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INTERRELATIONSHIP BETWEEN DENTAL DEVELOPMENT, SKELETAL MATURITY AND CHRONOLOGICAL AGE IN SAUDI MALE CHILDREN

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ABSTRACT

Assessment of skeletal maturity and dental development is a common clinical practice in many health professions. **Aims** of this investigation were: 1) to test the applicability of the Demirjian[46] method for dental age assessment and Greulich and Pyle[47] atlas method for assessment of skeletal maturity to the Saudi male children; 2) to study the relationship between dental development, skeletal maturity and chronological age in Saudi male children; and 3) to study the association between the dental maturity markers and the skeletal maturity stages in Saudi male children. **Materials and Methods**: The sample consisted of panoramic and hand-wrist radiographs of 148 Saudi male children between 9 and 15 years of age. Demirjian[46] method was used to estimate the dental age through the assessment of different calcification stages of the left mandibular dentition. Skeletal age was determined using Greulich and Pyle[47] atlas and skeletal maturity stage was established utilizing Björk's[21] skeletal maturity indicators. **Results**: Paired sample T-test revealed no significant difference between the mean dental, skeletal and chronological age. Tendency toward late skeletal maturation and early dental maturation was observed. Spearman rank order test showed high correlation between skeletal maturity markers and dental maturity markers of the 1st premolar (r=0.729) and 2nd molar (r=0.720). **Conclusion:** chronological age is a reasonable indicator of the dental and skeletal maturation in Saudi male children. The dental maturation stage of the left mandibular 1st premolar and 2nd molar can be used to predict the skeletal maturity stage in Saudi male children. The skeletal maturity rate of Saudi male children is analogous to previously reported rates in other groups with different ethnic backgrounds.

INTRODUCTION

Malocclusion is a highly prevalent trait among different populations[1-8]. It has been estimated that over 60% of Saudi children require orthodontic treatment related to one or more of malocclusion features[9]. Bimaxillary protrusion and Class III type of malocclusion were reported to be more prevalent among Saudi population than in Western communities[10]. Moreover, Class II malocclusion has been found generally to be more prevalent than the Class III type in the surveyed populations[6,11-12]. Skeletal mal-relationships in the facial region are commonly caused by differential growth potential of different skeletofacial components[13]. For example, 60% of patients demonstrating Class II skeletal pattern were found to have a mandibular skeletal

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retrusion relative to the maxilla and the cranial base[14]. Orthopedic intervention to influence the differential growth potential of skeletal components of the maxillo-mandibular complex is a commonly practiced treatment modality[15-17].

Timing of the orthopedic growth modification therapy is typically linked with the individual's peak of skeletal maturity to maximize the growth potential[18,19]. Generally, it has been the consensus that chronological age is regarded as a poor indicator of the skeletal development due to significant individual's variability[20]. Currently, few diagnostic tools are available for the clinician to forecast the occurrence of the patient's growth spurt in order to efficiently administer the planned interventional orthopedic therapy for optimum clinical outcome. Among the diagnostic tools available, hand-wrist radiographs have been used extensively and reliably to assess the skeletal maturity and predict the pubertal growth spurt[21-24]. Several other markers have been investigated for their ability to estimate the overall physiological maturity of the individual[25-29]. For most developmental indicators, the correlation with chronological age is considered acceptable[30].

Dental development has been widely investigated as a potential predictor of the skeletal maturity level[30-38]. Generally, the dental development can be assessed by either the phase of tooth eruption or the stage of tooth calcification, with the latter being more reliable[39,40]. The ability to assess skeletal maturity by the developmental stage of the dentition through the examination of a panoramic radiograph (orthopantomograph) offers several advantages over the conventional hand-wrist radiographic method. Generally, dental professionals are more familiar with the stages of dental development than with the skeletal maturity indicators present in the hand-wrist radiograph. Also, no additional exposure to radiation would be necessary if skeletal maturity can be assessed through routinely taken panoramic radiographs. Several investigations have evaluated the association between dental maturity and chronological age in different populations[31,33-35,38,41-44]. The relationship between skeletal maturity and the chronological age for Saudi male children has been recently established[45]. However, no previous attempts have been reported to investigate the association between dental maturity and skeletal and/or chronological ages in Saudi population.

