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Comparison of Dental mineralization stages using orthopantomogram (OPG) and Skeletal maturation using hand wrist radiographs during Pubertal growth period

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ABSTRACT

Introduction: Skeletal maturation is assessed from the analysis of cervical vertebral maturation using lateral cephalograms and analysis of bones in the Hand and wrist regions using hand wrist radiographs. which give an insight into the underlying dental and skeletal conditions of malocclusion and to some extent the skeletal maturation of the individual through cervical vertebral maturation and thereby facilitate the determination of the dental age.

Aims and Objectives: The present study aims to determine the correlation between dental mineralisation stages and skeletal maturation in determining the pubertal growth period by studying OPG and hand wrist of 600 samples in South Indian population.

Materials and methods: A total of 600 samples were selected in the age group between 7 to 17 years. OPG and Hand-wrist radiographs were taken using SIRONA Orthophos XG 5 DS/Ceph for all the samples the skeletal maturation and dental mineralization stages were analysed. The means of the chronologic ages for both the sexes in three periods of skeletal maturation was analysed by 2-way analysis of variance (ANOVA) and post hoc tukey test. And the analysis of ordinal multinomial logistic regression to evaluate the which teeth had the mineralization association to skeletal maturation.

Results: Mineralization stages of teeth at the Peak of Pubertal growth period for boys were seen in mandibular canine stage G and second molars. For girls, the stage G were seen in mandibular canine and first premolar, other teeth with higher percentage of distribution was seen in mandibular second molar but as the tooth was not statistically significant it was neglected.

Conclusion: It is concluded that dental mineralization stages studied from Orthopantomogram (OPG) a routine diagnostic tool can be used to determine the

skeletal maturation of the individual thereby reducing the additional radiation exposure to the patient.

Keywords: *Dental Mineralization, Skeletal maturation, Tooth mineralisation, Pubertal growth*

1. INTRODUCTION

Change is the law of nature and human beings are no exception to change. During their lifetime, they change in size, appearance and even psychologically. This change differs from individual to individual. However, the fundamental underlying patterns of growth are all the same. The various processes by which a germinating seed or conceived organism is turned into a mature plant or full-fledged human is collectively termed growth and development. Growth is usually measured

by physical appearances such as height, weight; all of which are pre- determined by the genetic backup of the individual, which he or she receives from the parents and that which is encoded into their DNA. Growth does not occur at the same pace and at same time for all, it varies based on the influence of environmental factors. In daily life one can witness the variations from lean and undernourished to obese and over nourished individuals.

The knowledge of growth is important for any clinician to differentiate normal growth from growth abnormalities and to understand the underlying reason can be useful for planning any growth modification treatment. Any modification in the growth of an individual to correct the underlying malocclusion should be undertaken during the period of growth spurts. Period of accelerated growth is called growth spurts, but there is difference in the age observed between females and males. Females mature earlier than males[1,2].

Growth spurts occurs at various periods in life just before birth, one year after birth, during the mixed dentition period and pre-pubertal age. Pre-pubertal growth spurt brings about multitude of changes in the human body and is ideal for correction of malocclusion using growth modification like myofunctional appliance. Though the chronological age of an individual gives an overall status of growth, it is not a reliable indicator of maturation[3]. To

understand the individual skeletal maturation, to know the ideal time for growth modification and to determine the amount of growth remaining we need methods of growth prediction.

Growth prediction methods have been classified into measurement approaches and experimental approaches. Measurement approaches are Implant radiology[4] and vital staining whereas experimental approaches are Craniometry, Anthropometry, Cephalometric radiology and Three-dimensional imaging. The use of the above methods though helpful had an increased level of invasiveness causing discomfort to the patient and is time consuming, to overcome these disadvantages the use of X-rays proved useful.

X-rays used in orthodontics are mostly Orthopantomogram (OPG) and Lateral Cephalogram which give an insight into the underlying dental and skeletal conditions of malocclusion and to some extent the skeletal maturation of the individual through cervical vertebral maturation and thereby facilitate the determination of the dental age.

