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Evaluation of Skeletal Maturity in Type 1 Diabetic Mellitus Subjects

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Abstract

Aim of the study: The accurate assessment of skeletal maturation and residual growth is critically important in orthodontics, especially in insulin-dependent diabetes mellitus growing subjects in which the available data on their growth are conflicting and are mainly derived from cross-sectional studies. This study aimed to examine the association between the calcification stages of the second mandibular molar, the maturation of the middle finger phalanx, and the chronological age of the patients.
Material and method: The sample consisted of 80 Iraqi subjects of Type1 Diabetic Mellitus (T1DM), 40 males and 40 females. For each subject, two per apical radiographic were used, one for the mandibular right second molar and the other for the middle phalanx of the middle finger (MP3). Demirjian method (1973) was assessed for the ossification of teeth, while Staging of the Middle phalanx of the third finger radiographs was done according to the Rajagopal and Kansal method.
Results: The results showed no significant association between skeletal and dental maturity for both genders in T1DM growing subjects and a negative association can be seen between dental age and skeletal age in total, male and female T1DM subjects.
Conclusion: Mandibular second molar calcification stages of Demirgian's classification are unreliable as a skeletal maturity indicator in TIDM.

Keywords: Demirjian method. MP3. T1DM.

Introduction

The World Health Organization defines diabetes as a metabolic illness described by persistently high blood sugar levels and encompasses disruptions in the metabolism of carbohydrates, lipids, and proteins. The aforementioned disruptions stem from inadequacies in either the synthesis of insulin, the functioning of insulin, or both (Shukur et al., 2021). A study examining the growth patterns of children with Diabetes found that both male and female individuals exhibited varying degrees of decreased growth (Abduljabbar, 2014; Hadi et al., 2018).

The assessment of dental development and skeletal maturity is widely utilized in clinical practice within different healthcare fields. The existence of significant disparities in developmental progress among children has diminished the significance of chronological age in assessing a child's maturation stage, thereby giving rise to the physiologic age importance. The physiologic age concept refers to the pace at which an individual progresses towards maturity. This measure is typically determined by assessing indicators like somatic, sexual, skeletal, and dental development (Chertkow and Fatti, 1979; Demirjian et al., 1985; Sierra, 1987).

Skeletal maturation is assessed through an observation of developing bones, including their initial appearance as well as any future growth and shape changes associated with ossification. Hand-wrist radiographs are frequently employed to assess skeletal growth, as demonstrated by numerous studies (Bjork, 1972; Grave, 1978; Ha¨gg and Taranger, 1980; Fishman, 1982; Grave, 1994).

The middle phalanx of the third finger (MP3) can be used for skeletal age evaluation of an individual (Hagg and Taranger, 1982). The MP3 region's anatomical alterations can be easily documented by employing periapical X-ray film, which reduces the amount of X-ray exposure. Consequently, this method is a simple, dependable, cost-effective, and effective approach to assessing skeletal maturity (Hegde et al., 2012).

The evaluation of dental age in adolescents and children can be achieved by examining the phases of tooth mineralization or the timing of the tooth eruption. The method proposed by Demirjian (Demirjian et al., 1973) improves the accuracy of mineralization phases in teeth by incorporating the ratios of root length to crown height, rather than relying solely on absolute length measurements. This method enhances the overall quality of the evaluation by reducing the influence of inaccuracies in the projections of developing teeth (Krailassiri et al., 2002).

Various methodologies have been implemented to evaluate maturation in the present day, such as the utilization of biomarkers like insulin-like growth factor 1 (IGF-1) that are present in blood serum or gingival crevicular fluid (GCF) extraction (Saloom et al., 2017). In this context, alkaline phosphatase (ALP) has also been examined as a biomarker. Nevertheless, the radiograph remains the primary diagnostic method (Masoud et al., 2008; Perinetti et al., 2011; Saloom et al., 2018).

This study was intended to examine the relationship between the developmental stages of the third metacarpal bone (MP3) and the calcification phases of the mandibular second molar in both sexes. Moreover, the objective of the investigation was to ascertain whether these phases could be regarded as reliable indicators for assessing skeletal

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maturation in children who have been diagnosed with Type 1 Diabetes Mellitus.