The aims of the present study were: 1) to test the applicability of the Demirjian[46] method and the Greulich and Pyle[47] atlas to the Saudi male children, 2) to establish the relationship between dental, skeletal, and chronological ages in the study sample, and 3) to find the best dental maturity indicator of the skeletal maturity stage in the study sample.

SUBJECTS AND METHODS

The study represents a cross-sectional descriptive investigation. Panoramic and hand-wrist radiographs of 148 Saudi male children were obtained from the initial records of patients attending the dental clinics of the College of Dentistry at King Saud University in Riyadh, Saudi Arabia. The inclusion in the study was set to include only those children who presented with the following criteria:

(1) Chronological age ranging from 9 to 15 years.

(2) Free of any serious illness.

(3) normal overall growth and development

(4) no abnormal dental condition, e.g. impaction, transposition and congenitally missing teeth.

(5) no previous history of trauma or disease to the face and the hand-wrist region.

(6) no history of orthodontic treatment.

The assessment of dental maturation from the panoramic radiographs was based on the

left mandibular teeth and following the method described by Demirjian et al.[46], in which eight stages of calcification from A to H are described for each tooth:

Stage A: In both uniradicular and multiradicular teeth, a beginning of calcification is seen at the superior level of the crypt. No fusion of these calcified points can be observed.

Stage B: Fusion of the calcified points forms one or several cusps which unite to give a regularly outlined occlusal surface.

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. In molars, the radicular bifurcation has started to calcify.

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. In molars, the bifurcation has developed sufficiently to give roots a distinct form.

Stage G: The walls of the root canal are now parallel, but the apical end is still partially open.

Stage H: The apical end of the root canal is completely closed and the periodontal membrane is uniform around the root and the apex.

After assignment of a dental maturation stage for each tooth in the left mandibular quadrant, stages were converted to scores through a conversion table and then a total score was calculated for each subject. Dental age was determined by comparing the total score of each subject with established norm tables, as described by Demirjian et al.[46].

The stage of skeletal maturation for each hand-wrist radiograph was assigned according to the method described by Björk[21]. The following selected ossification events were described:

PP2 Stage: Epiphysis of the proximal phalanx of the second finger equals its diaphysis.

MP3 Stage: Epiphysis of the middle phalanx of the third finger equals its diaphysis.

S stage: First mineralization of the ulnar sesamoid bone.

$MP3_{cap}$ *Stage:* Epiphysis of the middle phalanx of the third finger caps its diaphysis.

$DP3_{u}$ *Stage:* Visible union between epiphysis and diaphysis of the distal phalanx of the third finger.

$MP3_{u}$ *Stage:* Visible union between epiphysis and diaphysis of the middle phalanx of the third finger.

In the present study, a pre-PP2 stage has been assigned to any subject who has not reached the PP2 stage (width of the epiphysis of the proximal phalanx of the second finger is not yet equal to the width of its diaphysis).

Radiographic assessments for dental and skeletal maturity were performed simultaneously using an illuminated viewing box in a dark room by two trained dentists, with a single examiner performing all the dental maturation assessment while the other was assessing the skeletal maturity stage of all hand-wrist radiographs.

Skeletal age for each subject was determined using Greulich and Pyle's radiographic atlas of skeletal development of hand and wrist[47]. The chronological age for each subject was obtained by

referring to the birth date in the personal information section of each patient's chart. For all subjects, panoramic and hand-wrist radiographs were taken on the same day that chronological age for each subject was documented in the chart. All readings related to the study were recorded in a special form designed for that purpose.

Statistical Analysis

All statistics were performed using the SPSS software package (version 10, SPSS Inc., Chicago, IL, USA). All subjects were divided into groups according to the chronological age and descriptive statistics were obtained by calculating the mean and standard deviation of the chronological age, skeletal age and dental age for the different age groups and for the different skeletal maturity stages.

To test the reliability of the dental and skeletal assessment, each examiner re-evaluated 17 randomly-selected panoramic and hand-wrist radiographs of the same subjects. The correlation between first and second assessments was determined using Spearman Brown formula.

The significance of the difference between the means of different ages was determined using a paired-sample T-test. Pearson's correlation between means of different ages was also calculated.

To study the relationship between the stage of dental and skeletal maturation, the distribution percentage of the stages of calcification for each tooth was calculated.