Demirjian[5], Nolla's[6] have proposed their methods to study the dental maturation of an individual by studying the individual tooth maturation and determine the dental age. Demirjian A, et al[5] conducted a study on fifty subjects from the French-Canadian population to determine the dental maturation stages using OPG. The teeth were scored based on the developmental criteria like shape change of the pulp chamber and dentinal deposition. The teeth on the left side of the mandible from the central incisor to the second molar teeth were considered. The dental maturation was calculated by measuring the individual tooth score for each stage and the summed scores of all seven teeth gives the dental age.

Skeletal maturation is assessed from the analysis of cervical vertebral maturation using lateral cephalograms and analysis of bones in the Hand and wrist regions using hand wrist radiographs. Hand wrist radiograph is commonly used due to the ease in taking radiograph and the wide region available for assessment and reliability. Hand wrist radiographs have been used to detect skeletal maturation stages by analysing the small bones of the hand and wrist region.

Researchers like Fishmann[7], Grave and Brown[8], have proposed their methods of assessment of the bones in the hand and wrist region.

A.Bjork[9] and S.Helm conducted a study on Danish children and concluded that there was a close relationship between ossification of the ulnar sesamoid of the thumb. Leonard S. Fishman7 conducted a study to evaluate a new system for evaluation of the skeletal maturation by assessment of hand wrist radiographs and concluded that hand wrist radiographs can be used to determine the skeletal maturation of the individual.

Seymour chertkow[10], Christer Engstrom[11], Goyal et al[12], have suggested the possibility of using tooth maturation as an indicator of the pubertal growth period. Christer Engstrom[11] conducted a study on the lower molar development in relation to the skeletal maturity and found a strong correlation between third molar development and skeletal age and concluded that third molar can be used as a reliable tool for determination of skeletal maturation.

Hence, the present study aims to determine the correlation between dental mineralisation stages and skeletal maturation in determining the pubertal growth period by studying OPG and hand wrist of 600 samples in South Indian population.

2. MATERIALS AND METHODS

The samples were selected from the out patients visiting the J.K.K.Nattraja Dental college, Komarapalayam. A total of 600 samples were selected in the age group between 7 to

17 years. OPG (Fig-2) and Hand-wrist radiographs (Fig-3) were taken using SIRONA Orthophos XG 5 DS/Ceph (Fig-1) for all the samples the skeletal maturation and dental mineralization stages were analysed. Institutional ethical committee reviewed and approved the study. Informed consent was obtained from the parents or guardians of the children. Patients who

are 7 years to 17 years old with no previous history of orthodontic therapy and patient who are willing to take OPG and Hand-wrist radiographs were included in the study.

Patients with congenitally missing teeth, cleft lip or palate, Patients with history of any previous orthodontic therapy, Patients with debilitating diseases and Patients with poor periodontal condition were excluded from the study

Method of Assessment:

OPG and Hand-wrist radiographs were obtained from all the samples selected and the radiographs were assessed on **HP-Pavilion 15 Notebook PC** with a Screen size of **15.6 inches** and with a resolution of **1366*768** using **Windows Photo Viewer** software and the investigator was permitted to use zoom tool and change the contrast if needed. The panoramic radiograph and the hand-wrist radiograph were analysed separately.

Dental calcification:

Dental calcification stages were studied by using Orthopantamogram (OPG) analysing the teeth present on the left side of the mandibular arch and assessed using Demirjian et al[8] method. Tooth calcification stages were designated from stage A to stage H based on the development criteria like dentinal deposition, shape change of the pulp chamber; calcification of tooth from single occlusal points to root apical closure were analysed. The values for each stage were calculated separately and were summed up to give the dental maturity score of the individual which gives the dental age of the individual. The present study was performed with a slight modification on the original method proposed by Demirjian et al. The study was performed on mandibular canine, mandibular first premolar, mandibular second premolar and mandibular second molar to determine the dental mineralisation stages. The tooth with the highest correlation to skeletal maturation was identified.