Material and Methods

Participants in this cross-sectional study were chosen from those undergoing treatment at Baghdad's Children's Welfare Teaching Hospital. The study sample consisted of 80 participants, who were evenly distributed between two groups: 40 males and 40 females. Participants were chosen according to particular criteria and were aged 8 to 15. The sample was further divided into three categories, which represented the age groups of prepubertal, pubertal, and postpubertal. Before initiating the investigation, the ethical committee at the College of Dentistry, University of Baghdad, with reference number (604422), granted legal approval. Subsequently, the parents of the participant were asked to provide informed consent by signing the consent form.

The inclusion criteria included no documented medical record of any prior instances of trauma affecting the facial or hand-wrist areas. Patients who had not undergone orthodontic treatment in the past were included in the study. However, individuals with hypothyroidism or liver illness were excluded due to the potential impact of these conditions on bone maturation, and the assessment of radiographs. Additionally, those with a history of hand trauma or injury that could affect the evaluation of radiographs were also removed. The patient's date of birth, including the specific day, month, and year, was recorded. Subsequently, the patient's medical history was obtained. On the same day, two peri apical radiographs were taken one for mandibular second molar and the other for MP3.

The calcification stages, as described in the method designed by Demirjian et al., were employed to assess dental maturity (Demirjian et al., 1973) as seen in Table 1 and Figure 1, this assessment was performed using digital radiographs of the lower right second molar.

Table 1: Demirjian’s Index for dental age estimation

Stage A	Single occlusal spots that were calcified without the union of calcification areas.
Stage B	Fusion has occurred at the points of mineralization; dentine production and the contour of the occlusal surface have commenced

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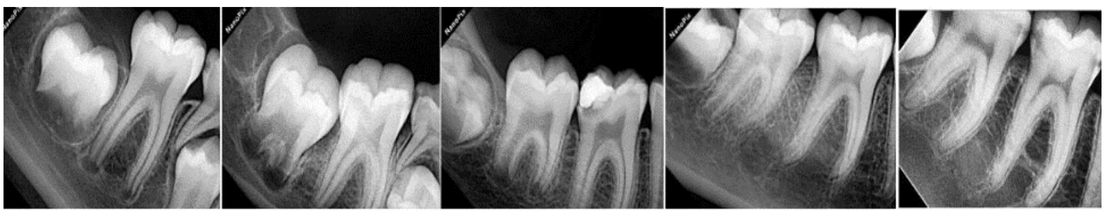
Stage C	The crown had been fully formed.
Stage D	Upon the completion of crown development at the CEJ level, root formation commenced.
Stage E	When the root length was less than the crown, calcification began through bifurcation.
Stage F	length of the root is equivalent to crown height, and roots exhibit an original shape.
Stage G	Root canal walls are parallel, with the apex end accessible.
Stage H	The apex has been closed and the root formation has been completed.



D E F G H

Figure 1: the mandibular developmental stages as presented by Demirjian et al. (1973).

The mandibular second molar was captured using an intraoral per apical film that was securely positioned in a film-holding device, following the paralleling approach. Subsequently, the film was positioned in contact with the lingual aspect of the jaw, ensuring that the posterior surface of the film extended to the retromolar region. The radiographic presentation of the mandibular right second molar was assessed using the methodology outlined by Demirjian (Demirjian et al., 1973) which involves categorizing the tooth's calcification into eight stages denoted by the letters A to H. The dental stages identified in this study spanned from stage D to stage H.

The developmental stages of the middle finger were recorded using intraoral per apical films. The participants were provided with instructions to position their left hand in a palm-downward orientation on a level table surface. The peri apical film was positioned to capture the middle finger. The X-ray machine's cone was positioned perpendicularly to the film, specifically targeting the middle phalanx. The modified MP3 approach, as outlined by Rajagopal and Kansal, was employed to assess skeletal