The Spearman's rank-order correlation coefficient was estimated to measure the association between skeletal maturational indicators and dental calcification stages of individual teeth and the statistical significance of the correlation was determined. Spearman's rank order test was also used to measure the correlation between skeletal maturity stages and the skeletal, dental, and chronological ages.

RESULTS

Reliability of Method

Spearman Brown correlation test showed high intra-examiner reliability for assessment of dental maturation from the panoramic radiograph, skeletal maturity stage from hand-wrist radiographs, and skeletal age determination using the atlas method, with coefficient values of 0.93, 0.98 and 0.99, respectively.

Interrelationship among dental, skeletal and chronological age

Sample distribution among various chronological age groups is shown in (Figure 1). The mean chronological, skeletal and dental ages for all groups combined were 11.92±1.49, 11.54±2.11 and 12.03±2.17, respectively (Table 1). No statistically significant difference at the level of ($p<0.05$) between means of chronological, skeletal and dental ages has been detected when paired-sample T-test was applied. Also, Pearson's correlation test demonstrated high correlation between chronological, skeletal and dental ages (Table 2).

Relationship between dental and skeletal maturity markers

The highest correlation between the dental maturation and the skeletal maturity stage was found in the 1st PM, followed by the 2nd Molar (Table 3). The linear association between the dental maturity stage of these two teeth and the skeletal maturity stages is demonstrated in Figure (2) and (3), respectively.

Association between skeletal maturity stage and age type

The mean chronological, skeletal and dental age at different skeletal maturity stages is presented in Table (4) and the relationship between skeletal maturity stages and the chronological age is plotted in Figure (4). The highest correlation was found between the skeletal maturity stages and the skeletal age, followed by the chronological age and the dental Age (Table 5).

Table (1). Mean and standard deviation of skeletal and dental age for different chronological age groups.

Age Group	9 yrs	10 yrs	11 yrs	12 yrs	13 yrs	14 yrs	15 yrs	Total
Skeletal age								
N	5	24	31	36	29	16	7	148
Mean	9.000	9.167	10.532	11.681	12.707	13.719	15.357	11.537
Std. Dev.	0.707	1.544	1.402	1.364	0.882	1.366	1.406	2.118
A-S	0.000	0.833	0.468	0.319	0.293	0.281	-0.357	0.382
P value	1.000	0.015*	0.073	0.169	0.084	0.423	0.526	0.001*

Age Group	9 yrs	10 yrs	11 yrs	12 yrs	13 yrs	14 yrs	15 yrs	Total
Dental age								
N	5	24	31	36	29	16	7	148
Mean	10.18	10.158	10.632	12.028	13.020	14.750	15.843	12.039
Std. Dev.	0.646	1.050	1.078	1.272	1.782	2.010	1.705	2.176
A-D	-1.180	-0.158	0.368	-0.028	-0.020	-0.750	-0.843	-0.120
P value	0.015*	0.468	0.067	0.896	0.951	0.156	0.239	0.315

Age Group	9 yrs	10 yrs	11 yrs	12 yrs	13 yrs	14 yrs	15 yrs	Total
Skeletal vs. Dental								
N	5	24	31	36	29	16	7	148
S-D	-1.180	-0.992	-0.100	-0.347	-0.313	-1.031	-0.486	-0.502
P value	0.075	0.002*	0.691	0.091	0.257	0.014*	0.322	<0.001*

N: number, A-S: Chronological Age vs. Skeletal Age, A-D: Chronological Age vs. Dental Age, S-D: Skeletal Age vs. Dental Age

Table (2): Pearson's correlation among chronological, skeletal and dental ages.

		Skeletal Age	Dental Age
Age	Pearson Correlation	.790	.748
	P value	.000	.000
	N	148	148
Skeletal Age	Pearson Correlation	1.000	.793
	P value	.	.000
	N	148	148

Table (3): Correlation between Skeletal and dental maturity markers for each tooth.

		C Incisor	L incisor	Canine	1st PM	2nd PM	1st M	2nd M
Skeletal Maturity stage	Spearman's rho	.156	.415	.679	.729	.700	.512	.720
	P value	.059	.000	.000	.000	.000	.000	.000
	N	148	148	148	148	148	148	148

Table (4): Mean chronological, skeletal and dental age at different skeletal maturity stages.

