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Research Article

Evaluation of the Accuracy of Demirjian's Method for Dental Age Estimation in Northern Sudanese Children and Adolescents

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Abstract

A variety of methods have been used worldwide in dental age assessment in the living. However, since dental development varies between populations, population-specific studies are necessary. This study aimed at investigating the accuracy of age estimation using developing teeth from panoramic radiographs according to the method devised by Demirjian and colleagues in a sample of Northern Sudanese children and adolescents (2) Methods: A total sample of 917 X-Rays from patients aged between 6-16 years of age was available, but only 527 were suitable (265 boys, 272 girls). (3) Results: The mean difference between chronological and dental age for Northern Sudanese boys, ranged between (–0.389 to +0.571) while, for the Northern Sudanese girls, the mean difference ranged between (–0.056 to+0.732); (4) Conclusions: The results showed that the Demirjian's method did not accurately predict age in this Northern Sudanese population. Standards were produced to convert the maturity scores calculated by Demirjian's method to a new dental age assessment for Northern-Sudanese population.

Keywords: *Age estimation; Dental age; Forensic anthropology; Forensic dentistry, Sudan*

1. Introduction

Age Assessment in living individuals can be an important process that has social, financial, medical, investigative and legal consequences.(1) Various growth parameters have been used to establish an accurate definition of the biological or physiological age of children.(2) The most commonly used developmental indicators include skeletal maturity, body height and weight , sexual development as well as tooth development and eruption.(3) Some researchers(4,5) have advocated the applicability of the bone age estimation methods; whilst others(6-12) have endorsed the applicability of the dental age determination method, which is less affected by environmental factors. (13,14)

The importance of the human dentition as a measure of maturity and the association of dental age (DA) with chronological age (CA) are of interest to forensic anthropologists, forensic odontologists and other professionals. (15) DA refers to the morphological state of an individual's dentition without reference to their actual or chronological age. (1) Moorrees *et al.* (16) described DA as involving both the formation and the emergence of the teeth; whilst Krogman(17) defined DA as the variable registry of biologic time in the developing dentition, which is divided into two subtypes: calcification age and eruption age.

In death investigations where there are issues of identification, age estimations from teeth are frequently used because teeth are the hardest tissue of the body and can withstand trauma, decomposition, heat degradation, water immersion and desiccation better than any other tissue. (18) Teeth can also resist the influence of environmental factors and disintegrates only very slowly. (19) This makes teeth very suitable for age estimation.

Some of the more accurate methods of age estimation in the juvenile and young adult individuals have been based on the assessment of the degree of dental development. These methods rely on radiographic assessment of the degree of calcification of the forming dentition. This assessment is then compared to reference tables or diagrams of examples of known age to estimate the chronological age of the individual. [1]

A variety of methods have been used to assess dental age in the living, for instance Demirjian[20] and Nolla[21]. However, since dental development varies between populations, population-specific studies are necessary. [22]

Demirjian et al. (1973) [20] developed an aging system using an approach published earlier by Tanner et al. (1962). [23] Their method used a seven-tooth system that was based on eight stages of calcification. Each tooth was given a score based on its phase of calcification. These evaluations were totaled for all teeth, which gave a maturity score measuring from 0 to 100. This maturity age could then be converted into a dental age. The 1973 method for estimating dental maturity was later reevaluated and updated by Demirjian and Goldstein (1976). [24]

Demirjian and Goldstein (1976) thus developed a system that extended the age range and the number of stages. They created a four-tooth system of analysis. The authors noted in their discussion that their sample was entirely of French-Canadian origin and may not be applicable to other populations. They conjectured that while the scores for the stages will likely not change very much, the maturity standards might change considerably. Nevertheless, Demirijian's method has been tested in different populations, although DA estimation is scarce for some regions.

Sudanese society is multiethnic, multicultural and multireligious. Reportedly, the country has 600 ethnic groups. Moreover, the Sudanese population is very culturally diverse, containing highly differentiated lifestyles, livelihoods and ancestral backgrounds. The majority of ethnic groups in North-Sudan fall under Arabs (70%), and the minority (30%) being other African ethnic groups such as the Beja, Fur, Nuba, and Fallata that lives in the westernmost region (Darfur). To our knowledge, only one study was published on Non-Arab Darfurian Sudanese people belong to West-Sudan, but no such study was available in North Sudan. Therefore, this study aimed at investigating the accuracy of age estimation using developing teeth from panoramic radiographs according to the method devised by Demirjian and colleagues and applied to a population sample of Northern Sudanese children and adolescents.

