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Research Article

Relationships between the Mandibular Second Molars Calcification Stages and Skeletal Maturity Indicators in Omani Subjects - A Cross Sectional Descriptive Study

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Abstract

Objective: To investigate the relationships between the stages of calcification of mandibular right and left second molars using Demirjian method and skeletal maturity stages using cervical vertebrae maturity index (CVMI) among Omani subjects.

To establish a valid clinical tool for indication of pubertal growth period in Omani children and adolescents from an OPG without the necessity of extra exposing patients to cephalometric or hand-writst radiographs. The null hypothesis tested was no clinically meaningful relationship between the stages of cervical vertebral maturation and mandibular second molar calcification stages among Omani subjects.

Materials and Methods: A sample of 149 healthy "Omani" subjects (71 Males and 78 Females; age range, 8 to 17 years) extracted from the total 360 patients attended Orthodontic department of Oman Dental College from January 2012 until January 2015. Mandibular right and left second molar maturation (stages E to H) according to the method of Demirjian and skeletal maturity using the cervical vertebral maturational (CVM) method assessed looking at pretreatment Orthopantogram and Cephalometric radiographs of Omani Orthodontic patients attended to Oman Dental College.

Results: Highly significant correlation (0.825 for males and 0.856 for females) was found between DI and CVMI amongst Omani 8-17 years old individuals. DI stage E corresponded to pre¬peak of CVMI and stages F and G corresponded to peak of, stage H was associated with post peak of CVMI.

Conclusion: There was no difference between right and left mandibular second molar maturity index for both Omani males and females. It can be concluded that mandibular second molar DI stages are a reliable indicator of skeletal maturity and can be used as clinical tool in predicting the skeletal maturity stages of 8 to 17 years old Omani males and females' individuals.

Keywords: Dimirjian Dental Maturation; CVM Skeletal Maturity Index; Growth Prediction; Orthodontics; Oman

Introduction

Assessing skeletal maturity and dental development is a frequent clinical practice in many healthcare professions, especially for growth modification in Orthodontics and Dentofacial Orthopedics and for age estimation in forensic sciences. Due to the considerable variations in development among children, chronological age may have little or no role in determination of the maturation stage of a child and led to the concept of biologic or physiologic age. Previously it was reported that the stages of permanent mandibular second molar calcification showed the highest correlation with the stages of skeletal maturity as compared to other teeth [1]. The ability to assess skeletal maturity by the stages of permanent mandibular second molar calcification through the examination of a panoramic radiograph (which is a routine diagnostic radiograph for dental/orthodontic treatment) would offer an advantage over the conventional hand-wrist radiographic method. The current study aims at assessing calcification stages of permanent mandibular second molar using panoramic radiograph and its comparison with cervical vertebrae maturation using lateral cephalogram.

Review of Literature

A study was conducted to derive a method of estimating overall dental maturity or dental age, based on the stages observed in each tooth, by reference to the radiologic appearances of the seven teeth on the left side of the mandible. Panoramic radiograph of 1446 boys and 1482 girls of French-Canadian parentage have been used. Each tooth has been rated according to developmental criteria (amount of dental deposit, shape change of the pulp chambered.) rather than change in size. Eight stages, A to H, have been defined from the first appearance of calcified points to the closer of the apex. The method of Tanner, White house and Healy for skeletal maturity has been used for deriving a score for each stage for each tooth. The summed scores on all 7 teeth give a dental maturity score which can be directly converted into a dental age [2].

In another study, correlation was made between cervical vertebrae maturation and the skeletal maturation of the hand wrist. The prime objective of the study was to create a method of evaluating the skeletal maturation of the orthodontic patient with the cephalometric radiograph that is routinely taken with pretreatment records. The sample of 220 subjects aged from 8 to 18 years was taken. By using the lateral profiles of the second, third and fourth cervical vertebrae, it was possible to develop a reliable ranking of patients according to the potential for future adolescent growth potential [3].