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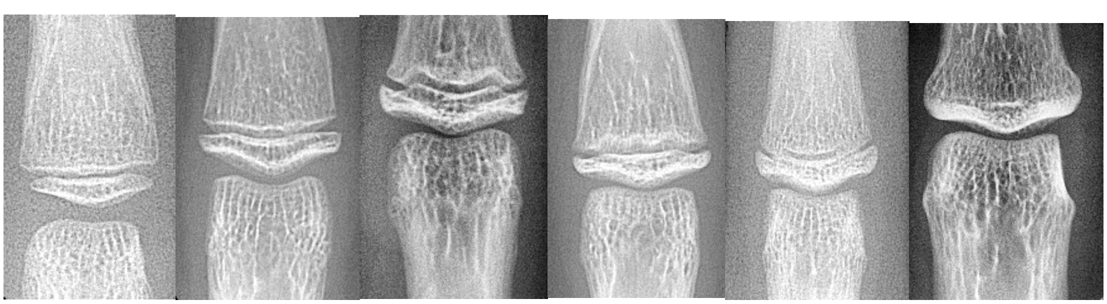
maturity (Rajagopal and Kansal, 2002) based on digital radiography. Per apical radiographs for MP3 offer reduced radiation exposure compared to orthopantomography, cephalometric radiographs, and hand-wrist radiographs. Additionally, they are more cost-effective and widely accessible in dental clinics (Saloom, 2011).

The approach consists of six stages, as seen in Table 2 and Figure 2. The radiograph recordings for each sample were staged independently by two researchers at separate instances

Table 2: The ossification stages of MP3 described by Rajagopal and Kansal 2002

MP3-F	The epiphysis is equivalent to the metaphysis in width. The extremities of the epiphysis are rounded and tapered. There is no indication of undulation in the metaphysis. The epiphysis and metaphysis are separated by a wide radiolucent fissure. This signifies the commencement of the pubertal growth explosion.
MP3-FG	The epiphysis is equivalent to the metaphysis in width. Beginnings of undulation are evident in the metaphysis. The metaphysis and epiphysis are separated by a wide radiolucent fissure.
MP3-G	A pointed edge grows distally on one or both sides of the epiphysis, which is thickened and caps its metaphysis. The metaphysis exhibits a distinct undulation that resembles a "Cupid bow." The radiolucent distance between the epiphysis and metaphysis is moderate.
MP3-H	Fusion of the epiphysis and metaphysis has commenced. Start of epiphyseal narrowing. Seen beneath the central portion of the metaphysis is a slight convexity. As the radiolucent distance narrows.
MP3-HI	The metaphysis exhibits a uniform convex surface that nearly matches the reciprocal concavity of the superior surface of the epiphysis. The metaphysis is devoid of undulation. The radiolucent distance between the epiphysis and metaphysis is negligible.
MP3-I	The epiphysis and metaphysis Fusion are finished. The metaphysis and epiphysis are not separated by a radiolucent fissure.



F FG G H HI I

Figure 2: The stages of the modified MP3 method as outlined by Rajagopal and Kansal

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The tooth formation stage of the patients was afterward compared to the equivalent phases of skeletal maturity in order to determine if there is any correlation between these two variables.

To facilitate the estimation of puberty peak, the skeletal and dental classification stages can be divided into 3 stages: prepubertal phase, pubertal phase, and postpubertal phase as shown in Table 3 (Surendran and Thomas, 2014; Saloom, 2014).

Table 3: The relative distributions of the dental maturation stages and MP3 stages to the pubertal phases.

MP3 stages	Pubertal phases	Lower 2nd molar stage
MP3- F	prepubertal	D
MP3-FG		E
		F
MP3-G	pubertal	G
MP3-H		
MP3-HI	postpubertal	H
MP3-I		

Results

Procedures for Calibration

A-Inter-examiner calibration: The researcher determined the skeletal and dental ages of 10 cases. Decisions were also made by radiologists and orthodontists, both experts in their respective fields, to ensure accuracy.

B-Intra-examiner calibration: After one month, the same 10 cases were re-evaluated by the researcher to determine their skeletal age, skeletal maturation stage, and tooth maturation stage. These results were then compared to the initial readings to assess consistency.

Cohen's Kappa scores for MP3 were 0.855 and dental maturity was 0.830, respectively.

The statistical package for social science (IBM Corp., 2017. IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY: IBM Corp.) was employed to analyze all of the data. To determine whether quantitative data were distributed normally, the Shapiro-Wilk test was carried out. Since they weren't, non-parametric tests were used,

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and the Chi-square test was used to see if there were any changes between the groups.

To explore the association between dental age and skeletal age, the frequency and distribution of the stages of calcification were recorded and separated according to pubertal phases, as shown in Table 3. These were determined individually for male and female individuals (**Table 6**).

