

# Dental age estimation using Willems method: A digital orthopantomographic study

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## Abstract

In recent years, age estimation has become increasingly important in living people for a variety of reasons, including identifying criminal and legal responsibility, and for many other social events such as a birth certificate, marriage, beginning a job, joining the army, and retirement. **Objectives:** The aim of this study was to assess the developmental stages of left seven mandibular teeth for estimation of dental age (DA) in different age groups and to evaluate the possible correlation between DA and chronological age (CA) in South Indian population using Willems method. **Materials and Methods:** Digital Orthopantomogram of 332 subjects (166 males, 166 females) who fit the study and the criteria were obtained. Assessment of mandibular teeth (from central incisor to the second molar on left quadrant) development was undertaken and DA was assessed using Willems method. **Results and Discussion:** The present study showed a significant correlation between DA and CA in both males ( $r = 0.71$  and females ( $r = 0.88$ ). The overall mean difference between the estimated DA and CA for males was  $0.69 \pm 2.14$  years ( $P < 0.001$ ) while for females, it was  $0.08 \pm 1.34$  years ( $P > 0.05$ ). Willems method underestimated the mean age of males by 0.69 years and females by 0.08 years and showed that females mature earlier than males in selected population. The mean difference between DA and CA according to Willems method was 0.39 years and is statistically significant ( $P < 0.05$ ). **Conclusion:** This study showed significant relation between DA and CA. Thus, digital radiographic assessment of mandibular teeth development can be used to generate mean DA using Willems method and also the estimated age range for an individual of unknown CA.

**Keywords:** Age estimation, chronological age, dental age, forensic odontology, Willems method

## Introduction

Dental age (DA) determination is required in various clinical and scientific disciplines such as pediatric dentistry, orthodontics, archaeology, paleontology and forensic

dentistry.<sup>[1]</sup> In certain communities, the chronological age (CA) of living people bears significant importance regarding social benefits, employment and marriage.<sup>[2]</sup> Age of an unknown person can be assessed by correlating the physical, skeletal, and dental maturity of an individual. To be able to measure DA directly is important because it is a useful tool to estimate the CA of a child with an unknown birth date.<sup>[3]</sup>

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Several methods have been proposed for assessing dental development, which is generally referred to as dental aging. Dental aging appears in two forms: Tooth mineralization and tooth eruption patterns, both biological and developmental patterns. Eruption refers to the emergence of the tooth through the gum rather than to the emergence from the bone or reaching the occlusal plane. This makes it impossible to use eruption for age estimation on skeletal remains in forensics. Tooth emergence may be influenced significantly by local exogenous factors such as infection, obstruction, crowding, and premature extraction of the deciduous predecessor or adjacent permanent teeth.

There is now full accordance in the literature that the methods of DA estimation relying on the evaluation of the mineralization and growth stage of the teeth seem to be scarcely affected by local and systemic factors,<sup>[4]</sup> but are dependent on the genetics of the populations as they show an ethnic variability.<sup>[5]</sup> The estimation of age through the study of the calcification of the permanent teeth has been demonstrated to provide reliable and accurate methods and results.

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Ideally, age estimation in a specific population should be done by the usage of different methods provided by existing literature and practices, as well as the development of new methods to ensure the application of the most adequate technique.<sup>[5]</sup> Different methods are available for estimating the DA as advanced by Nolla's,<sup>[6]</sup> Haavikko's,<sup>[7]</sup> Demirjian's, and modified Demirjian method by Willems *et al.*,<sup>[8]</sup> In order to quantify continuous process from first traces of cusps mineralization until root apex closure, many authors suggested different number of radiographic stages. Demirjian *et al.*, method in which tooth formation is divided in to eight stages and criteria of these stages for each tooth were given separately. Each stage of the left mandibular seven teeth was allocated a score and the sum of the scores gave an evaluation of the subject's dental maturity and the DA was calculated using the sex specific tables. When applying this method, toward the end of dental maturation fewer stages contribute more, so that a single stage change can lead to a large jump in DA. Nolla's study was one of the first to assess tooth formation longitudinally and quantify dental maturation. In this method, a sum of tooth scores against each year of age were given and which were used to predict age in to 1 year age groups and also provides an age at each stage for each tooth. Haavikko *et al.*, suggested to adopt an age estimation method based on the determination of one of 12 radiographic stages of each permanent teeth. The difficulty with Haavikko method was deciding if the children who were considerably delayed in one tooth, were to be included in the full analyses in order to compare with other methods.