2. Materials and Methods

The research protocol was approved by the Faculty of Dentistry Ethical Committee, Khartoum University, Sudan.

Study Sample

This study was cross-sectional and retrospective. Data were collected from anonymized patients' files and records from various hospitals, private clinics and dental health centers in Khartoum, Sudan. These data provided included the individua's gender, date of birth, and date of radiograph and medical history if relevant.

Nationality and/or ethnicity was based on self-declared information from the patients' files. Although in a few cases ethnicity may be questionable, every effort was made to exclude patients with surnames suggesting a non-Northern-Sudanese ancestry.

Patients were divided into 10 groups according to their Chronological Age (CA). The first group, consisted of 6-year-olds, included patients with ages ranging from 6.0 to 6.9 years by converting CA into decimal age. The next group included 7-year-olds and so on. The total CA for this population sample ranged from 6.0 to 15.9. Mandibular teeth were examined. Chronological age for each subject was calculated as a decimal age for ease of manipulation and comparison by using the website http://www.simd.org/Tools/age.asp [15] by entering the child's reported date of birth.

Inclusion and Exclusion Criteria

Criteria for inclusion

1- Children must be between 6 and16 years of age at the time the panoramic radiographs were obtained.

2- Availability of a panoramic radiograph of adequate quality.

3- No medical history or previous surgery that could affect the presence and development of mandibular permanent teeth.

Criteria for Exclusion

1- Considerable orthodontia (such as braces).

2- More than one absent mandibular tooth, whether this was as a result of agenesis or extraction amongst other factors.

3- Significant delay in dental development (with the exception of the third molar).

4- Known systemic diseases for example (hypothyrodism, cleidocranial dysplasia).

5- If there were twins, only one individual was selected.

6- Panoramic radiographs where the data of the examination was unknown.

Out of data available for 917 patients, only 527 met these criteria and were suitable for this study (265 boys, 272 girls).

Calculating Dental Age

The Dental Age (DA) was evaluated in this study by applying Demirjian's method [20] which is based on the development of seven left mandibular permanent teeth. These were the central incisor, the lateral incisor, the canine, the first and second premolars and the first and second molars. The eight-grade scale of Demirjian was used to rate the development of each tooth, accompanied by written descriptions and supplementary illustrations. In case of any missing left mandibular teeth, the right antimere was scored.

Each assigned scale was then assigned an appropriate score representing the developmental stage using standard tables. All scores were then added up. The sum of the scores provided an estimate of the subject's dental maturity, measured on a scale from 0 to 100. The overall maturity score (the obtained total score) was then converted to a dental age by using standards tables given separately for each gender aged from 6 to 16 years.

Reliability

Two different observers assessed tooth development on 100 radiographs randomly selected from the sample. Patient ID, age, date of birth and date of radiograph were not known to the observers. Each observer repeated the reading of the radiographs after one month. The second evaluations were compared with those recorded during the first trial (intra-observer). Readings of both observers were then compared to assess reliability (inter-observer).

Any differences between the first and the second evaluation regarding any given tooth never exceeded one developmental stage. When disparities occurred, a lower developmental stage was chosen.

Intra-observer agreement was 96%. The assessments of inter-observer variation agreed in 93% of the cases studied.

Statistical Analysis

Descriptive statistics were calculated for quantitative variables as means and standard deviation. Comparison of chronological and dental age were done using signed rank un-paired t-tests. In addition, the difference between both genders groups was investigated using signed rank t-test. Significance level was set at 5% level ($p \leq 0.05$).

Calculating accuracy

Accuracy of dental age estimation was defined as how closely chronological age could be predicted, measured as the difference between chronological age and dental age. [25] The mean difference for DA and CA was measured. A positive result indicated an overestimation, while a negative value, an underestimation. This was done for the entire age range for boys and girls separately.

Standard dental maturation tables were obtained using function formulae for the Northern Sudanese population.

