual characteristics and the radiological assessment of hand–wrist radiograph [5-7], Cervical Vertebrae Maturation (CVM) [8,9], serial cephalometric methods or panoramic radiographs (dental maturation) [10-14].

Even though CVM method is a reliable method for the evaluation of the growth phase, it requires a lateral cephalometric radiograph, which is not an essential diagnostic record for every patient [15]. Moreover increasing awareness of risks associated with x-rays (keeping in mind ALARA {As Low as Reasonably Achievable} principle) particularly its stochastic effects have led clinicians to re judge the indications of taking a lateral cephalometric radiograph. According to a recent survey, of orthodontists, regarding the routine use of lateral cephalograms, 60.34% practitioners always take this as pre-treatment record and 38.53% always perform a cephalometric "analysis" on pre-treatment lateral cephalograms [16]. In this survey, investigators concluded that in present day orthodontic practice, there is decreased trend towards routinely tracing lateral cephalometric radiographs [16]. Therefore, in contemporary orthodontic practice panoramic radiographs are routinely available and may be useful to assess skeletal maturity.

As a result of this, dental development has frequently been investigated possible predictor of the skeletal maturation as an alternative to hand wrist radiograph or CVM [10-14,17,18]. Generally, the dental maturity can be inferred by either the stage of tooth calcification or the phase of tooth eruption, with the former being more consistent [19,20].

Dental and skeletal maturation correlation also affected by racial variations [3,13,14]. It has been reported that racial variations is caused by certain factors like; predominant ethnic origin of the population, climate, nutrition, socioeconomic levels, and urbanization [21]. Earlier with the same sample size, a study had already been conducted on skeletal maturation evaluation using mandibular second molar calcification stages [10].

The aim of this study was to evaluate whether the calcification stages of permanent maxillary canine are useful to assess skeletal maturity. The null hypothesis with chi-square test will be considered as no correlation exists between the calcification stages of permanent maxillary canine and CVM and both the variables are statistically independent. Null hypothesis will be rejected if the critical value of chi-square will be more than 37.556 with 20 degrees of freedom (*p* 0.01) and the variables will be considered statistically dependent.

MATERIALS AND METHODS

This cross-sectional descriptive study was carried out between April 2016 to September 2016 (6 months) in Department of Orthodontics, Kalka Dental College, Meerut, Uttar Pradesh, India. Pre-treatment digital panoramic and lateral cephalometric radiographs of 300 north Indian orthodontic patients (137 males and 163 females), were analyzed. Sample size calculation for anticipated correlation coefficient was done on the basis of significance level (0.01) and power of the test (80%). The selection criteria were as follows: North Indian with chronological age ranging from 9 to 18 years; no serious illness, congenital abnormalities and syndromes; normal overall growth and development; absence of abnormal dental condition, such as impaction, transposition and missing teeth; absence of previous history of trauma or disease to the face & neck; absence of Orthodontic treatment; none of permanent teeth got extracted; good quality pre-treatment panoramic and lateral cephalometric radiographs, taken at the same day.

Dental Maturity Evaluation on Panoramic Radiograph

In this study, we used the maxillary left canine as a sample. Tooth calcification was scored according to the method described by Demirjian A et al., (Demirjian Index [DI]), in which one of eight stages of calcification (A to H) was assigned to the tooth [Table/Fig-1] [19].

Stage A	Calcification of single occlusal points without fusion of different calcifications.
Stage B	Fusion of mineralization points; the contour of the occlusal surface is recognizable.
Stage C	Enamel formation has been completed at the occlusal surface, and dentine formation has commenced. The pulp chamber is curved, and no pulp horns are visible.
Stage D	Crown formation has been completed to the level of the cementoenamel junction. Root formation has commenced. The pulp horns are beginning to differentiate, but the walls of the pulp chamber remain curved.
Stage E	The root length remains shorter than the crown height. The walls of the pulp chamber are straight, and the pulp horns have become more differentiated than in the previous stage.
Stage F	The walls of the pulp chamber now form an isosceles triangle, and the root length is equal to or greater than the crown height.
Stage G	The walls of the root canal are now parallel, but the apical end is partially open.
Stage H	The root apex is completely closed. The periodontal membrane surrounding the root and apex is uniform in width throughout.

[Table/Fig-1]: Demirjian Index (DI) - Dental calcification stages.

Cervical Vertebrae Maturity Evaluation on Lateral Cephalogram

CVM were evaluated by dividing the second, third and fourth vertebrae into six Cervical Stage (CS) depending on their maturation patterns on lateral cephalogram using the method proposed by Baccetti T et al., [9] [Table/Fig-2].