Even though, other methods have been used, the most widely used method for DA estimation was described in 1973 by Demirjian *et al.*,<sup>[9]</sup> because of its simplicity. This method has been tested in various populations and has been mostly reported to overestimate the age of an individual.<sup>[10-14]</sup> In 2001, Willems *et al.*, evaluated the accuracy of Demirjian method in Belgian Caucasian population and modified the scoring system when a significant overestimation was reported. This modification has been evaluated among various communities and has been reported to be more accurate<sup>[15-19]</sup> compared with the original method. As this method has not been tested in South Indian children, for that reason, the aim of this study was to evaluate the applicability of Willems *et al.*, method of DA estimation in South Indian children of 6-16 years age.

## Materials and Methods

The study sample consisted of 332 randomly selected subjects (166 males and 166 females) of age ranging from 6 to 16 years (of South Indian descent and parents of each subject having same ethnicity) divided into five groups according to age [Table 1]. Informed consent was taken from all individuals and the study was approved by the Ethical Clearance Committee of our institution, Visakhapatnam, A.P. India. Initial screening was done to satisfy the inclusion criteria namely

**Table 1: Distribution of entire sample according to age and sex**

Age groups	Males (N)	Females (N)	Total (N)
6-7.99	21	20	41
8-9.99	19	19	38
10-11.99	35	37	72
12-13.99	44	51	95
14-15.99	47	39	86
Total	166	166	332

N: Number

children (1) of South Indian descent and having parents of the same ethnicity (2) with no medical history of systemic diseases or nutritional disorders (3) with no missing left mandibular teeth. Subjects with (a) serious medical illness (psychiatric problems, endocrine diseases), (b) history of extraction of permanent teeth, (c) Trauma to the face, (d) impacted or ankylosed teeth, (e) congenital developmental abnormalities, (f) physically or mentally challenged children, and (g) gross malocclusion, were excluded from the study. Clinical examination of all 332 individuals was performed and name, sex, and date of birth of each individual and date of radiography were recorded. All the radiographs were taken with PROMAX digital Planmeca Machine (Planmeca OY, Asentajankatu 6, FIN-00880 Helsinki, Finland). The sample size was calculated to be around 344 from the pilot study. After keeping the confidence interval limits as 95%, with the minimum marginal error to 1% (to estimate the difference of at least 1 year between the CA and the DA), the sample size came out to be 332.14, i.e., approximately 332. A convenience sampling method was performed to select the panoramic radiographs available in the Department of Oral Medicine and Radiology of our institution.

### Assessment of dental age using Willems method

CA of an individual was calculated by subtracting the birth date from the date on which the radiographs were exposed for that particular individual. Digital panoramic radiographs (orthopantomograms [OPGs]) of all children were used to assess the status of maturation on the basis of calcification of the permanent teeth in mandibular left side, from central incisor to the second molar, using Demirjian *et al.*, method. To avoid observer bias, each digital OPG of an individual was coded with a numerical identity number (1-332) to ensure that the examiner was blind to sex, name and age of subjects. Two evaluators (Orthodontists) were supplied with all 332 OPGs each and with written instructions for staging, including drawings and written descriptions of stages of tooth development of Demirjian *et al.*, method [Table 2].<sup>[9]</sup> Tooth formation is divided in to eight stages and criteria of these stages for each tooth were given separately. After noting all stages of teeth from central incisor to the second molar by the two examiners, the developmental status of a particular tooth was calculated in years on the basis of tables given by Willems

