Original Article

Assessment of correlation between dental calcification stages and skeletal maturity indicators

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Abstract

Introduction: Assessment of age is a critical step in the identification of an individual in forensic cases. The hand–wrist radiographic evaluation and tooth development is also a useful measure of maturity because it represents a series of recognizable changes that occur in the same sequence from an initial event to a constant end point. **Aim of the Study:** To investigate the relationship of dental calcification stages and skeletal maturity indicators as assessed by the hand–wrist bone radiograph. **Objectives:** (1) Correlation of dental calcification stages and skeletal maturation. Information for decision-making in treatment plan in growing patients. **Materials and Methods:** A cross-sectional pilot study was performed using orthopantomograph (OPG) and hand–wrist radiographs of fifty children (25 males and 25 females) with age ranging from 8 to 14 years. The hand–wrist radiographs and OPG were analyzed using Fishman's Skeletal Maturity Index and the Demirjian's system, respectively. SPSS software version 19 (IBM) was used in the calculation of all statistical analyses. **Results:** Correlation coefficient ranged from 0.61 to 0.83 for males and from 0.81 to 0.86 for females. The canine stage F for both sexes coincided with the MP3 stage, which is indicative of the onset of a period of accelerating growth. **Conclusion:** The findings of this pilot study indicated that tooth calcification stages might be clinically used as a maturity indicator of the pubertal growth period.

Key words: Demirjian's method, dental age, Fishman's method, forensic odontology, skeletal age

Introduction

Growing individuals differ in the timing of maturational events due to genetic and racial diversity and environmental influences.[1,2] Children having same chronological age may differ in their developmental biological stages.[3] Various parameters to assess the developmental status include height, weight, secondary sexual characters, and skeletal age. Skeletal age evaluation is considered to be the most reliable method for diagnosis and treatment planning, and it also helps in the indication of the therapeutic outcome of treatment.[1]

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Another physiologic method for skeletal growth assessment is the calcification of dental tissue. This method seems to be reliable because of comparatively low variability.[4,5] It is least affected by nutrition and endocrine status.[3]

Various procedures are based on increased and decreased craniofacial growth such as the age estimation in mass disaster or medicolegal cases/criminal cases, use of functional appliances, extraction versus nonextraction, the selection and execution of orthodontic retention, and the timing of orthognathic surgery.[5]

Age estimation is the primary step in forensic conditions if dental records are maintained properly such as cast, prosthesis, and radiographs.

Assessment by tooth calcification is considered to be superior to the clinical emergence of the teeth because tooth calcification is rarely influenced by local factors. Calcification is a continuous developmental process, thus considered to be a better method.[3,4]

The dental calcification stages can be used to estimate the age in forensic situations if the relation between skeletal maturity indicators and calcification exists.

Materials and Methods

This study is based on fifty hand–wrist radiographs and orthopantomographs (OPGs) of children aged from 8 to 14 years.

Inclusion criteria

1. Participants should not have any craniofacial abnormality and should be free of any known serious illness
2. Participants should have never undergone any orthodontic treatment or extraction of any permanent teeth
3. Participants should have no history of trauma or injury to the face, hand, and wrist regions.

Tooth calcification is assessed by the method described by Demirjian *et al*., in which one of the eight stages of calcification, A to H, was assigned to each tooth[6] as shown in the following manner:

- Stage A: Calcification of single occlusal points without fusion of different calcifications
- Stage B: Fusion of mineralization points; the contour of the occlusal surface is recognizable
- Stage C: Enamel formation has been completed at the occlusal surface, and dentin 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 that in the previous stage. In molars, the radicular bifurcation has commenced 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 the roots a distinct form
- Stage G: The walls of the root canal are now parallel, but the apical end is partially open. In molars, only the distal root is rated
- Stage H: The root apex is completely closed (distal root in molars). The periodontal membrane surrounding the root and apex is uniform in width throughout.[7]

Hand–wrist radiograph is used for the assessment of skeletal maturity according to a method described by Fishman.[8] The sequence of the four ossification stages proceeds through epiphyseal widening on selected phalanges, the ossification of the adductor sesamoid of the thumb, the "capping" of selected epiphyses over their diaphyses, and the fusion of selected epiphyses and diaphyses.[9] The following selected ossification events were determined:

1. MP3: The middle phalanx of the third finger; the epiphysis is equal to its diaphysis
2. S stage: The first mineralization of the ulnar sesamoid bone
3. $MP3_{cap}$: The middle phalanx of the third finger; the diaphysis is capped by epiphysis
4. $DP3_u$: The distal phalanx of the third finger; complete epiphyseal union takes place
5. $MP3_u$: The middle phalanx of the third finger; complete epiphyseal union takes place.