Cervical stage 1 (CS1)	The lower borders of all the three vertebrae (C2-C4) are flat. The bodies of both C3 and C4 are trapezoid in shape (the superior border of the vertebral body is tapered from posterior to anterior). The peak in mandibular growth will occur on average two years after this stage.
Cervical stage 2 (CS2)	A concavity is present at the lower border of C2 (in four of five cases, with the remaining subjects still showing a cervical stage 1). The bodies of both C3 and C4 are still trapezoid in shape. The peak in mandibular growth will occur on average one year after this stage.
Cervical stage 3 (CS3)	Concavities at the lower borders of both C2 and C3 are present. The bodies of C3 and C4 may be either trapezoid or rectangular horizontal in shape. The peak in mandibular growth will occur during the year after this stage.
Cervical stage 4 (CS4)	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. The peak in mandibular growth has occurred within one or two years before this stage.
Cervical stage 5 (CS5)	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. The peak in mandibular growth has ended at least one year before this stage.
Cervical stage 6 (CS6)	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.

[Table/Fig-2]: Cervical vertebrae maturation stages (CS).

Errors in Method

To minimize the error factors we determined all DI and CS stages in a darkened room with a radiographic illuminator with the unwanted surfaces covered by cardboard to block the light. To test the reproducibility of the assessments of DI and CS, the same two observers' re-evaluated randomly selected lateral cephalogram and panoramic radiographs from 10 of the same male and female subjects two weeks after the first evaluation. Inter-observer and intra-observer agreement for both investigators were determined in terms of the weighted kappa statistics for DI and CS.

STATISTICAL ANALYSIS

All statistical analyses were performed using the Microsoft Office Excel 2013 and statistical software package 'SPSS 22.0 for Windows'. Means and standard deviations of the chronological ages for the CS stages were calculated. To study the relationship between DI and the CS, the frequency and the percentage distribution of the stages of calcification were recorded for each tooth, and these were calculated separately for male and female subjects. Cross-tabular statistics were performed. The Pearson chi-square test (χ^2) value and Sakoda adjusted Pearson contingency coefficient (C*) were estimated to determine the relationships between DI and CS. p-value of <0.01 was considered statistically significant.

RESULTS

All the teeth were in D, E, F, G, H stages of calcification. The reproducibility of all the DI and CS stages were good. For inter-observer agreement, the weighted kappa statistics for DI assessments and CS stages were 0.79 and 0.82, respectively. The kappa statistics for intra-observer agreement were 0.87 for DI assessments and 0.91 for CS stages assessments. It is clear, therefore, that there was almost perfect [22] inter-observer and intra-observer agreement for both DI and CS assessments.

[Table/Fig-3] shows the distribution of sex and chronological ages for all the subjects, grouped by CS stage. Each stage appeared earlier in female subjects than in male subjects.

Stages	Gender	Number of Subjects	Chronological Age (Years) (mean ± SD)	
			Mean	SD
CS 1	Male	11	11.18	0.90
	Female	15	9.45	0.59
CS 2	Male	25	11.56	1.04
	Female	32	10.56	0.58
CS 3	Male	46	12.59	1.14
	Female	52	11.59	0.69
CS 4	Male	22	14.61	0.92
	Female	23	13.30	0.87
CS 5	Male	15	15.81	1.10
	Female	17	14.82	0.91
CS 6	Male	18	17.50	0.45
	Female	24	16.56	1.15
	Total Number of Subjects	300 (137 males and 163 females)		

[Table/Fig-3]: Distribution of chronological ages for all subjects grouped by CS stages.

[Table/Fig-4] shows the associations between DI and CS for male subjects. The value of χ^2 was highly significant at 189.08 with 20 degrees of freedom (p<.001). The value of C* was 0.851 and showed a highly significant association between DI and CS for male participants. From [Table/Fig-4], it is also clear that lower stages of DI were associated with lower CS stages. Again, the higher the DI stage, the higher the CS stage. DI Stage E included the highest percentage distribution (72.00%) at CS2 (pre-peak of pubertal growth spurt). DI Stage F included highest distribution (65.21%) at CS3 (peak of pubertal growth spurt). DI stage G included a highest percentage distribution (77.27%) of CS4 (deceleration of growth spurt) subjects. Stage H displayed a high percent distribution with CS5 (93.33%) and 100% distribution with CS6.