A study was conducted to know the relationships between dental calcification stages and Skeletal Maturity Indicator in Thai individuals. The relationship between the stages of calcification of various teeth and skeletal maturity stages were evaluated from dental panoramic and hand-wrist radiographs of 139 male subjects and 222 female subjects between 7 years to 19 years. From the correlation coefficient and the percent distribution of stages, there was a relationship between dental and skeletal development, however, the relationship differed for individual teeth. The findings of this study indicate that tooth calcification stages might be clinically used as a maturity indicator of the pubertal growth period [4].

Another study was conducted to investigate the relationships between the stages of calcification of various teeth and the skeletal maturity stages among Turkish subjects. The samples were derived from dental panoramic and hand-wrist radiographs of 500 subjects of which 215 males and 285 females of age ranging between 7 to 20 years with mean age of 12.01 +/-3.03 years. All statistical analyses were performed using the SPSS software package. The appearance of each skeletal stage is consistently earlier in the females than in males. At the same skeletal maturity stage, males had a more advanced trend in tooth calcification. The tooth sequence in order of the lowest to the highest correlation for female subject was third molar, canine, first premolar, second premolar and second molar. The corresponding sequence in male subjects was third molar, canine, first premolar, second premolar, second molar. The second molar showed the highest and the third molar showed the lowest relationship for female and male subject. Statistically significant relationships were determined between dental calcification and skeletal maturation stages according to Spearman rank-order correlation coefficients [5].

A comparative study of hand wrist and cervical vertebrae was done to assess the validity of cervical vertebrae as maturity indicators. The sample consisted of 50 subjects (25 females and 25 males) in the age group of 10-12 years. The results of the study proved that cervical vertebrae can be used as maturation indicator with the same confidence as hand wrist radiographs. Cervical vertebrae has the same potential as hand wrist radiograph for determining the skeletal maturation of an individual, thus avoiding the patient from an additional radiographic exposure [6].

A recent study was conducted for skeletal maturation evaluation using mandibular second molar calcification stages. Samples were derived from panoramic and lateral cephalometric radiographs of 300 subjects (137 males and 163 females) from the pretreatment records of patients attending clinics for orthodontic treatment. Estimation of dental maturity was carried out using Demirjian Index [DI] and skeletal maturity using Cervical Vertebrae Maturation Indicators [CVMI]. A highly significant association was found between DI and CVMI. The results of the study concluded that the permanent mandibular second molar DI stages are reliable indicators of skeletal maturity [1].

The aim of this research was to investigate the relationships between the stages of calcification of Mandibular right and left second molars using Demirjian method and skeletal maturity stages using cervical vertebrae maturity index (CVMI) among Omani subjects.

Materials and Methods

A sample of 149 healthy "Omani" subjects (71 Males and 78 Females; age range, 8 - 17 years) extracted from the total 360 patients attended Orthodontic department of Oman Dental College from January 2012 until January 2015. Assessment of Mandibular second molar maturation (stages E to H) according to the method of Demirjian (Figure II) and Skeletal maturity using the cervical

vertebral maturational (CVM) method (Figure I) looking at pre-treatment Orthopantogram and Cephalometric radiographs of Omani Orthodontic patients attended to Oman Dental College.

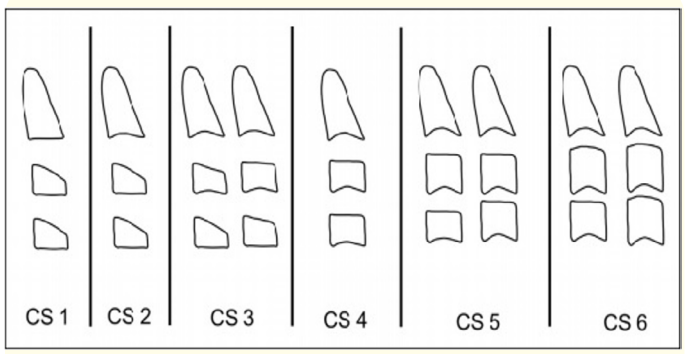

Figure I: Schematic representation of the stages of the cervical vertebral maturation method.