Significant correlation was observed between skeletal age and chronological age in both males and females. Thus, skeletal age assessment using Fishman method is a reliable technique for estimating age.

Statistical analysis

The Spearman's rank-order correlation coefficient was applied 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 study the relationships between the stage of mineralization of the teeth and the stage of skeletal maturation, the percentage distribution of the stages of calcification for each tooth was calculated.

Results

- MP3 stage: The canine stage F had shown the highest percentage distribution in males (92%) as well as females (80%) in the MP3 stage, whereas all the remaining teeth had scattered distribution, which indicated the onset of a period of accelerating growth [Table 1]
- $MP3_{cap}$ stage: In this stage, root completion of canine as well as the 1st and 2nd premolars had been taken place in a majority of participants. The second molar development was highly concentrated in stage G (50%) [Table 2]
- $MP3_u$ stage: In this stage, all males showed calcification stage G, whereas in females, G and H calcification stages were shown [Table 3]
- S stage: The second molar stage G was related to the S stage and is indicative of the period of very rapid growth velocity [Table 4].

Table 1: Distribution of participants according to gender in MP3 stage

Sex	Frequency (%)			
	2nd molar	2nd premolar	1st premolar	Canine
Male				
D	2 (15.4)	0 (0)	0 (0)	0 (0)
E	3 (23.1)	5 (38.5)	2 (15.4)	0
F	7 (53.8)	5 (38.5)	9 (69.2)	12 (92.3)
G	1 (7.7)	3 (23.1)	2 (15.4)	0 (0.0)
H	0 (0.0)	0 (0.0)	0 (0.0)	1 (7.7)
Total	13 (100.0)	13 (100.0)	13 (100.0)	13 (100.0)
Female				
D	1 (20.0)	1 (20.0)	0 (0.0)	0 (0.0)
E	2 (40.0)	1 (20.0)	2 (40.0)	0 (0.0)
F	2 (40.0)	2 (40.0)	2 (40.0)	4 (80.0)
G	0 (0.0)	1 (20.0)	1 (20.0)	1 (20.0)
Total	5 (100.0)	5 (100.0)	5 (100.0)	5 (100.0)

Note: None of the patients showed up in DP_u stage.

Correlation coefficient

Correlation coefficient ranged from 0.61 to 0.83 for males and from 0.81 to 0.86 for females [Table 5]. The tooth sequence in order of the highest to the lowest correlation for males was the canine, 1st premolar, 2nd premolar, and 2st molar. The corresponding sequence in females was the 2nd molar, canine, the 1st premolar, and the 2nd premolar. $P < 0.001$ was considered statistically significant.

Note: *R*-value denotes correlation coefficient, closer to 1 indicates strong positive correlation.

Discussion

The developmental status is assessed in relation to the various physical events such as skeletal ossification stages and pubertal changes of a growing individual. For treatment planning and diagnosis, indicators of developmental growth are more reliable than the chronological age.[10]

For the assessment of Skeletal age-foot, hand, wrist, ankle, elbow, and hip measurements have been used. In this study, the assessment of dental calcification was done by Demirjian's classification.[11] Demirjian's method has good reproducibility and is based on the stages of tooth calcification which is unaffected by systemic or endocrinal factors.[12]

Significant correlations have been recorded in several studies done by Krailassiri,[5] Chertkow,[12] and Uysal[13] between dental calcification stages and skeletal maturity indicators. If the individual is too young or too old, i.e., a wide range of age may affect the correlation results as the skeletal maturity methods are unable to detect the changes accurately. The participants enrolled in this study

Table 2: Distribution of participants according to gender in $MP3_{cap}$ stage

Hand wrist stage	Sex	Tooth stages	Frequency (%)			
			2nd molar	2nd premolar	1st premolar	Canine
$MP3_{cap}$	Male	F	1 (50.0)	0 (0)	0 (0)	0 (0)
		G	1 (50.0)	1 (50.0)	1 (50.0)	1 (50.0)
		H	0 (0.0)	1 (50.0)	1 (50.0)	1 (50.0)
		Total	2 (100.0)	2 (100.0)	2 (100.0)	2 (100.0)