Pre PP2	Mean	10.35	8.538	10.1385
	N	26	26	26
	Std. Deviation	.89	1.029	.9790
PP2	Mean	10.86	10.023	10.4455
	N	22	22	22
	Std. Deviation	1.13	.763	1.0564
MP3	Mean	11.90	11.667	11.6078
	N	51	51	51
	Std. Deviation	1.01	.988	1.2947
S	Mean	12.71	12.833	13.1762
	N	21	21	21
	Std. Deviation	.85	.242	1.5407
MP3cap	Mean	13.25	13.650	14.3300
	N	20	20	20
	Std. Deviation	.97	.432	1.6871
DP3u	Mean	14.50	15.250	16.7000
	N	2	2	2
	Std. Deviation	.71	.354	.2828
MP3u	Mean	14.67	16.167	16.6167
	N	6	6	6
	Std. Deviation	.52	.516	.6940
Total	Mean	11.92	11.537	12.0392
	N	148	148	148
	Std. Deviation	1.49	2.118	2.1757

Table (5): Correlation between skeletal maturity stage and chronological, skeletal and dental ages.

		Skeletal Age	Dental Age
Skeletal Maturity	Spearman's rho	.759	.793
	Sig. (2-tailed)	.000	.000
	N	148	148

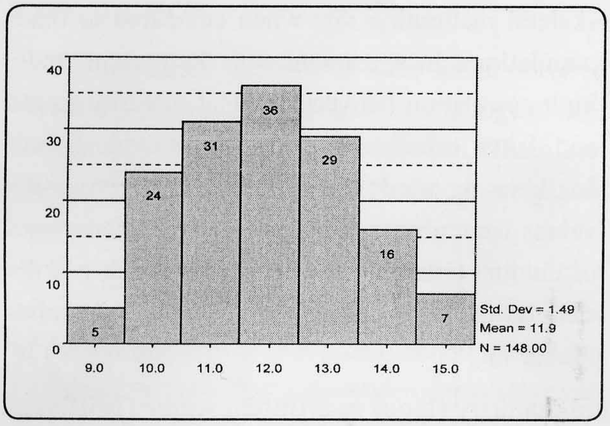

Figure 1: Sample distribution based on chronological age groups.

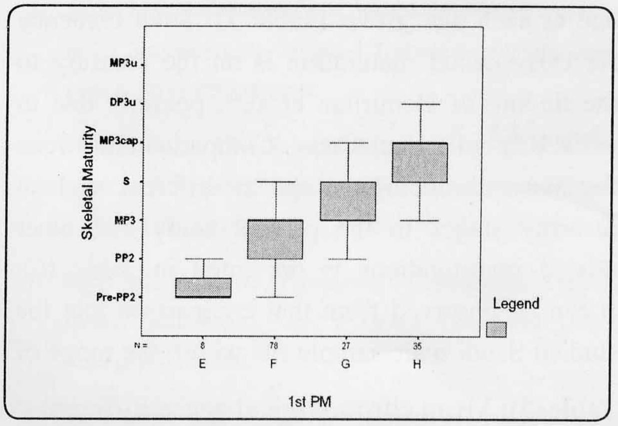

Figure 2: Box plot showing the relationship between skeletal maturity stage and mineralization stage of the first premolar tooth.

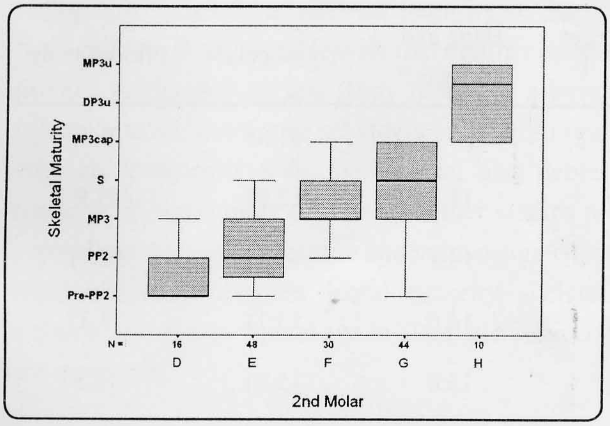

Figure 3: Box plot of the relationship between skeletal maturity stage and mineralization stage of the second molar tooth.