Methods of assessment was by mean of descriptive statistics, calculating the chronological ages (grouping subjects into 10 groups; 8-17), Dental (8 Demirjian stages) and Skeletal (6 CVMI stages). At last Spearman rank order used to find the correlation between Demirjian and CVMI stages of individuals 2nd molars according to their pubertal stages.

Statistical method

All statistical analyses were performed using the Microsoft excel 2007 and SPSS software package (SPSS for Windows 98, version 10.0, SPSS Inc, Chicago III). Descriptive statistics were obtained by calculating the means and standard deviations of the chronological ages for the the stages of skeletal maturity indicators. To study the relationship between the stage of mineralization of the teeth and the stage of skeletal matu¬ration, the percentage distribution of the stages of calcifi¬cation for each tooth was calculated. The

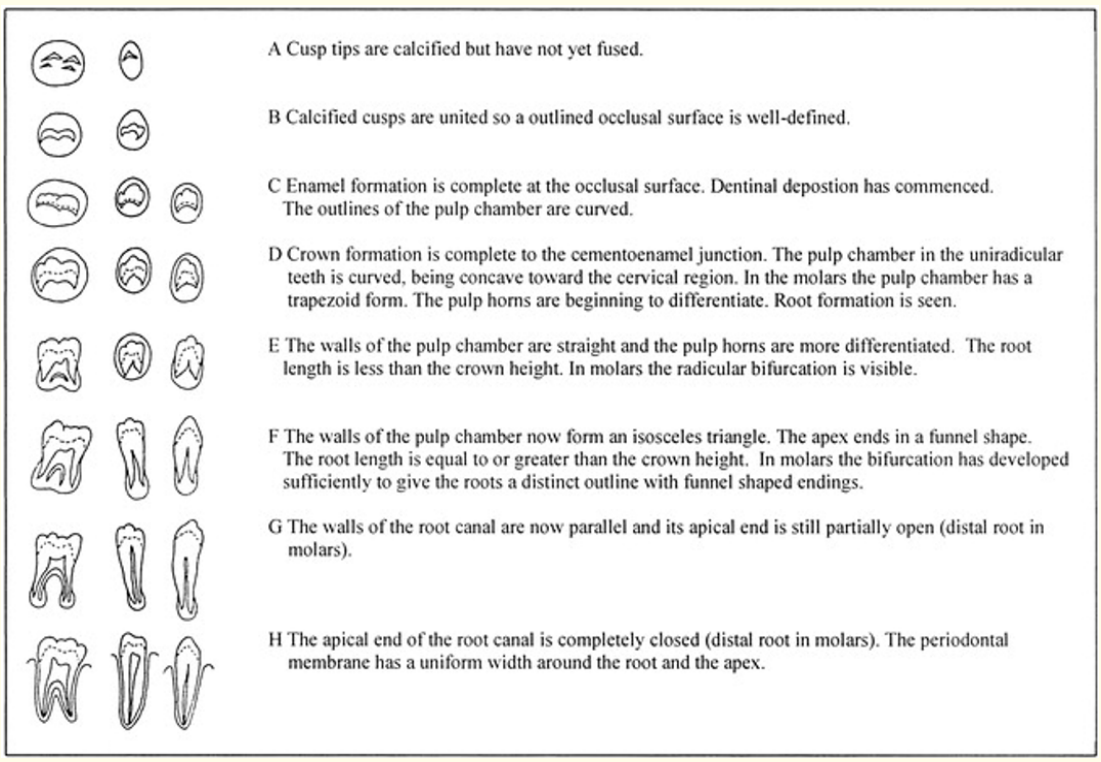

Figure II: Dental calcification stages by Demirjian., *et al.* (1973), modified by Krailassiri., *et al*. (2002).