**Table 2: Description for developmental stages of teeth**

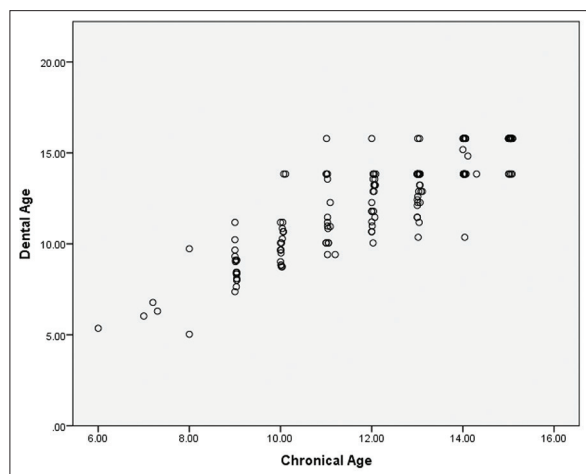
Stage	Description
A	A beginning of calcification is seen at the superior level of crypt in the form of cones. There is no fusion of these calcified points
B	Fusion of the calcified points forms one or several cusps, giving a regularly outlined occlusal surface
C	Enamel and dentin formation is complete at the occlusal surface and converge at cervical region Dentin deposition is seen The outline of the pulp chamber has a curved shape at the occlusal border
D	Crown formation is completed down to the cementoenamel junction Superior border of pulp chamber in uniradicular teeth has a definite curved form; projection of pulp horns gives an umbrella top. In molars, pulp chamber has a trapezoidal form Beginning of root formation is seen in the form of a spicule
E	Uniradicular teeth The walls of pulp chamber form straight lines, whose continuity is broken by the pulp horn The root length is less than the crown height In molars Initiation of radicular bifurcation is seen as a calcified point or a semi-lunar shape Root length is less than crown height
F	Uniradicular teeth The walls of pulp chamber form isosceles triangle. Apex ends in a funnel shape The root length is equal to or greater than the crown height In molars The bifurcation has developed down to give the roots a distinct outline with funnel shaped endings Root length is equal to or greater than crown height
G	The walls of root canal are now parallel and its apical end is partially open (distal root in molars)
H	The apical end of the root canal is completely closed Periodontal membrane has a uniform width around the root and apex

et al., [Table 3]. All the values from central incisor to the second molar thus obtained were summed to obtain an overall maturity score, which will indicate the DA of that particular patient. To test the intra-examiner variability, each examiner re-evaluated 50 images after 1 month of the same subjects. Data were analyzed by Statistical Package for the Social Sciences computer software (SPSS, version 20.0, SPSS Inc., Chicago, IL, USA) using Pearson’s Chi-square test,  $P < 0.05$  was considered to be significant. Reliability of Willems method was verified by testing Intra and Inter observer variability using Wilcoxon Signed Ranks test and Mann-Whitney U-test. The differences between DA and CA in different age groups in both sexes were tabulated using descriptive statistics and the differences were compared using ANOVA test.

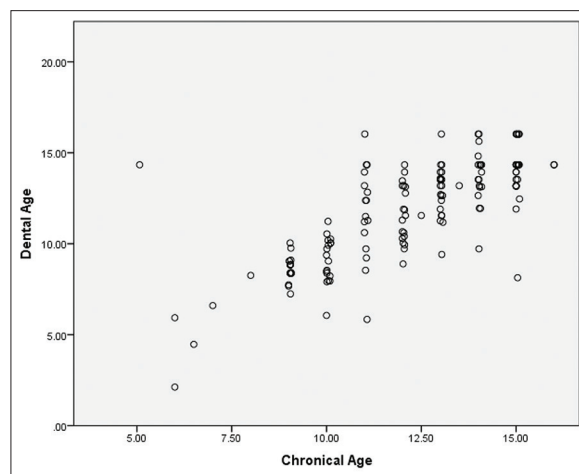
### Results

Comparison of the DA applying the Willems method, the CA and differences between DA and CA (DA and CA) of both gender and age groups are presented in Table 4. The independent samples *t*-test results indicated that the mean CA was  $11.92 \pm 2.63$  and the mean DA was  $11.53 \pm 2.91$ . This mean indicated an under aging of the entire sample as by about  $0.39 \pm 1.81$  years. The mean age difference between DA determined using the Willems method (from the Belgian Caucasian population) and the CA of this Andhra population was 0.69 years for males and 0.08 years for females and independent *t*-test showed that these differences were statistically not significant ( $P > 0.05$ ).