In females, the distribution of 2nd molar stages was almost equal except stage G occupied the highest value representing the pubertal phase at about 35%, while in MP3 stages G and H represented the highest percentage and the lowest was stage I and F **(Table 4).** In the pre-pubertal phase of 2nd molar occupied the highest percentage of all the phases, while in MP3 pubertal phase represented the highest value **(Table 5)**. The associations between 2nd molar and MP3 for female subjects. The value of X2 was 4.583 at 2 degrees of freedom ($p \geq 005$), showing that there is no significant association between dental age and skeletal age for female participants (**Table 6**).

Males, regarding the frequency and distribution of 2nd molar and MP3 stages in males, in 2nd molar stages the lowest value was F followed by the D stage, and the highest value was the E stage then G and H stage **(Table 4).**

In the MP3 stages, there was a gradual decrease from the highest-level F stage to reach the lowest limit in the H and I stage **(Table 4).** Almost equal percentage between the 2nd molar and MP3 prepubertal and pubertal phases while the post-pubertal phase of MP3 had less percentage than the 2nd molar **(Table 5).**

The correlation between the 2nd molar and MP3 pubertal phases as X^2 value was 3.135 at 2 degrees of freedom ($p \geq 005$) as there is no significant association (**Table 6**).

The chi-square test (X2) value was estimated to examine the association between the MP3 calcification stage and 2nd molar stage for total subjects, X^2 was 1.337, and degree of freedom was 2 and the result was no significant association ($p \geq 005$) **(Table 6)**.

Table 4: Distribution and frequency for 2nd molar and MP3 stages in male and female.

Female	2nd molar stage					MP3 stage					
Age	D	E	F	G	H	F	FG	G	H	HI	I
8	5					5					
9	1	4				1	4				
10	1		4				1	4			
11			1	4				2	3		

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12		2		2	1			2	1	2	
13		1		4				1	2	2	
14			1	3	1				2	2	1
15				1	4				1	1	3
total	7	7	6	14	6	6	5	9	9	7	4
Percentage%	17.5	17.5	15	35	15	15	12.5	22.5	22.5	17.5	10

Male	**2nd molar stage**					**MP3 stage**					
Age	**D**	**E**	**F**	**G**	**H**	**F**	**FG**	**G**	**H**	**HI**	**I**
8	3	2				4	1				
9	2	3				2	3				
10		5				5					
11				5		2	1	2			
12		2		3			2	3			
13				2	3		1	2	2		
14		1		2	2		1	1	3		
15					5				1	2	2
total	5	13		12	10	13	9	8	6	2	2
Percentage %	12.5	32.5	0	30	25	32.5	22.5	20	15	5	5

Table 5: pubertal phases for 2nd molar and MP3 in male and female

Age	**Gender**	**2nd molar pre**	**MP3 Pre**	**2nd molar peak**	**MP3 peak**	**2nd molar post**	**MP3 post**
8	Male	5	5				
	Female	5	5				
9	Male	5	5				
	Female	5	5				

10	Male	5	5				
	Female	5	1		4		
11	Male	2	2	5	3		
	Female	1		4	5		
12	Male		2	3	3		
	Female	2		2	3	1	2
13	Male	1	1	2	4	3	
	Female	1		4	3		2
14	Male		1	2	4	2	
	Female	1		3	2	1	3
15	Male				1	5	4
	Female			1	1	4	4
Total	Male	18	21	12	15	10	4
	Female	20	11	14	18	6	11
percentage	Male	45%	52.5%	30%	37.5%	25%	10%
	Female	50%	27%	35%	45%	15%	27%

Table 6: Association between 2nd molar stage and MP3 stage in Total, Male and Female

Pubertal	**2nd molar**	**MP3**	**Total**	**2nd molar**	**MP3**	**Male**	**2nd molar**	**MP3**	**Female**
Pre	38	33	71	18	21	45	20	11	26
At	26	32	58	12	15	26	14	18	34
Post	16	15	31	10	4	9	6	11	19
Total	80	80	160	40	40	80	40	40	80
Chi-square		1.005		3.135			4.583		
Degree of freedom		2		2			2		
P value		0.604		0.208			0.101		