		D	E	F	G	H	Total
CS 1	Frequency	2	4	5			11
	Percentage	18.18%	36.36%	45.45%			100.00%
CS2	Frequency	1	18	5	1		25
	Percentage	4.00%	72.00%	20.00%	4.00%		100.00%
CS3	Frequency			30	16		46
	Percentage			65.21%	34.79%		100.00%
CS4	Frequency			2	17	3	22
	Percentage			9.09%	77.27%	13.63%	100.00%
CS5	Frequency				1	14	15
	Percentage				6.67%	93.33%	100.00%
CS6	Frequency					18	18
	Percentage					100.00%	100.00%
Total	Frequency	3	22	42	35	35	137
	Percentage	2.19%	16.05%	30.65%	25.54%	25.54%	100.00%

[Table/Fig-4]: Association between CS and DI for male subjects (Contingency table).
χ^2 (20) = 189.08; Sakoda's adjusted Pearson's Contingency coefficient (C*) = 0.851; *p*<.001 (Highly Significant)

		D	E	F	G	H	Total
CS 1	Frequency	11	4				15
	Percentage	73.33%	26.67%				100.00%
CS2	Frequency	4	23	5			32
	Percentage	12.50%	71.87%	15.63%			100.00%
CS3	Frequency		1	38	13		52
	Percentage		1.93%	73.07%	25.00%		100.00%
CS4	Frequency			10	13		23
	Percentage			43.47%	56.53%		100.00%
CS5	Frequency				7	10	17
	Percentage				41.18%	58.82%	100.00%
CS6	Frequency					24	24
	Percentage					100.00%	100.00%
Total	Frequency	15	28	53	33	34	163
	Percentage	9.20%	17.18%	32.51%	20.24%	20.86%	100.00%

[Table/Fig-5]: Association between CS and DI for female subjects (Contingency table).
χ^2 (20) = 263.94; Sakoda's adjusted Pearson's Contingency coefficient (C*) = 0.879; p<.001 (Highly Significant)

[Table/Fig-5] shows the associations between DI and CS for female subjects. The value of χ^2 was 263.94 at 20 degrees of freedom (p<.001). The value for C* was highly significant at 0.879, showing a highly significant association between CS and DI for female participants. These values indicate stronger statistical association for female subjects as compare to male subjects. [Table/Fig-5] exhibits that for females lower DI stages consistently associated with lower CS stages, whereas, the higher DI stages, are correlated to higher CS stages. DI Stage E included the highest percentage distribution (71.87%) at CS2. DI Stage F included highest percentage distribution (73.07%) at CS3. DI stage G included a higher percentage distribution (56.53%) of CS4 subjects. Stage H displayed a high percent distribution with CS5 (58.82%) and 100% distribution with CS6.

DISCUSSION

Skeletal maturation can be precisely estimated from various methods, however literature shows conflicting results in relation to dental and skeletal maturation [4,18]. The purpose of this study was to determine whether the calcification of the maxillary canine, was useful for determining skeletal maturation phase.

Dental maturation can be easily estimated from routine panoramic radiographs. If we use specialized radiographs (Hand-wrist radiographs or Lateral cephalograms), we are adding on the radiation exposure time as well as dosage that ultimately puts a question mark on ALARA principle. Since this is very important especially for children and young adults who have proliferating cells in crucial organs, such as thyroid gland, bone marrow and salivary gland, hence limiting the medical professional to assess growth frequently [10]. In addition, the cost of equipments required for taking these specialized radiographs are very high thus making these radiographs expensive too [10].

Previously, it has been reported that there is high correlation between the skeletal maturity indicators and the tooth calcification stages, therefore panoramic radiograph may be easily utilized for identifying the stages of the pubertal growth period [10-14,17,18,21]. On the other hand, a few studies have reported skeletal and dental maturation stages are poorly correlated [23,24]. This discord among the outcomes of earlier studies to some extent may be because of dissimilar methods used to evaluate skeletal and dental development. Racial variations also affect the relationship between dental and skeletal maturity [3,13,14].

Previously, it was reported DI stages from panoramic radiographs might be clinically useful as a skeletal maturity indicator and the mandibular second molar calcification stages showed the highest correlation with skeletal maturity stages [10,11,13,14].

In this study, we used the maxillary canine as a sample because most of the times, this tooth erupts at the same time or a little bit earlier than the mandibular second molars [11]. Maxillary canine is the last tooth, which erupts after loss of primary tooth in the upper arch and complete the period of mixed dentition [11]. Mandibular teeth were usually preferred for calcification stages evaluation in previous studies because the upper molar roots are overlapped with anatomic structures such as the palate, the inferior border of the zygomatic arch or the maxillary sinus septum [25]. Therefore, it is difficult to observe the roots of upper posterior teeth, but the roots of maxillary canines have good visualization as compared to other maxillary teeth and DI stages can be easily estimated [11].