[Figures 1 and 2] demonstrate the distribution of estimated DA in comparison with CA in males and females respectively. They show that underestimation was more common than overestimation in both sexes. The mean difference between DA and CA according to Willems method was 0.39 years and is statistically significant ( $P < 0.001$ ). The mean absolute differences were 1.02 years for females and 1.6 years for males and showed that absolute accuracy was better for females



**Figure 1:** Scatter plot for dental age versus chronological age in males



**Figure 2:** Scatter plot for dental age versus chronological age in females

**Table 3: Developmental tooth stages with corresponding age scores expressed directly in years for each of the seven left mandibular teeth in boys and girls**

Gender	Tooth	A	B	C	D	E	F	G	H
Boys	Central incisor	-	-	1.68	1.49	1.5	1.86	2.07	2.19
	Lateral incisor	-	-	0.55	0.63	0.74	1.08	1.32	1.64
	canine	-	-	-	0.04	0.31	0.47	1.09	1.9
	First bicuspid	0.15	0.56	0.75	1.11	1.48	2.03	2.43	2.83
	Second bicuspid	0.08	0.05	0.12	0.27	0.33	0.45	0.4	1.15
	First molar	-	-	-	0.69	1.14	1.6	1.95	2.15
	Second molar	0.18	0.48	0.71	0.8	1.31	2	2.48	4.17
Girls	Central incisor	-	-	1.83	2.19	2.34	2.82	3.19	3.14
	Lateral incisor	-	-	-	0.29	0.32	0.49	0.79	0.7
	canine	-	-	0.6	0.54	0.62	1.08	1.72	2
	First bicuspid	-0.95	-0.15	0.16	0.41	0.6	1.27	1.58	2.19
	Second bicuspid	-0.19	0.01	0.27	0.17	0.35	0.35	0.55	1.51
	First molar	-	-	-	0.62	0.9	1.56	1.82	2.21
	Second molar	0.14	0.11	0.21	0.32	0.66	1.28	2.09	4.04

compared with males. Mean absolute differences and standard deviations for age cohort for males and females are presented in Table 5. Spearman rank test showed a significant correlation between DA and CA ( $r = 0.78; P < 0.0001$ ). ANOVA test showed significant differences in the estimation between the CA and DA for both males ( $F = 610.01, P < 0.001$ ) and females ( $F = 167.74, P < 0.001$ ). Wilcoxon test showed no statistically significant differences between readings of two observers ( $Z = -0.275; P > 0.05$ ) and also showed significant relation between DA and CA ( $Z = -4.254; P < 0.05$ ) [Table 6]. The difference between DA and CA on the first and second readings was significant at 5% level of significance ( $Z = -2.008; P < 0.05$ ).

## Discussion

Developing teeth in radiographs are frequently used to assess dental maturity and estimate age. Age estimation has become increasingly important to determine the age of living individuals. Identification of age is very important for a variety of reasons, including identifying criminal and legal responsibility, determining the emotional support needed for the victim of a sexual assault and for many other social events such as a birth certificate, marriage, beginning a job, joining the army, and retirement.<sup>[19]</sup>

The evaluation of mineralization from OPGs is the most suitable method for age estimation using teeth in children because a single radiograph gives the complete developmental status of dentition in children. Digital OPGs were used as the images can be magnified to make analysis easier. Subjects with history of trauma to the face were excluded as it may lead to delayed eruption or early mineralization of teeth and also with gross malocclusion were excluded as it may lead to discrepancies during staging of teeth development.

Although various age assessment methods showed high degrees of reliability, ethnic differences between various population groups were found to affect the accuracy resulting in overestimation or underestimation of the DA. In 2001, Willems *et al.*,<sup>[8]</sup> evaluated the accuracy of Demirjian's method in Belgian Caucasian population and modified the scoring system. No two individuals grow and develop at the same rate.<sup>[20]</sup> Tooth development has variations among populations and these differences exist between several ethnic groups worldwide. Therefore, this study was performed to compare the DA assessment in South Indian children using the Belgian-Caucasian standard from Willems' study.