Spearman rank order correlation coefficients were estimated to measure the association between skeletal maturational indicators and dental calcification stages of individual teeth, and the statistical significance of the correlation was tested.

To test the reproducibility of the assessments of skeletal maturity and dental development stage, the same in-vestigator (M.Z) and second examiner (P.S.V) reevaluated randomly selected lateral and panoramic radiographs from 30 (20%) of the same male and

fe¬male subjects two weeks after the first evaluation. The differences between double interpretations were statistically tested. Interobserver and interobserver agreement for both investigators were determined in terms of the weighted Kappa statistics for DI and CVMI. No statistically significant difference in measurements found between the inter and intra investigators results hence the data can be counted reliable and reproducible.

Results

Table 1 shows the distribution of sex and chronological ages for all the subjects, grouped by CVMI stage. Each stage appeared earlier in Omani female subjects than in Omani male subjects. The reproducibility of all the assessments was very good.

CVMI stage	Gender	No. of Subjects	Chronological Age (y) Mean SD	
Stage 1	Male	1	9.0	0.0
	Female	4	9.7	0.52
Stage 2	Male	6	10.35	2.03
	Female	13	11.55	1.98
Stage 3	Male	24	12.37	1.17
	Female	20	12.17	1.41
Stage 4	Male	15	13.46	1.19
	Female	11	13.05	1.3
Stage 5	Male	18	14.8	1.42
	Female	18	14.42	1.34
Stage 6	Male	7	15.17	1.28
	Female	12	15.2	1.09
	Total	149 (71 males, 78 females)		

Table 1: Correlation Coefficients between Skeletal (CVMI) and Dental Maturity (DI 2nd molars) Stages of Subjects.

Correlation coefficients between skeletal (CVMI) and dental maturity stages (DI) of subjects are shown in Table 2. These correlation coefficients indicate that both the right and left second molars show the highest relationship with skeletal maturity stages for both sexes among Omani subjects. This was in consistent with the earlier study of Turkish individuals [10].

Very high correlation coefficients found between dental maturity and pre peak (Table 3), peak (Table 4) and post peak (Table 5) skeletal growth stages according to Baccetti., *et al.* (2008). These findings are highly notable for both Omani males and females' individuals.

Tooth		Correlation Coefficients	
	Male Subjects		Female Subjects
	r	Significance	r Significance
Right 2nd molar	.825	***	.856 ***
Left 2nd molar	.825	***	.832 ***

Table 2: The distribution of sex and chronological ages for all the subjects, grouped by CVMI stages.

$P < 0.01$

*** Highly Significant.

Tooth		Correlation Coefficients	
	Male Subjects		Female Subjects
	r	Significance	r Significance
Right 2nd molar	1.0	***	1.0 ***
Left 2nd molar	1.0	***	1.0 ***

Table 3: Correlation Coefficients between Pre Peak Skeletal growth (CVMI 1,2) and Dental Maturity (DI 2nd molars) Stages of Subjects.

$P < 0.01$

*** Highly Significant.

Tooth		Correlation Coefficients	
	Male Subjects		Female Subjects
	r	Significance	r Significance
Right 2nd molar	1.0	***	1.0 ***
Left 2nd molar	1.0	***	.907 ***

Table 4: Correlation Coefficients between Peak Skeletal growth (CVMI 3,4) and Dental Maturity (DI 2nd molars) Stages of Subjects.

$P < 0.01$

*** Highly Significant.

Tooth		Correlation Coefficients	
	Male Subjects		Female Subjects
	r	Significance	r Significance
Right 2nd molar	1.0	***	1.0 ***
Left 2nd molar	.84	***	.85 ***

Table 5: Correlation Coefficients between Post Peak Skeletal growth (CVMI 5,6) and Dental Maturity (DI 2nd molars) Stages of Subjects.