3. Results

Northern-Sudanese boys

Table (1) and Figure (1) show a comparison of CA and DA according to Demirjian's method for the Northern-Sudanese boys. The table shows the difference in mean and standard deviation between CA and DA. When CA was compared with DA, the boys' sample showed no statistically significant differences. The mean difference between CA and DA ranged from –4.67 to +6.85 months.

The overestimation of +6.85 months occurred at age group 14 years, while the underestimation of –4.67 months occurred at age group 8 years. By contrast, age groups 9, 10, and 12 to 15 years showed a positive difference which meant acceleration in their maturity (overestimation); whereas age groups 6, 7, 8 and 11 yess showed a negative difference (underestimation).

Only age groups 6, 9 and 12 years showed a small difference between CA and DA using Demirjian's method which did not exceed one month. Only group age 14 years showed an overestimation of more than 6 months (6.852 months).

Table 1: Comparison of CA and DA according to Demirjian's method applied to Northern-Sudanese boys along with the mean difference between both CA and DA.

Age group (years)	n	CA as a decimal		Dental Age		Mean Difference			P
		Mean	SD	Mean	SD	(Year)	(Month)	SD	
6 -	29	6.60	0.28	6.52	0.53	-0.08	- 0.99	0.56	0.51
7 -	24	7.43	0.32	7.20	0.53	-0.23	- 2.82	0.44	0.13
8-	24	8.46	0.31	8.07	0.78	-0.38	- 4.66	0.65	0.24
9 -	22	9.55	0.30	9.59	1.03	0.04	0.54	0.96	0.88
10 -	40	10.49	0.31	10.66	0.92	0.16	1.98	0.84	0.36
11 -	31	11.53	0.30	11.27	1.05	-0.26	- 3.13	0.97	0.41
12 -	19	12.41	0.27	12.45	0.73	0.03	0.45	0.77	0.66
13 -	28	13.52	0.29	13.83	1.30	0.31	3.74	1.20	0.41
14-	20	14.35	0.23	14.92	0.97	0.57	6.85	0.89	0.09
15 -	28	15.42	0.29	15.61	0.76	0.19	2.30	0.79	0.65

n: Number of cases

P was calculated by unpaired signed rank t-test.

Statistically significant at P≤0.05.

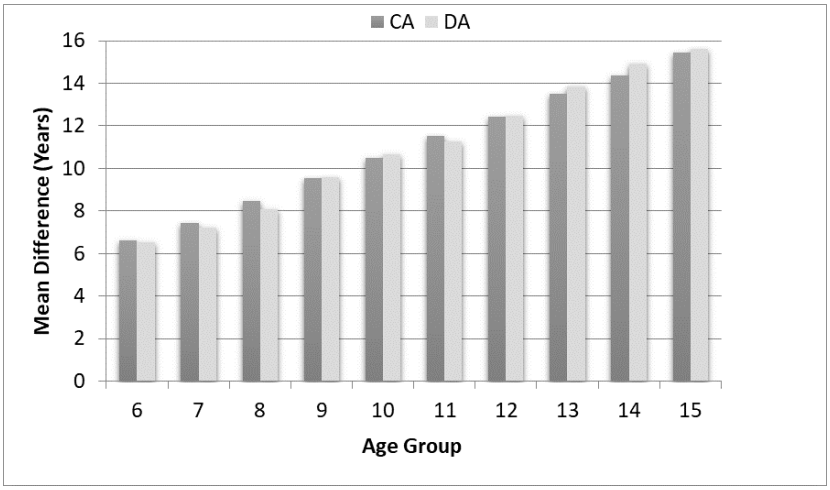

Figure 1: *Mean difference of CA and DA for Northern-Sudanese boys.*

Northern-Sudanese girls

Table (2) and Figure (2) compares CA and DA according to Demirjian's method for Northern-Sudanese girls. The table shows the difference in mean and standard deviation between both the actual and the estimated age CA and DA.

The sample for girls showed no statistically significant differences except for group 14 years which was the only group that gave a statistically significant result (p=0.05).

The mean difference between CA and DA ranged from -0.67 to +8.78 months. The overestimation of 8.784 months was observed in group 12 years, while the underestimation of -0.67 month occurred at age group 14 years.

Age groups 6,8, 10 to13, and 15 years showed a positive difference which meant acceleration in their maturity (overestimation). Whereas, age groups 7, 9 and 14 years showed a negative difference (underestimation).