Table 3: Distribution of participants according to gender in $MP3_u$ stage

Hand-wrist stage	Sex	Tooth stages	Frequency (%)			
			2nd molar	2nd premolar	1st premolar	Canine
$MP3_u$	Male	G	1 (100.0)	1 (100.0)	1 (100.0)	0 (0.0)
		H	0 (0.0)	0 (0)	0 (0)	1 (100.0)
	Female	G	0 (0.0)	1 (50.0)	1 (50.0)	1 (50.0)
		H	2 (100.0)	1 (50.0)	1 (50.0)	1 (50.0)
		Total	2 (100.0)	2 (100.0)	2 (100.0)	2 (100.0)

Table 4: Distribution of participants according to gender in S stage

Hand-wrist stage	Sex	Tooth stages	Frequency (%)			
			2nd molar	2nd premolar	1st premolar	Canine
S stage	Male	G	1 (100.0)	0 (0.0)	0 (0.0)	0 (0.0)
		H	0 (0.0)	1 (100.0)	1 (100.0)	1 (100.0)
	Female	H	1 (100.0)	1 (100.0)	1 (100.0)	1 (100.0)

Table 5: Correlation of skeletal maturity indicators and calcification stages of teeth

Sex	Canine	1st premolar	2nd premolar	2nd molar
Male				
Hand-wrist stage				
R	0.835	0.740	0.676	0.619
P	<0.001	<0.001	0.0028	0.0080
n	17	17	17	17
Hand-wrist stage				
R	0.861	0.817	0.812	0.882
P	0.0060	0.0132	0.0143	0.0037
n	8	8	8	8

Highlighted values are significant correlations. *R*-value indicates correlation coefficient, with closer to 1 indicating strong positive correlations[5,13]

were within or close to the circumpubertal period.[14] Chertkow[13] and Chertkow and Fatti[2] have suggested a high relationship between calcification of mandibular canine and skeletal maturity indicators, which would probably allow the forensic odontologist or dentist to assess age using hand–wrist radiograph. According to Motghare *et al*.,[15] the correlation coefficients indicate that the second molars showed the highest relationship. The present study found a similar trend, with an *r* value of 0.83 for males and 0.86 for females.

According to Grave and Brown, the accelerative growth spurt is accompanied by the width of epiphysis being equal to diaphysis. Phase in which the growth is at its peak, epiphysis caps the diaphysis. Ossification of sesamoid bone also occurs in this phase. In decelarative phase, epiphysis unites with diaphysis.[10]

In this study, hand–wrist radiograph is used for assessment as in this area of skeleton, there are various growth centers which undergo changes with time. OPG was used in the present study as it has a larger area of involvement of dental structure. Thus, the individual does not undergo multiple X-ray exposures.

Carpals were not included in the system as there is irregularity in the order of onset of ossification in the carpals than in the metacarpal or phalangeal epiphysis.[16,17] Maxillary teeth are not taken in the study as their roots overlap with the calcified structures in this area such as zygomatic arch, maxillary sinus, or zygomatic process, which makes the interpretation difficult.[12] As apical closure of mandibular incisors and first molars had already taken place, they were not included in the study.[5] Also because of uncertainty regarding the formation of third molars and poor correlation with skeletal maturity, third molars were excluded from the present study.[12] Teeth rated were the mandibular canines, the first and second premolars, and the second molars.

In this study, only 5 out of 11 skeletal maturity indicators were used for clear discrimination.[5] The correlation coefficients between skeletal maturity and calcification stages of the teeth were high, ranging from 0.61 to 0.88, and were statistically significant ($P < 0.001$).

Conclusion

The relationship between the stages of calcification of various teeth and skeletal maturity stages was evaluated by OPG and hand–wrist radiographs of 34 males and 16 females ranging in age from 8 to 14 years. The canine stage F for both sexes coincided with the MP3 stage, which is indicative of the onset of a period of accelerating growth.

The findings of this pilot study indicated that tooth calcification stages might be clinically used as a maturity indicator of the pubertal growth period.

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Conflicts of interest
There are no conflicts of interest.

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