$P < 0.01$

*** Highly Significant.

Table 6 shows the associations between CVMI and DI for male subjects. It is clear that lower stages of DI were associated with lower CVMI stages and the higher the DI stage, the higher the CVMI stage. Stage C included the highest percentage distribution (100%) at stage 1 of the CVMI. Stages E has recorded almost double (66.7%) compare to stage F (33.3%) for CVMI stage 2. DI stages F and G also included a large percentage of CVMI stage 3 subjects. Stage G displayed a high percent distribution with CVMI stage 4 (86.7%) and 5 (72.2%). Stage H had highest distribution with CVMI stage 6 (100%).

		C	D	E	F	G	H	Total
CVMI 1	Frequency	1						1
	Percentage	100%						100%
CVMI 2	Frequency			4	2			6
	Percentage			66.7%	33.3%			100%
CVMI 3	Frequency			5	11	8		24
	Percentage			20.8%	45.8%	57 33.3%		100%
CVMI 4	Frequency				1	13	1	15
	Percentage				6.7%	6 86.7%	6.7%	100%
CVMI 5	Frequency					13	5	18
	Percentage					72.2%	8 27.8%	100%
CVMI **6**	Frequency						7	7
	Percentage						100%	100%
Total	Frequency	1		9	14	34	13	71
	Percentage	1.4%		12.6%	19.7%	47.9%	18.4%	100%

Table 6: Association Between CVMI and DI for Male Subjects.

Table 7 shows the associations between CVMI and DI for female subjects. It is also evident that lower stages of DI were associated with lower CVMI stages. Again, the higher the DI stage, the higher the CVMI stage. Stage D included the highest percentage distribution (76.0%) at stage 1 of the CVMI. Stages E has recorded almost double (48.2%) compare to stages D and F that were equally distributed (33.3%) for CVMI stage 2. DI stages F (35.0%) and G (55.0%) also included a large percentage of CVMI stage 3 subjects same as Omani males. Stage G displayed a high percent distribution with CVMI stage 4 (54.5%) and 5 (55.6%). Similarly, stage H had highest distribution with CVMI stage 6 (91.7%).

Table 8 shows the associations between DI and CVMI for male subjects. The highest percentage distribution was for stage C at CVMI 1. Stages E was almost equally distributed between both CVMI 2 (44.5%) and CVMI 3 (55.5%). Similarly, stage F was equally distributed between CVMI stages 4 and 5 (38.5) but it was highly distributed for CVMI stage 3 (78.5). Stage H was highly distributed for CVMI stage 6 (53.8).

Table 9 shows the associations between DI and CVMI for female subjects. The highest percentage distribution was for stage E at CVMI 2. Stage D was equally distributed between both CVMI 1 (50%) and CVMI 2 (50%). Stage F was highly distributed for CVMI stages 3 (53.8). Similar to males, stage H was highly distributed for CVMI stage 6 (52.4).

To better understand tables 8 and 9, we looked at the associations between each DI and CVMI growth spurts. Table 10 (males) and table 11 (females) clearly show the association between each DI and pre, peak and post peak stages of CVMI. Figures 1 and 2 illustrate the same.

		C	D	E	F	G	H	Total
CVMI 1	Frequency		3	1				4
	Percentage		75.0%	25.0%				100%
CVMI 2	Frequency		3	6	3	1		13
	Percentage		23.1%	46.2%	23.1%	7.7%		100%
CVMI 3	Frequency			2	7	11		20
	Percentage			10.0%	35.0%	57 55.0%		100%
CVMI 4	Frequency				3	6	2	11
	Percentage				27.3%	6 54.5%	18.2%	100%
CVMI 5	Frequency					10	8	18
	Percentage					5.6%	44.4%	100%
CVMI 6	Frequency					1	11	7
	Percentage					8.3%	91.7%	100%
Total	Frequency		6	9	13	29	21	78
	Percentage		7.7%	11.6%	16.7%	37.1%	26.9%	100%

Table 7: Association Between CVMI and DI for Female Subjects.

