Aims and Objectives: Assessing dental and bone ages is frequently required in a wide range of fields such as odontology, forensic science, as well as orthopedics. The aim of this study was to evaluate applicability of two methods of bone age assessment and two methods of dental age (DA) assessment for Lebanese children.

Materials and Methods: Skeletal age (SA) of 260 orthodontic patients (124 males, 136 females divided into four groups each) was consecutively assessed using Greulich and Pyle and Fishman’s SMI methods. DA was evaluated using both Demirjian’s and Willem’s methods. Mean age was 11.89 ± 1.38 years for males and 11.75 ± 1.58 years for females. Data were collected and statistically analyzed using the SPSS software (IBM SPSS Statistics, version 21, USA). The differences between estimated DA, estimated SA, and chronological age (CA) were compared by gender and age group.

Results: Greulich and Pyle method showed nonsignificant difference with CA in male sample, while in both assessment methods, the difference between skeletal and CAs is significant in female sample. Results of Willem’s method in the whole sample suggested a statistically nonsignificant difference, when compared to CA. Demirjian’s method delivered higher mean value than Willem’s assessment in both genders.

Conclusions: Greulich and Pyle method is accurate for SA assessment in males and only in one group of females, while it significantly overestimates age in all other female groups. Willem’s method is more suitable to assess DA in both genders. A strong correlation exists between both dental and skeletal assessment methods and CA.

Keywords: Dental age, hand-wrist radiograph, Lebanese children, skeletal age

INTRODUCTION

Evaluation of chronological age (CA) is an essential step of diagnosis and treatment planning in pediatrics, dentofacial orthopedics, and pediatric dentistry. In forensic science, age determination is needed for identification of human remains. CA is linked solely to the scale of time and printed on civil registry or family status. However, the information might be lacking in certain circumstances, hence leading to consider a different way for age evaluation based on growth. If growth is a continuous phenomenon throughout the years, huge modifications occur in almost the first two decades of life with great variations among individuals. Some children start their growth and finish their maturation early, compared to others with same age, depicting a delayed growth but showing later, greater amount of growth.[1]

Among all the possible means of assessment, hand-wrist radiograph is the most commonly used indicator to evaluate bone age or bone maturation of a patient, for its simple, little irradiant, and inexpensive aspects.

Address for correspondence: Dr. Antoine Saadé, Department of Orthodontics, Lebanese University School of Dentistry, Beirut, Lebanon. E-mail: saadeantoine@hotmail.com

This is an open access article distributed under the terms of the Creative Commons Attribution-NonCommercial-ShareAlike 3.0 License, which allows others to remix, tweak, and build upon the work non-commercially, as long as the author is credited and the new creations are licensed under the identical terms.

For reprints contact: reprints@medknow.com

How to cite this article: Saadé A, Baron P, Noujeim Z, Azar D. Dental and skeletal age estimations in Lebanese children: A retrospective cross-sectional study. J Int Soc Prevent Community Dent 2017;7:90-7.
This radiograph provides precious information on hand bones’ ossification, based on the shape and volume of metacarpal bones,[2,3] and the presence of epiphyseal plates at certain age.[4,5]

However, if bone age assessment has reached a consensus to predict patient maturation, one more tool has to be considered on dental side leading to evaluate dental age (DA) of an individual.

Multiple radiological approaches (e.g., periapical radiograph, cone-beam computed tomography, or panoramic radiographs) will allow an accurate view on the whole dental system, the latter being the most commonly used for this purpose. Different methods of DA assessment were elaborated by several workers and frequently found in literature.[6-8] However, Demirjian’s method,[9] readapted by Willems et al.,[10] has been widely used since its inception although several studies currently compare the applicability of two or more methods on populations from different origins. In Lebanon, the different methods of skeletal and dental assessments cited above are used without a prior testing regarding their accuracy. Thus, verifying applicability of the traditionally used methods and their correction (when necessary) is a must. The present study sheds light on the problem faced during orthodontic treatment of Lebanese children and proposes the optimal assessment tool to be applied on Lebanese individuals.

Herein, we aim to:
1. Evaluate the applicability of Greulich and Pyle (1959) and Fishman (1982) methods of bone age assessment for Lebanese children
2. Evaluate the applicability of Demirjian (1973) and Willems (2001) methods of DA assessment for Lebanese children.

**Materials and Methods**

**Participants**
In this retrospective cross-sectional study, all files of growing patients who have undergone orthodontic treatment for jaw discrepancies (known as orthopedic correction), between 2002 and 2015, were selected among 1427 orthodontic files from the database of the Department of Orthodontics and Dentofacial Orthopedics of the Lebanese University, School of Dentistry, Beirut, Lebanon. Prior to the orthodontic treatment, each patient (or his/her legal representative) was required to sign an informed consent form allowing dental staff to use the records obtained from potential patients. This study had obtained approval of Ethical Committee at Lebanese University (CUEMB 51/2016).