Skeletal maturation:

Skeletal maturation was assessed from hand-wrist radiograph using Grave and Brown method9. This method studied skeletal maturation using the left hand of the individual and classified it into fourteen stages of bone ossification categorizing them into three growth

periods; Onset, Peak and End of pubertal growth spurt. Stages were designated on the basis of the ossification events occurring at various points in the hand wrist. Epiphyseal events like epiphysis as wide as the diaphysis , epiphysis capping and union of the epiphysis and diaphysis are studied on the first, second, third fingers and radius. Other events studied included the hooking of the hamate and appearance of the pisiform. The onset, peak and end of the pubertal growth spurt were studied by using the indicators like appearance of the pisiform for onset of puberty, Epiphysis capping the diaphysis in radius bone for peak of the pubertal period, and fusion of the epiphysis and diaphysis of the radius bone for the completion of the pubertal growth period.

Statistical analysis:

The measured data obtained from the analysis of the Orthopantamograms and hand wrist radiographs were measured and tabulated separately and evaluated statistically by using SPSS (Statistical Package for Social Sciences) 21.0 software. The means of the chronologic ages for both the sexes in three periods of skeletal maturation was analysed by 2-way analysis of variance (ANOVA) and post hoc tukey test. And the analysis of ordinal multinomial logistic regression to evaluate the which teeth had the mineralization association to skeletal maturation. **Results:**

The results showed differences between the sexes of the sample ($P < 0.05$) and between the skeletal maturation periods ($P < 0.05$). A consistent early occurrence of each skeletal maturation stages were observed in girls when compared to boys. The mean chronologic age for girls was approximately 1.6 years (range 1.5-1.7 years) younger than the boys (Table I).

Table I: Chronologic age of males and females based on skeletal maturation

Maturation Event	**Number of subjects**		**Chronologic age, mean (SD)**	
	Male	**Female**	**Male**	**Female**
Onset	118	68	11.09 (2.19)	9.57 (1.93)
Peak	99	59	13.03 (1.58)	11.31 (2.12)

End	77	179	15.10 (1.94)	13.41 (2.28)

Table II: Results of ordinal multinomial logistic regression analysis for male

Variable	Estimate	SE	Wald chi-square	P value	OR	95% CI
Canine	1.403	0.491	8.171	0.004	4.069	1.554-6.649
First Premolar	0.772	0.648	1.423	0.233	2.165	0.608-7.702
Second Premolar	0.244	0.526	0.215	0.643	1.276	0.455-3.577
Second Molar	0.908	0.352	6.659	0.010	2.481	1.244-4.946

The results reveal mandibular canine and mandibular second molar were statistically significant predictors for males (P <0.05), the odds ratio was 4.069 (P value-0.004) for mandibular canine suggesting that mineralization of the tooth can predict the skeletal maturation four times more than any other tooth (Table II & Table III).

The other tooth with statistically significant correlation was seen in mandibular second molar; Odds ratio of 2.481 (P value-0.010), suggesting that the second molar is 2.5 times more reliable for prediction of skeletal maturation than other teeth. Similarly, the statistically significant correlation was observed in relation to mandibular canine and mandibular first premolar for females. The results suggest that mandibular canine odds ratio 1.729 and for mandibular first premolar odds ratio was at 1.715.

Table III: Results of ordinal multinomial logistic regression analysis for female

Variable	Estimate	SE	Wald chi-square	P value	OR	95% CI
Canine	0.547	0.358	2.344	0.012	1.729	0.858-3.483
First Premolar	0.539	0.457	1.390	0.023	1.715	0.700-4.203
Second Premolar	0.67	0.42	2.539	0.111	1.954	0.857-4.454
Second Molar	0.334	0.309	1.170	0.279	1.397	0.762-2.560

There was a wide range of distribution of the mineralization stages in all teeth for both the sexes. The dental maturation stages with most reliable predictor was observed in stage F of the mandibular canine and mandibular second molar for boys. For girls, stage F of the mandibular canine and first premolar was seen as a reliable predictor of maturation.