Calcification Stages	CVMI 1 CVMI 2		CVMI 3 CVMI 4		CVMI 5 CVMI 6	
	(%)	(%)	(%)	(%)	(%)	(%)
C	100					
D						
E		44.5	55.5			
F		14.3	78.5	7.2		
G			23.4	38.3	38.3	
H				7.7	38.5	53.8

Table 8: Association between DI and CVMI for Male Subjects.

Calcification Stages	CVMI 1 CVMI 2		CVMI 3 CVMI 4		CVMI 5 CVMI 6	
	(%)	(%)	(%)	(%)	(%)	(%)
C						
D	50	50				
E	11.1	6.6	22.3			
F		3.1	53.8	23.1		
G		3.5	37.9	20.6	34.5	3.5
H				9.5	38.1	2.4

Table 9: Association between DI and CVMI for Female Subjects.

	Pre-Peak (CVMI 1 and 2)	Peak (CVMI 3 and 4)	Post-Peak (CVMI 5 and 6)
C	100		
D			
E	44.5	55.5	
F	14.2	85.8	
G		61.8	38.2
H		7.7	92.3

Table 10: Percent distribution (%) of each second molar calcification stage and CVMI growth spurts for Omani Males.

	Pre-Peak (CVMI 1 and 2)	Peak (CVMI 3 and 4)	Post-Peak (CVMI 5 and 6)
C			
D	100		
E	77.8	22.2	
F	23.1	76.9	
G	3.5	58.6	37.9
H		9.5	90.5

Table 11: Percent distribution (%) of each second molar calcification stage and CVMI growth spurts for Omani Females.

Figure 1: Percent distribution (%) of each second molar calcification stage and CVMI growth spurts for Omani Males.

Figure 2: Percent distribution (%) of each second molar calcification stage and CVMI growth spurts for Omani Females.

Discussion

Many methods for precise prediction of growth have been suggested [3-5]. Dental maturity, in particular, has the advantage of easy evaluation during routine dental treatment. Radiation exposure time and dose are high when specialized radiographs are used (hand-wrist radiographs or lateral cephalograms), making their use questionable according to the ALARA principle. The ALARA principle is especially important for children and young adults, and, hence, high-radiation methods should not be used frequently to assess growth. The ease of recognizing the stages of dental development and the availability of panoramic radiographs are practical reasons for attempting to assess physiologic maturity without resorting to hand-wrist or lateral cephalometric radiographs. Others have questioned these latter approaches from the radiation safety point of view. In addition, the cost of the equipment that is required for these radiographs is high, making them expensive.

It has long been contended that dental eruption, which is the most conspicuous and easily determined indicator of dental maturation, is much more variable in its timing than skeletal maturation [13,37]. According to Nolla [13], dental eruption has also been reported to be more variable than the calcification sequence in the dentition. Many studies have reported high correlations between tooth calcification stages and skeletal matu¬rity indicators, which would probably allow clinicians to more easily identify pubertal growth stages from panoramic radiographs [4,5,13,15,17,21-26,28,29]. On the other hand, Lewis and Garn [14] Garn., *et al.* [30] and Tanner [31] reported low or insignificant correlations between skeletal and dental maturation. The lack of agreement among previous studies is a result, at least in part, of the different methods used for assessing skeletal and dental maturity.

Previously it was reported [21-25] that tooth calcification stages from panoramic radiographs might be clinically useful as a maturity indicator of pubertal growth and that mandibular second molar calcification showed the highest correlation with skeletal maturity versus other teeth. Racial variations in the relationships between the calcification stages of individual teeth and skeletal maturity also have been reported [1,24-26].

The present radiographic study was therefore taken up to assess the reliability of using the developmental stages of mandibular second molars as an indicator of maturity in an Arab population, Omani individuals. Choice of second molar tooth offers an advantage over other teeth because its development tends to continue over a longer period and until a later age. Apex closure generally extends up to the age of 16 years in normal children.