The overall mean difference between the estimated DA and CA for males was  $0.69 \pm 2.14$  years ( $P < 0.001$ ) while for females, it was  $0.08 \pm 1.34$  years ( $P > 0.05$ ). In the entire sample, the difference in estimated DA varied between 0.51-1.6 years for males and 0.08-0.61 years for females, respectively. It should be noted that except in 8-9.99 and 14-15.99 year age groups, statistically significant differences between the DA and the CA were not found. The greatest underestimation in males was found in the 14-15.99 year old age group followed by 12-13.99 and 8-9.99 year age groups. The greatest overestimation in males was found only in 6-7.99 year age group. In females, the greatest underestimation was found in 8-9.99 year age group followed by 14-15.99 and 12-13.99 year age groups. The greatest overestimation in females was found only in 10-11.99 year age group. In the entire sample, there was considerable underestimation of age in all age groups except in 6-7.99 year age group. Also before the age of 10, males were more advanced in DA compared to females, but after this age the overestimation in females became more frequent, but these gender differences in the entire sample were not statistically significant ( $P > 0.05$ ). This may be due to the fact that Willems method gives separate standards for each sex, accounting for sexual differences. When the entire sample was considered, underestimation of age was noted, in agreement with previous studies.<sup>[10,21,22]</sup> These differences can be explained by the difference in sample size, method of age calculation, age groups, the age and sex distribution of the original study population and statistical methodologies.

When comparison among genders is done, females mature earlier than males, but the mean difference between DA and

**Table 4: Unpaired t test between DA according to Willems method and CA for South Indian males and females with the mean difference between both**

Age group	Sex	N	CA		DA		DA-CA		95% CI of DA-CA		t value	P value
			Mean	SD	Mean	SD	Mean	SD	Lower	Upper		
6-7.99	Male	21	7.16	0.56	7.67	1.86	0.51	1.79	-0.30	1.33	-1.31	0.21
	Female	20	7.27	0.43	7.24	1.31	-0.03	1.36	-0.67	0.61	0.09	0.93
	Total	41	7.21	0.50	7.46	1.61	0.25	1.60	-0.26	0.76	-1.00	0.33
8-9.99	Male	19	9.46	0.31	8.98	1.78	-0.49	1.79	-1.35	0.38	1.19	0.25
	Female	19	9.25	0.30	8.64	1.28	-0.61	1.30	-1.24	0.02	2.04	0.06
	Total	38	9.36	0.32	8.81	1.54	-0.55	1.54	-1.05	-0.04	2.19	0.04*
10-11.99	Male	35	10.85	0.67	10.36	2.58	-0.48	2.45	-1.32	0.36	1.17	0.25
	Female	37	10.82	0.59	10.90	1.78	0.08	1.65	-0.47	0.63	-0.31	0.76
	Total	72	10.83	0.62	10.64	2.21	-0.19	2.08	-0.68	0.30	0.78	0.44
12-13.99	Male	44	12.96	0.48	12.41	1.85	-0.55	1.86	-1.12	0.01	1.97	0.06
	Female	51	12.95	0.52	12.91	1.32	-0.04	1.26	-0.39	0.32	0.21	0.84
	Total	95	12.95	0.50	12.68	1.60	-0.28	1.58	-0.60	0.05	1.70	0.09
14-15.99	Male	47	15.13	0.60	13.53	2.02	-1.60	2.12	-2.22	-0.98	5.17	0.00*
	Female	39	14.97	0.60	14.91	1.19	-0.05	1.09	-0.41	0.30	0.32	0.76
	Total	86	15.06	0.60	14.16	1.82	-0.90	1.89	-1.30	-0.49	4.41	0.00*
Total	Male	166	11.99	2.71	11.30	2.90	-0.69	2.14	-1.02	-0.36	4.17	0.00*
	Female	166	11.84	2.55	11.76	2.90	-0.08	1.34	-0.28	0.13	0.76	0.45
	Total	332	11.92	2.63	11.53	2.91	-0.39	1.81	-0.58	-0.19	3.89	0.00*