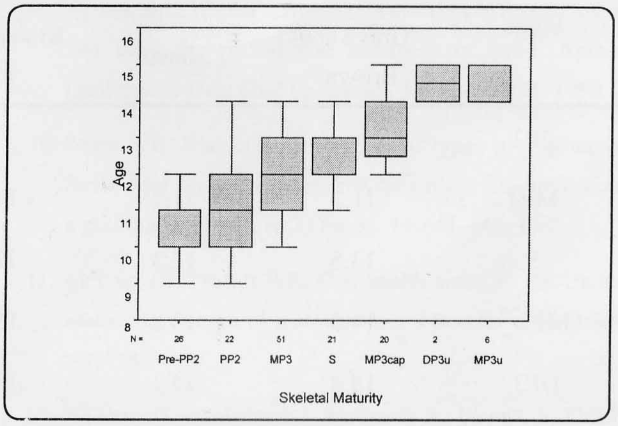

Figure 4: Box plot of the relationship between skeletal maturity stage and chronological age.

DISCUSSION

The present study represents a basic cross-sectional investigation to establish the relationship between dental maturity, skeletal maturity and chronological age in a sample of Saudi male children. The method described by Demirjian et al.[46], which was utilized in the present study, has been extensively used in the literature to assess the dental maturation and determine the dental age[49-52].

In the present study, Björk's[21] standards were the bases for skeletal maturity assessment, while the Greulich and Pyle's atlas[47] was used to determine the skeletal age of the sample. Both methods are commonly used in related studies because of their simplicity, popularity and reliability. For the present study sample, no significant difference between the mean dental age, skeletal age and chronological age was detected.

Generally, there is a tendency for the mean skeletal age to be less than the chronological age at each age group (Table 1), which demonstrates the tendency of the male Saudi children to be late maturers. This finding is in harmony with a previous investigation to establish the relationship between skeletal maturity and chronological age among Saudi male children[45]. In contrast, although not statistically significant, the mean dental age tends to be more advanced than the mean chronological

age at each age group (Table 1). Such tendency for early dental maturation is on the contrary to the finding of Demirjian et al.[46], possibly due to variability of populations. Comparison between the mean chronological age at different skeletal maturity stages in the present study and other related investigations is presented in Table (6). It can be observed from that comparison that the studied Saudi male sample fits within the range of skeletal maturation rate when compared to other populations. In agreement with the present study, high correlation between skeletal maturity stages and dental calcification stages of individual teeth has been reported[(41,42)]. In fact, higher correlation values were observed between calcification stages of the first premolar and the second molar and the skeletal maturation level than in previous studies (Table 7).

Table (7): Mean chronological age at different skeletal maturity stages in different studies (different populations).

Stage	Chronological Age					
	Grave and Brown[48]	Fishman[23]	Krailassiri et al[41]	Hägg and Taranger[24]	Uysal et al[42]	Present study
PP2	-	-		-	11.03	10.86
MP3	11.2	11.7	11.2	11.7	12.01	11.9
S	13.5	12.3	11.6	13.1	13.05	12.71
$MP3_{cap}$	14.0	13.8	13.2	14.6	13.11	13.25
$DP3_{u}$	15.4	15.1	14.3	15.6	15.01	14.5
$MP3_{u}$	16.0	16.4	15.4	16.3	15.05	14.67

Table (7): Correlation between skeletal maturity stage and dental mineralization stages for different teeth in different studies

Tooth	Correlation Coefficient		
	Krailassiri[22]	Uysal[23]	Present study
Canine	0.56	0.633	0.679
1st PM	0.64	0.634	0.729
2nd PM	0.66	0.659	0.700
2nd M	0.63	0.706	0.720

CONCLUSION

No significant differences were found between dental age, skeletal age, and chronological age in this sample of Saudi male children. Therefore, chronological age can be regarded as an acceptable indicator of the skeletal maturity and dental development in Saudi male children. Significant association between the dental calcification stage of the left mandibular first premolar and the second molar and the individual's skeletal maturity stage was demonstrated, which can be a useful clinical tool to estimate the skeletal maturity stage of the individual by examination of his/her routine dental panoramic radiograph. The rate of skeletal maturity of Saudi male children is comparable with that of other ethnic groups. Findings from this study represent a basic reference to all health care providers in Saudi Arabia who are concerned with the skeletal and dental maturity of Saudi male children. Further studies to expand the sample distribution and to investigate the interrelationship between dental maturity, skeletal maturity and chronological age in Saudi girl subjects are inevitable.

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