In this study, mandibular second molars maturity index used because estimation errors occur more frequently in calculating the maturation of maxillary molars than that of mandibular molars. Sometimes the maxillary molar roots overlap with anatomic structures such as the palate, the inferior border of the zygomatic arch, or the maxillary sinus septum. This makes it difficult to observe the roots [32].

It has long been contended that dental eruption, which is the most conspicuous and easily determined indicator of dental maturation, is much more variable in its timing than skeletal maturation [19,33]. According to Nolla [19] dental eruption has also been reported to be more variable than the calcification sequence in the

dentition. Dental eruption is a fleeting event that is under greater environmental influence [18]. In the present study, calcification stages of teeth, rather than eruption, were preferred because tooth formation is proposed as a more reliable criterion for determining dental maturation [19]. Therefore, the dental maturity assessment stages of Demirjian., *et al*. [18] were used. This method showed high accuracy when applied to Omani populations. This method's criterion consists of distinct details based on shape criteria and proportions of root length, using the relative value versus crown height, rather than on absolute length. Therefore, foreshortened or elongated projections of developing teeth will not affect the reliability of assessment [24].

Several studies [21-25] have indicated that each CVMI stage consistently appears earlier in girls than in boys. Thus, the observations of the present study are in line with earlier studies (Table 1). We considered the DI, relative to CVMI, separately for male and female subjects. The findings of Krailassiri., *et al* [24] and Uysal., *et al*. [25] indicated that the maturation patterns of tooth development in male subjects tend to be more advanced versus female subjects in relation to skeletal maturity stages. Chertko [1] reported that a markedly more advanced trend in tooth calcification was evident among both black and white boys. In this study, it was determined that at the same CVMI, male subjects had a more advanced trend in DI, and the opposite pattern was present in female subjects. These findings confirm previous reports [1,24,25].

The present study revealed a highly significant association between the DI of mandibular second molars and the CVMI (Table 2). The relationship between skeletal maturity and peak height velocity (PHV) is well established [3,8,9,36]. Fishman [8], Hagg and Taranger [9], and Bjork and Helm [36] found that the appearance of the adductor sesamoid of the thumb indicate the beginning of the pubertal growth spurt (onset of PHV), which corresponds to stage 2 of CVMI [37]. For both sexes, DI stage E showed the highest percent distribution at stage 2 of CVMI, which signifies the pre-peak of pubertal growth spurt or onset of PHV. Bjork and Helm [36]. found that the MP3cap stage heralds the peak of the pubertal growth spurt, which corresponds to Fishman's skeletal maturity indicator 6 (stage 3 of the CVMI [37]). In the present study, for both male and female subjects, stages F and G corresponded to CVMI stages 3 and 4, which infers that DI stages F and G represent the peak of the pubertal growth spurt. This finding supports the suggestions of previous studies [21,25]. Fishman's skeletal maturity indicator 11 corresponds to CVMI stage 5 [37], and the fusion of the epiphysis and diaphysis of the radius (which signifies the end of growth) corresponds to CVMI stage 6 [37]. Stage H displayed a higher percent distribution with stage 5 and 100% distribution with stage 6 of the CVMI. DI stage H suggests no remaining adolescent growth [38].

The unique and significant findings from the present study imply that the stages of mandibular second molar calcification as observed on panoramic radiographs give very accurate results and can be considered reliable indicators of skeletal maturity with the methodology suggested by Demirjian., *et al*. in Omani 8-17 years old males and females population [18].

Conclusion

- Highly significant association (0.825 for males and 0.856 for females) was found between DI and CVMI amongst Omani 8-17 years old individuals.
- DI stage C in males and stage D in females corresponded to pre-peak of CVMI. For both males and females stages F and G corresponded to peak of CVMI, stage H was associated with post peak of CVMI.
- There was no difference between right and left mandibular second molar maturity index for both Omani males and females.
- It can be concluded that mandibular second molar DI stages are a reliable indicator of skeletal maturity and can be used as clinical tool in predicting the skeletal maturity stages of 8-17 years old Omani males and females' individuals.

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