Age groups 6, 7, 8, 9, 14 and 15 years showed a small difference between CA and DA using Demirjian's method which did not exceed one month. While, age groups 6, 10, 11 and 13 years showed mean difference within a range of (1 to 6 months).

Only the 12 year-old age group showed an overestimation of more than 6 months (8.78 months).

Table 2: Comparison of CA and DA according to Demirjian's method applied to Northern-Sudanese girls along with the mean difference between both CA and DA.

Age group (years)	n	CA as a decimal		Dental Age		Mean Difference			P
		Mean	SD	Mean	SD	(Year)	(Month)	SD	
6 -	21	6.51	0.23	6.60	0.67	0.08	1.05	0.64	0.36
7 -	27	7.48	0.29	7.46	0.66	- 0.01	- 0.24	0.72	0.41
8 -	28	8.48	0.30	8.49	1.12	0.00	0.08	1.17	0.85
9 -	20	9.47	0.32	9.44	1.02	- 0.02	- 0.34	1.07	0.65
10 -	35	10.53	0.28	10.98	0.91	0.44	5.37	0.86	0.32
11 -	21	11.44	0.33	11.86	1.03	0.42	5.05	0.90	0.29
12 -	20	12.61	0.30	13.34	0.88	0.73	8.78	0.85	0.74
13 -	28	13.47	0.28	13.73	1.09	0.25	3.10	0.94	0.33
14 -	29	14.45	0.30	14.39	1.06	- 0.05	- 0.67	1.01	0.05 *
15 -	33	15.48	0.27	15.53	0.71	0.05	0.63	0.78	0.08

n: No. of cases.

P was calculated by unpaired signed rank t-test.

* Statistically significant at P≤0.05.

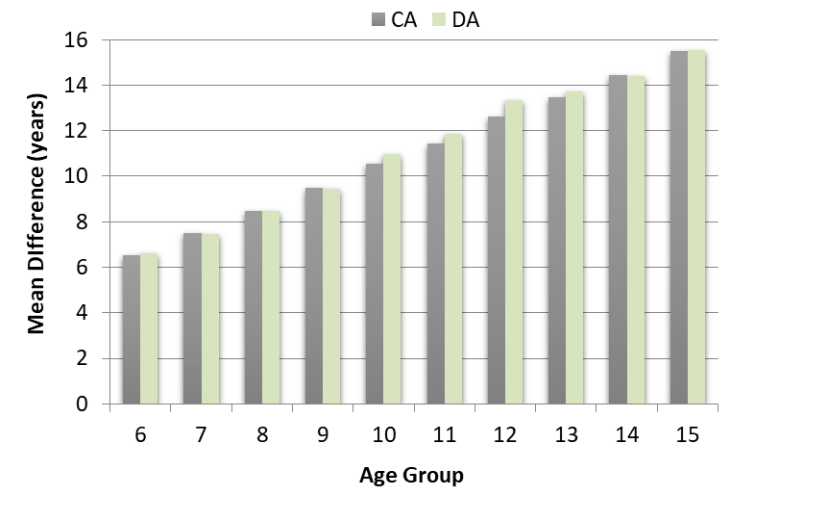

Figure 2: *Mean difference between CA and DA for the Northern-Sudanese girls.*

Gender differences regarding dental maturity

The results showed variations between boys and girls in this population sample.

Table (3) and Figure 3) shows a statistically significant difference between boys and girls in all age groups with the exception of age groups 6 and 13 years.

Girls were more advanced in their dental development in age groups 6, 8, 10, 11 and 12 years; while boys were more dentally mature in groups 9, 13, 14 and 15 years.

Table 3: Comparison between Sudanese boys and girls with regards to the difference in age calculation in different age groups.