It has been argued that dental eruption, which is most evident and easily identifiable dental maturity indicator, is inconsistent in its timing than skeletal maturation [20]. It has also been reported that the upper permanent canine can erupt at any stage between CS1 to CS4 [26]. It has been reported that the dental eruption is more inconsistent than the appearance of calcification stages of dentition [20]. In the current study, we considered DI stages of teeth instead of eruption because calcification stages are anticipated as more reliable criteria for assessing dental maturation [20]. Therefore, tooth calcification stages was scored using the method described by Demirjian et al., [19]. Demirjian's method exhibits high precision when used to north Indian population [27]. This method's criteria consist of distinctive details of shape of root and root length in proportion to relative crown height, instead of absolute length. Thus, foreshortened or elongated projections of developing teeth will not influence the consistency of estimation [28]. It has been confirmed that Demirjian's method illustrates the least intra-examiner and inter-examiner errors and is highly correlated with biological age [10,29].

In our study each cervical stage consistently appears earlier in females than in males and this observation is in line with earlier studies [10,14,28] [Table/Fig-3]. Association between CS and DI is considered independently for male and female subjects. The findings of Kumar S et al [10], Srkoc T et al., Krailassiri S et al., signifies that DI stages in male subjects tend to be ahead as compared with female subjects in relation to cervical stages [14,28]. In this study, we also observed that at the same cervical stage, males had a more advanced trend in DI, as compare to female subjects.

Findings from the study done on Indian subjects by Sachan K indicated that correlation between cervical vertebrae maturation indicator and maxillary and mandibular canine calcification is good for both males and females and canine calcification stages can used for assessing skeletal maturity [30]. In a recent study [11] on

Caucasian population again it was concluded that calcification stages of upper canine and mandibular second molar could be indicator of growth stage. The findings of present study are in concordance with these studies.

This study revealed very highly significant association between the DI of maxillary canine and the cervical stages [Table/Fig-4,5]. For both the sexes, DI Stage E demonstrates the highest percent distribution at CS2 that signifies pre-peak of mandibular growth spurt. It has been reported [4,6,7,31] that there is a relationship between skeletal maturity and Peak Height Velocity (PHV). Fishman, Hagg U & Bjork A, Alkhal HA et al., found appearance of adductor sesamoid of thumb marks the beginning of pubertal growth spurt (onset of PHV) which corresponds to CS3 [6,7,31,32]. In present study for both male and female subjects, Stages F correspond to CS3 which infers DI stages F represent peak of pubertal growth spurt. This finding supports the suggestions of previous studies [10,14]. DI Stage H displayed higher percent distribution with CS5 and 100% distribution with CS6. DI stage H suggests insignificant / no remaining adolescent growth.

These significant findings from the study implies that the maxillary canine calcification stages from panoramic radiographs gives fairly accurate results and maxillary canine DI stages could be useful to assess skeletal maturation with the methodology suggested by Demirjian A et al., [19].

LIMITATION

In our opinion, the limitation of this study is that sample was derived from the patients reported to single centre only, which might not have covered the ethnic and racial variability of the north Indian population hence multicentre study may be recommended in the future.

In future, correlation studies can also be done between dental calcification stages of maxillary canine and Insulin like Growth Factor -1(IGF-1) levels to further strengthen the validity of maxillary canine DI stages as skeletal maturity indicator.

CONCLUSION

A highly significant association was found between maxillary canine DI stages and CS. Maxillary canine DI stages could be useful to assess skeletal maturity. Identifying skeletal maturation with panoramic radiographs using only one tooth could facilitate decision by the orthodontist as a valid clinical complementary tool to assess skeletal maturity and mandibular growth, which could reduce the need for specialized radiographs.

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PARTICULARS OF CONTRIBUTORS:
1. Professor and Head, Department of Orthodontics and Dentofacial Orthopedics, Kalka Dental College, Meerut, Uttar Pradesh, India.
2. Reader, Department of Orthodontics and Dentofacial Orthopedics, Kalka Dental College, Meerut, Uttar Pradesh, India.
3. Senior Lecturer, Department of Orthodontics and Dentofacial Orthopedics, Kalka Dental College, Meerut, Uttar Pradesh, India.
4. Senior Lecturer, Department of Orthodontics and Dentofacial Orthopedics, Kalka Dental College, Meerut, Uttar Pradesh, India.
5. PG Student, Department of Orthodontics and Dentofacial Orthopedics, Kalka Dental College, Meerut, Uttar Pradesh, India.
6. PG Student, Department of Orthodontics and Dentofacial Orthopedics, Kalka Dental College, Meerut, Uttar Pradesh, India.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:
Dr. Sushil Kumar,
150/21, Panchsheel Colony, Sonepat-131001, Haryana, India.
E-mail: docshilu@yahoo.com

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