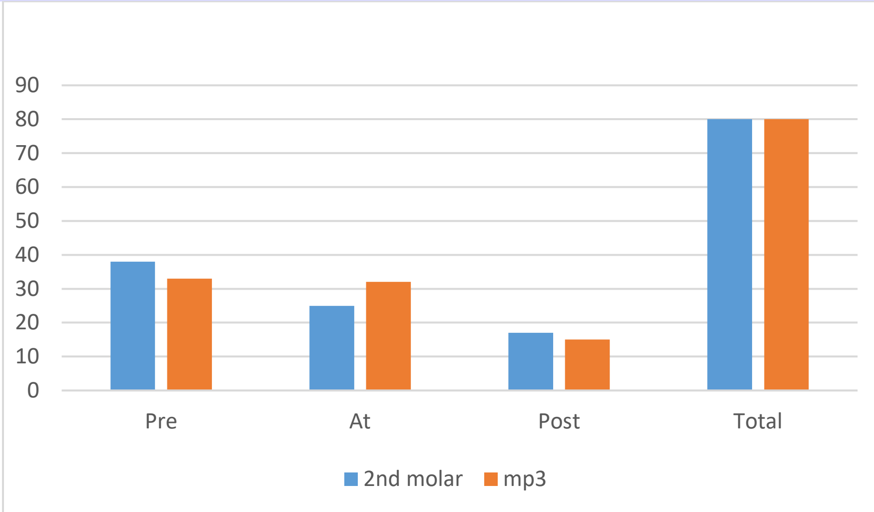

Figure 3: Correlation between MP3calcification stage and 2nd molar stage for the total sample

Discussion

Dental development is tightly controlled by heredity and has little or nothing to do with hormonal changes during puberty, nutrition, or the environment. Even if a person has a severe systemic disease, it doesn't seem to have much of an effect on how their teeth grow (Kostara et al., 2000). So, estimating dental age as a way to predict skeletal growth is not likely to be helpful. This fits with what other researchers have said about estimating the pubertal growth spurt based on how old a person's teeth are (Perinetti et al., 2013).

In this study, The Demirjian method was employed to quantify dental maturation, as it is predicated on the proportion of root length and shape parameters, not the absolute length to crown height.

So, the fact that growing teeth may have shorter or longer projections won't change how well they can be judged (Demirjian, Goldstein and Tanner, 1973).

The benefit of using the second molar is that it continues to grow and develop for a longer time. In normal children, the ends may not close until they are 16 years old (Kumar et al., 2012) Because it is harder to estimate maxillary molars, Sometimes the roots of the maxillary molars touch other parts of the body, Like the lower edge of the zygomatic arch, as well as the septum of the maxillary sinus causing it difficult to detect the roots (Cho and Hwang, 2009). The second molars show the strongest correlation with skeletal maturity, while the third molars exhibit the weakest correlation in individuals of both genders (Uysal et al., 2004).

Skeletal growth is influenced by various factors, but in normal, healthy children, it typically occurs simultaneously with tooth development. While a correlation is known to exist, it is unlikely to be highly accurate, especially for children with unusual growth patterns. However, these are the individuals for whom precise predictions are most critical (Houston, Miller and Tanner, 1979).

In this study, no significant correlation between MP3 and 2nd molar stages was found in total male and female subjects, which agreed with other studies that found no association between dental and skeletal ages (Şahin and Gazilerli, 2002; Koutsikou, Sidiropoulou and Kawadia, 2003) while disagreeing with another study that revealed significant relationships between the skeletal and dental maturation level (Motghare et al., 2016; Kumar et al., 2012; Jourieh et al., 2021; Poulsen and Sonnesen, 2023). Three factors contribute to the difference between skeletal age and chronological age: variability in skeletal maturation rates among individuals, which leads to systematic errors in methods for estimating skeletal age, The disparity in research results may be partially attributed to the diverse methodologies used to assess skeletal and dental development; and variability caused by differences among observers (Jourieh et al., 2021).

In our study, the lowest and nearly equal distribution between males and females was observed in the post-pubertal phase for both the second molar and MP3, with no gender difference. This could be attributed to the closure of the apex of the second lower molar occurred at a similar age range of 14.5 to 15.4 years. These findings align with the result of previous studies (Usman, 2022; Ogodescu, 2011) but contradict another study, which reported that 80% of females are in the post-peak stage compared to less than 10% of males (Saloom, 2011).

Conclusion

- Mandibular second molar calcification stages of Demirgian's classification are unreliable as a skeletal maturity indicator in TIDM showing no significant correlation with MP3 stages of skeletal maturation despite of approximate frequency between them.

- Skeletal maturation cannot be predicted solely based on chronological age

Supplementary Material

None.

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Data Availability Statement

Data are available from the authors upon reasonable request.

Conflict of interest

The authors reported that they have no conflicts of interest.

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