Age group (years)	Boys			Girls			P
	Mean		SD	Mean		SD	
	Year	Month		Year	Month		
6 -	-0.08	-1.00	0.56	0.08	1.06	0.64	0.21
7 -	-0.23	-2.82	0.44	-0.01	-0.20	0.72	0.01*
8 -	-0.38	-4.67	0.65	0.007	0.09	1.17	0.001*
9 -	0.04	0.54	0.96	-0.02	-0.34	1.07	0.02*
10 -	0.16	1.98	0.84	0.44	5.38	0.86	0.02*
11 -	-0.26	-3.14	0.97	0.42	5.05	0.90	0.02*
12-	0.03	0.46	0.77	0.73	8.78	0.85	0.001*
13 -	0.31	3.75	1.20	0.25	3.11	0.94	0.11
14 -	0.57	6.85	0.89	-0.05	-0.68	1.01	0.001*
15 -	0.19	2.30	0.79	0.05	0.63	0.07	0.02*

P was calculated by unpaired signed rank t-test.

* Statistically significant at P≤0.05.

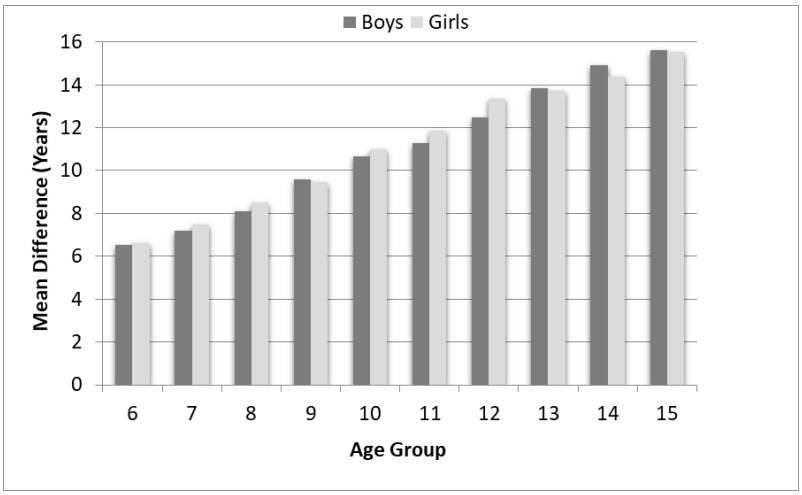

Figure 3: *Mean difference between Northern-Sudanese boys and girls.*

Towards creating standards for the studied populations

The results confirmed that Demirjian`s method slightly deviates when applied to Northern-Sudanese children. New population- specific standard should be created.

New standard tables were produced based on the function formula, where y was the sum of the points from Demirjian's tables and x was the chronological age.

Standards for Northern-Sudanese population

In the case of Northern-Sudanese boys, the function formula was [y = 13.498 + (x ´ 6.2106)] presented as a scattered graph in Figure (4), while in the case of girls was [y = 33.42 + (x ´ 4.726)] (Figure 5).

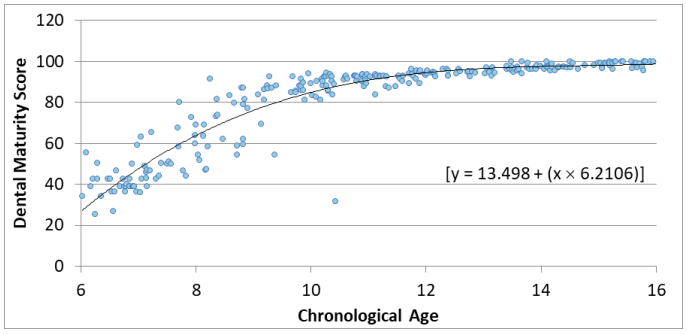

Figure 4: *Standards for dental age for Northern-Sudanese boys between 6 and 16 years of age, according to the maturity score calculated using Demirjian's method.*

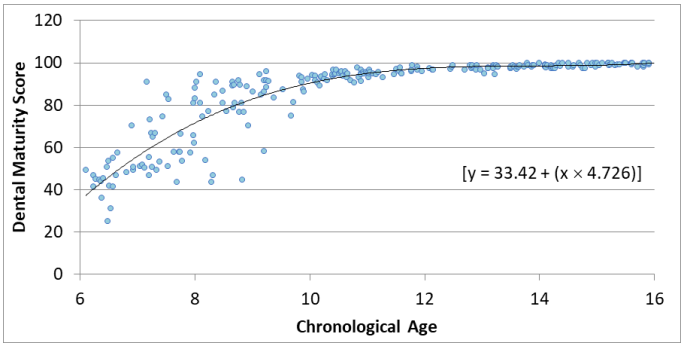

Figure 5: *Standards for dental age for Northern-Sudanese girls between 6 and 16 years of age, according to the maturity score calculated using Demirjian's method.*

Dental maturity scores

Tables were produced separately to transform the dental score to dental age for each age group (Tables 4-a to 4-j).