Table IV: Distribution of mineralization stages of teeth at the Onset of Pubertal growth period

Dental Maturation Stages	Canine		First Premolar		Second Premolar		Second Molar	
	Male	Female	Male	Female	Male	Female	Male	Female
C				3.20%		2.20%	5.20%	6.10%
D	1.00%	4.50%	9.20%	10.10%	11.30%	14.60%	21.60%	27.00%
E	10.30%	15.70%	20.60%	24.60%	25.80%	21.30%	9.30%	9.00%
F	36.00%	37.60%	22.70%	36.00%	26.80%	23.70%	44.30%	34.30%
G	32.00%	22.50%	35.10%	15.70%	27.90%	30.30%	18.60%	18.00%
H	20.70%	19.70%	12.40%	10.40%	8.20%	7.90%	1.00%	5.60%

Table V: Distribution of mineralization stages of teeth at the Peak of Pubertal growth period

Dental Maturation Stages	Canine		First Premolar		Second Premolar		Second Molar	
	Male	Female	Male	Female	Male	Female	Male	Female
D						2.70%	1.20%	5.00%
E	1.30%	1.20%	4.80%	5.30%	4.70%	7.10%	5.30%	9.60%
F	8.00%	9.60%	12.50%	13.30%	17.30%	20.00%	21.70%	26.70%
G	60.00%	56.70%	33.30%	44.10%	35.30%	33.90%	54.50%	45.40%
H	30.70%	32.50%	49.40%	37.30%	42.70%	36.30%	17.30%	13.30%

Mineralization stages of teeth at the Peak of Pubertal growth period for boys were seen in mandibular canine stage G and second molars. For girls, the stage G were seen in mandibular canine and first premolar, other teeth with higher percentage of distribution was seen in mandibular second molar but as the tooth was not statistically significant it was neglected.

Mineralization stages of teeth at the End of Pubertal growth period for boys, stages H of the mandibular canine and the second molar had higher percentage of distribution. For girls, higher distribution was observed in stage H of mandibular canine and first premolar.

Table VI: Distribution of mineralization stages of teeth at the End of Pubertal growth period

Dental Maturation Stages	Canine		First Premolar		Second Premolar		Second Molar	
	Male	Female	Male	Female	Male	Female	Male	Female
F		1.50%		4.40%	3.30%	8.20%	13.10%	18.60%
G	8.20%	13.40%	16.40%	17.20%	18.90%	17.90%	28.70%	29.90%
H	91.80%	85.10%	83.60%	78.40%	77.80%	73.90%	58.20%	51.50%

3. DISCUSSION:

Correction of skeletal malocclusion during growth period can be achieved by growth modification. Growth modification using myofunctional appliance and orthopaedic appliances is mainly dependent on the timing of the pubertal growth spurt. It is during the pubertal growth period that an individual exhibits highest growth potential, but the timing varies between individuals. Chronologic age though a common indicator of the maturation, does not provide accurate information due to influence of factors like climate, ethnic origin, nutrition, genetic and environmental factors, hence it would be useful to understand the developmental age[45]

The present study is conducted on six hundred samples from the south Indian population to determine the pubertal growth period by studying the correlation between dental maturation stages studied from panoramic radiographs and skeletal maturation stages from hand-wrist radiographs.

The mean chronological age for each skeletal maturation level indicates that in each stage of development females preceded males. (Table I) A.Bjork[7] reported that the maximum pubertal growth in girls preceded males by approximately eighteen months, the appearance of the ulnar sesamoid also was seen advanced in females by twenty one months. Chapman19 also reported that ossification of the adductor sesamoid appeared in females approximately one year earlier than males. S.Mittal et al[45] reported that females maturation was consistently earlier than males in all stages of maturation.