\*P < 0.05 is statistically significant. N: Number; SD: Standard deviation; CI: Confidential interval; CA: Chronological age; DA: Dental age

**Table 5: Absolute difference for (DA-CA)**

Age group	Sex	Mean	N	Standard deviation	Median
6-7.99	Males	1.36	21	1.242	0.86
	Females	1.192	20	0.605	1.165
	Total	1.279	41	0.976	1.03
8-9.99	Males	1.215	19	1.371	1.08
	Females	1.134	19	0.854	1.07
	Total	1.175	38	1.127	1.07
10-11.99	Males	1.874	35	1.615	1.62
	Females	1.201	37	1.116	1.04
	Total	1.528	72	1.412	1.07
12-13.99	Males	1.43	44	1.292	1.09
	Females	0.992	51	0.767	0.72
	Total	1.198	95	1.061	0.95
14-15.99	Males	1.863	47	1.892	1.40
	Females	0.78	39	0.74	0.57
	Total	1.372	86	1.575	1.05
Total	Males	1.61	166	1.558	1.19
	Females	1.02	166	0.853	0.80
	Total	1.32	332	1.288	1.01

CA: Chronological age; DA: Dental age

CA was not statistically significant ( $P > 0.05$ ). However, in the present study Willems method was better applied for females when compared with males, which is in agreement

with Grover *et al.*,<sup>[23]</sup> but in contrast to previous studies<sup>[10,14,16]</sup> where Willems method “ favored” males. In the present study, it was observed that South Indian Children were significantly delayed in dental maturation (0.69 years in males and 0.08 years in females) than the Belgian and also other populations evaluated in previous studies.

In contrast to previous studies,<sup>[14-16,18,23-25]</sup> the present study underestimated the age in South Indians. This delay in dental maturation may be partly explained by the environmental factors, genetic variations, population differences, socio-economic status, nutrition, dietary habits, and lifestyle. This study also showed a significant correlation between DA and CA in both males ( $r = 0.71$ ) and females ( $r = 0.88$ ) and in the entire sample ( $r = 0.78$ ). To avoid errors, proper visual discrimination between formation stages should be improved by training and calibration, but it remains subjective and even a one stage difference may have an impact on DA.

Moreover, it is equally important to realize that no age estimation will accurately determine the exact age for every individual since development naturally varies between individuals. Moreover, DA is not same for all children of a specific known age. Most important aspect of DA estimation is to remember that one should not restrict to only one age estimation technique, but to apply different techniques available and perform repetitive measurements and calculations.

**Table 6: Difference between intra and inter observer difference and DA and CA (Wilcoxon signed ranks test)**

Variables	N	Mean	SD	Z value	P value
B1	332	12.81	22.29	-0.275	0.783
A1	332	11.53	2.91		
B2	50	11.99	3.49	-2.482	0.013*
A2	50	12.28	3.12		
A2	50	12.28	3.12	-0.294	0.769
A1	332	11.53	2.91		
B2	50	11.99	3.49	-0.385	0.700
B1	332	12.81	22.29		
DA	332	11.53	2.91	-4.254	0.000*
CA	332	11.92	2.63		

\*P<0.05 is significant; B1: First reading by second evaluator; B2: Second reading by second evaluator; A1: First reading by first evaluator; A2: Second reading by first evaluator; CA: Chronological age; DA: Dental age; SD: Standard deviation

## Conclusion

Age estimation plays an important role in forensic, legal and social issues. When Willems method of age estimation has been applied to South Indians, underestimation of age was noted leading to delayed dental maturity compared to Belgians. In this study, significant relation was found between estimated DA and CA and thus the Willems method seems to be applicable in estimating age in South Indian Children. As no published data is available regarding the application of Willems method in selected population, this paper provides an insight in using Willems method in South Indians for estimating mean age of a child with unknown CA.

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