Table (4): Scores for the Sudanese boys and girls (age groups 6-15 years) calculated using Demirjian`s method.

Table (4-a): Six years

Dental Age	Boys	Girls
6.0	50.76	61.78
6.1	51.38	62.25
6.2	52.00	62.72
6.3	52.62	63.19
6.4	53.25	63.67
6.5	53.87	64.14
6.6	54.49	64.61
6.7	55.11	65.08
6.8	55.73	65.56
6.9	56.35	66.03

Table (4-b): Seven years

Dental Age	Boys	Girls
7.0	56.97	66.50
7.1	57.59	66.97
7.2	58.21	67.45
7.3	58.84	67.92
7.4	59.46	68.39
7.5	60.08	68.87
7.6	60.70	69.34
7.7	61.32	69.81
7.8	61.94	70.28
7.9	62.56	70.76

Table (4-c): Eight years

Age	Boys	Girls
8.0	63.18	71.23
8.1	63.80	71.70
8.2	64.42	72.17
8.3	65.05	72.65
8.4	65.67	73.12
8.5	66.29	73.59
8.6	66.91	74.06
8.7	67.53	74.54
8.8	68.15	75.01
8.9	68.77	75.48

Table (4-d): Nine years

Age	Boys	Girls
9.0	69.39	75.95
9.1	70.01	76.43
9.2	70.64	76.90
9.3	71.26	77.37
9.4	71.88	77.84
9.5	72.50	78.32
9.6	73.12	78.79
9.7	73.74	79.26
9.8	74.36	79.73
9.9	74.98	80.21

Table (4-e): Ten years

Age	Boys	Girls
10.0	75.60	80.68
10.1	76.23	81.15
10.2	76.85	81.63
10.3	77.47	82.10
10.4	78.09	82.57
10.5	78.71	83.04
10.6	79.33	83.52
10.7	79.95	83.99
10.8	80.57	84.46
10.9	81.19	84.93

Table (4-f): Eleven years

Age	Boys	Girls
11.0	81.81	85.41
11.1	82.44	85.88
11.2	83.06	86.35
11.3	83.68	86.82
11.4	84.30	87.30
11.5	84.92	87.77
11.6	85.54	88.24
11.7	86.16	88.71
11.8	86.78	89.19
11.9	87.40	89.66

Table (4-g): Twelve years

Age	Boys	Girls
12.0	88.03	90.13
12.1	88.65	90.60
12.2	89.27	91.08
12.3	89.89	91.55
12.4	90.51	92.02
12.5	91.13	92.50
12.6	91.75	92.97
12.7	92.37	93.44
12.8	92.99	93.91
12.9	93.61	94.39

Table (4-h): Thirteen years

Age	Boys	Girls
13.0	94.24	94.86
13.1	94.86	95.33
13.2	95.48	95.80
13.3	96.10	96.28
13.4	96.72	96.75
13.5	97.34	97.22
13.6	97.96	97.69
13.7	98.58	98.17
13.8	99.20	98.64
13.9	99.83	99.11

Table (4-i): Fourteen years

Age	Boys	Girls
14.0	100.45	99.58
14.1	101.07	100.06
14.2	101.69	100.53
14.3	102.31	101.00
14.4	102.93	101.47
14.5	103.55	101.95
14.6	104.17	102.42
14.7	104.79	102.89
14.8	105.41	103.36
14.9	106.04	103.84

Table (4-j): Fifteen years

Age	Boys	Girls
15.0	106.66	104.31
15.1	107.28	104.78
15.2	107.90	105.26
15.3	108.52	105.73
15.4	109.14	106.20
15.5	109.76	106.67
15.6	110.38	107.15
15.7	111.00	107.62
15.8	111.63	108.09
15.9	112.25	108.56

4. Discussion

The aim of this study was to investigate the accuracy of Demirjian's method for assessing dental maturation in Northern-Sudanese children and adolescents. This also enabled an investigation into the relation between chronological age and the estimated dental age. Furthermore, this paper aimed at providing some equations for the studied population.