Highest correlation between the skeletal maturation and dental maturation stages was observed in mandibular canine (Pvalue-0.004<0.05 for males and 0.012<0.05 for females) for both the sexes in south Indian population. This result is in accordance with the works done by B.Rai et al[43], Uysal et al[37], Seymour Chertkow[10], Chertkow and Paul Fatti[21]. Seymour Chertkow[10] from his study concluded that the calcification of the mandibular canine can be used as reliable tool

for assessment of skeletal maturation. Reshma Nayak[51] found that a high correlation existed between mandibular canine calcification and MP3 stage.

Other tooth with significant correlation were the second molars in males and first premolars in females. The first premolars (Pvalue-0.023<0.05) in girls showed significant correlation in females, results are in accordance with the results given by Sharmila surendran[72] they found stage E of the first premolars showed correlation to pre-pubertal growth period and second molar had highest correlation to post-pubertal growth period.

The second molar (Pvalue-0.010<0.05) Table-ii showed a significant correlation in boys, the results are in accordance with the results of Sushil kumar et al[51] study on Indian population and Krailassiri et al[34] study on Thai population. Vijayashree et al[70] found that there was a high positive correlation between the mandibular second molar calcification and skeletal maturation and suggested that mandibular second molar can be used as a reliable tool for skeletal maturation assessment.

Tooth mineralisation relative to the stages of skeletal maturation is considered separately for both sexes for determination of the pubertal growth period. Hagg[3] and Bjork[9] found ossification of the adductor sesamoid in relation to the onset of the pubertal growth period. Seymour Chertkow[10] found the relationship between mandibular canine calcification prior to apical closure and appearance of the ulnar sesamoid which indicated the circumpubertal growth period.

Tooth mineralisation stages that have correlation to skeletal maturation was observed in stage F for mandibular canine (36.00%) and mandibular second molar (44.30%) in Table-iv for males the results are in accordance with Reshma nayak et al[51] and Sandra Coutinho et al[29] whose results show that stage F of the canine had higher correlation to onset of the pubertal growth period.

Pubertal growth period is observed with relation to stage G (60.00%) in mandibular canine and second molars (54.50%) which are in accordance with the results published by Sushil kumar et al[65] and B.Rai et al[43] which suggested stage G of the canine coincided with the pubertal peak period.

The end of the pubertal growth period was found in relation to stage H of mandibular canine (91.80%) and mandibular second molar (58.20%) similar results were obtained from the studies done by Vijayashree et al[70] who found that stage H of the second molar coincided with end of the pubertal growth period. Reshma nayak et al[51] found that stage H of the canine coincided with end of the pubertal growth period.

For females the onset of the pubertal growth period was correlated to Stage F of the mandibular canine and first premolar which is in accordance with the results of the study by Perinetti et al[85] on Italian population which suggested stage E to be correlated to the onset of the pubertal onset the difference in stages may be attributed to the environmental and local factors.

During peak of the pubertal growth the stages G of the canine (56.70%) and first premolar (44.10%) are statistically significant, they are in close relation to the results of Vijayta Yadav et al[86] which suggested Stage G of the first premolar to the peak of the pubertal growth. End of the Pubertal growth was significant with stages H of the mandibular canine (85.10%) and mandibular first premolar (78.40%).

The current study results suggest that there exists a relationship between dental maturation and skeletal maturation stages. It also found that dental maturation stages can be used as a reliable tool for identification of skeletal maturation in individuals, but one must also consider the racial variations and environmental changes. The study results reveal that skeletal maturation of females was advanced than males by an average of 1.6 years in all three stages of skeletal maturation.

These results also suggest that any growth modification therapy like myofunctional appliances, orthopaedic appliances must be initiated for females at a younger age when compared with males. The study results suggest that dental maturation stages can be used as a reliable tool for identification of pubertal growth period.

4. CONCLUSION:

There is a correlation between dental maturation and skeletal maturation stages in determining the pubertal growth period. On comparison of chronological age the females preceded males in all three stages of skeletal maturation by approximately 1.6 years. From the current study, it is concluded that dental mineralization stages studied from Orthopantamogram(OPG) a routine diagnostic tool can be used to determine the skeletal maturation of the individual thereby reducing the additional radiation exposure to the patient.

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