This study focused on a cross sectional study because it was more feasible. It also has the advantage compared to longitudinal studies, of minimizing the effects of radiation through multiple panoramic images per subject.

In the present study, the age groups ranged from 6.0 to 15.9 years. One of the reasons for selecting this age range is due to the fac that data is available because children tend to have their first dental visit at around five or six years of age. At the other end, by around the age of 15 years, permanent teeth (excluding M_3) are nearing full occlusion. [26-28]

Demirjian's method was chosen for this study as it is one of the simplest, most practical, and reliable method which is internationally accepted and widely employed to predict age and maturation. [29,30] Moreover, the method has been plied and tested in different populations worldwide [3,8,10,26,31-37] and therefore allows comparisons in dental maturity between the studied population with that of the other population groups.

Panoramic radiographs were used in the present study to investigate dental development due to their accessibility and the possibility to visualize all teeth. [11,14,38-40] Evaluation of dental development on a panoramic radiograph has the advantage that it is based on assessment of a developmental stage of a tooth using its shape and proportions rather than its dimensions. Consequently, shortening or elongation of a radiographic image of a tooth as a consequence of projection geometry or known magnification related to the type of panoramic X-ray machine, does not affect the result of assessment of the dental age.[41]

Only teeth from the left side of the mandible were examined as several authors [6,7,14,21,30,37,42-46] have demonstrated a very high correlation between the developmental stages of the teeth of the left and right sides of the maxilla and mandible and the rate of growth being approximately the same on both sides. Nolla[21] and Demirjian et al.[20] reported that the differences between the left and the right side of the jaw are not statistically significant, so that only one lower quadrant needs to be assessed.

For methodological error estimation, the present study reported high levels of intra and inter-observer agreement. The intra-observer agreement (96%) was considerably higher than that of the inter-observer agreement (93%). Almost similar results were obtained by Farah et al.[2], while lower inter-observer agreement of 90% was reported by Demirjian et al.[20], as well as Demirjian and Levesque[46] who reported 75-80% level of inter-observer agreement.

In the present study, the accuracy using Demirjian's method was evaluated by calculating the difference between the chronological and the estimated dental age. The results from this analysis indicates that the estimated age range was wide and not accurate. Although a minor significant difference was shown in age group 14 years or Northern-Sudanese girls; the overall estimated dental age was not significantly different from chronological age in both boys and girls in this studied populations.

These results agree with those of Rizig et al. [47], as well as Sharaf and Al-Sulimani's study [48]; both concluded that assessment of dental age according to Demirijian's method was not accurate and hence not applicable for Darfurian and Saudi children, respectively. By contrast, in other populations albeit a small sample size, Hegde and Sood[49 found that Demirjian's method showed high accuracy when applied to a sample of 197 children aged between 6 and 13 years living in Belgaum (India). Mean difference between CA and DA was (51 days) in boys and (15 days) in girls.

Overall, Northern-Sudanese children and adolescents showed a more advanced dental age compared with French-Canadian standards reported by Demirjian in a sample from 1971.[20] Similar findings were obtained for Finnish,[32],[50] Swedish,[51] Norwegian,[52] Dutch,[53 British,[31] Black and Latino American,[54] children in Perth and Western Australia,[2] and Brazilian[3]. On the other hand, Poyry et al.[55] reported different results, when concluded that Chinese children were delayed in their dental development by means of eleven month for males and seven month for females when compared to the 1971 French-Canadian sample.

Regarding gender difference, the present study found that girls were more advanced in their dental development than boys. These results are supported by Liversidge and Speechly [31], Leurs et al. [53] and Nystrom et al.[50] who reported acceleration of DA in girls at least since an age of 2.5 years.

5. Conclusions

- Demirjian's method did not accurately predict age in the Northern Sudanese children and adolescents and hence not applicable for them.
- The Northern Sudanese children and adolescents were more advanced in dental maturity compared to Demirjian's 1971 reference sample.
- The variation in difference between chronological age and dental age increased in older age groups; therefore, estimating age in younger children can be more accurately predicted than in older children.
- The overall results showed statistically significant differences between boys and girls in the studied population.
- Girls were more advanced in their dental development.

Conflict of Interest

The authors do not have any conflicts of interest relating to this study.

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