**Criteria**
Inclusion criteria were as follows:
- Healthy patients from Lebanese lineage, with age ranging between 8 and 17 years, without any syndrome or systemic pathology that might affect growth or dental formula (dental agenesis, dental impaction, or supernumerary teeth).
- Patients whose presence in the orthodontic file of both orthopantomogram (OPG) and left hand-wrist radiograph taken at the same date during the same month following the first orthodontic consultation were included in the sample.

Patients with extracted or absent teeth or with a history of orthodontic treatment were excluded from the sample (orthodontic treatment might involve teeth extraction or affect apex shape).

After file selection, the name, gender, and CA of each individual were recorded.

The sample of 260 individuals included 124 males and 136 females [Table 1].

Both male and female samples were divided into four groups, according to CA, as follows:
- Group 1: 8 to <10 years
- Group 2: 10 to <12 years
- Group 3: 12 to <14 years
- Group 4: 14 years and above.

For males, ages ranged from 8.7 to 16.5 years with a mean age of 11.89 years and standard deviation of 1.38 years, whereas for females, ages ranged from 8.1 to 14.9 years, with a mean age of 11.75 years and standard deviation of 1.58 years.

**Methods**
All OPGs and hand-wrist radiographs were scored separately by two observers to assess DAs and skeletal ages (SAs) according to:
- Demirjian and Willems methods for DA assessment [Figure 1]
- Greulich and Pyle and Fishman methods for SA assessment [Figure 2].

**Table 1: Sample distribution by age and gender**

| Age (years) | Gender | Total |
|-------------|--------|-------|
|             | Males  | Females |     |
| 8-<10       | 9      | 16     | 25  |
| 10-<12      | 58     | 61     | 119 |
| 12-<14      | 49     | 47     | 96  |
| 14 years and above | 8   | 12     | 20  |
| Total       | 124    | 136    | 260 |
Assessment of dental age by Demirjian’s method
Each of the seven mandibular left-side teeth (excluding third molar) were rated on a maturity scale of A to H (A corresponding to the beginning of tooth calcification and H to the closure of apical end of the root canal). Each scale is translated into score. The sum of the seven allocated scores corresponds to the DA of the patient.\[9\]

Assessment of dental age by Willems method
The developmental tooth stages of each of the seven mandibular left teeth according to Demirjian’s method with corresponding age scores were expressed directly in years. The Willem’s estimation method is a modified Demirjian method.\[10\]

Assessment of skeletal maturity using Greulich and Pyle’s atlas
The radiograph of the patient’s left hand and wrist was compared with the images listed in the Radiographic Atlas of Greulich and Pyle (1959)\[2\] in the corresponding section (males and females). The matching image in the Atlas will provide the SA (as recorded by authors on the top of the Atlas page).

Assessment of skeletal maturity using the Fishman SMI method
Eleven skeletal maturity indicator (SMIs) were consecutively depicted in a stable sequence on selected epiphyseal plates of left hand radiograph, leading to gradual bone maturation.\[9\] At SMI 11 (ossification of radius bone), complete ossification is considered to be reached. Localization of an SMI step on patient’s radiograph gives corresponding age as listed in Fishman’s tables.

Statistical analysis
Data were collected and statistically analyzed using the Statistical Package for Social Sciences computer software (IBM SPSS Statistics, version 21, USA). The differences between estimated DA, estimated SA, and CA were compared by gender and age group with paired $t$-test and Wilcoxon signed-rank test. The nonparametric test (Wilcoxon signed-rank test) was used for groups with size <30. For all tests, $P < 0.05$ was considered statistically significant. Spearman’s rank correlation test was used to assess the relation between estimated DA, estimated SA, and CA.

Intraclass correlation coefficient values were above 0.95 for both examiners, for the four methods, showing a high reliability.

Results
Statistical results and comparisons between groups and methods are shown in Tables 1-5. The sample of 260 individuals was distributed into 124 males and 136 females.

Mean CA was 11.90 ± 1.39 years for male sample and 11.76 ± 1.59 years for female sample. Groups 2 and 3 included higher number of patients in comparison to Groups 1 and 4, due to the ideal age of orthodontic treatment, frequently occurring between age 10 and 14.

Comparison between chronological age and different methods of skeletal age estimation in males [Tables 2 and 3]
The SA as recorded by both Fishman or Greulich and Pyle methods, compared to CA, delivers higher mean values for the whole male sample, the latter method being closer to the mean CA of the sample (12.69 ± 1.38 years for Fishman and 11.94 ± 1.79 years for Greulich and Pyle). Statistically, the difference between CA and SA as provided by Greulich and Pyle method is not significant.
Table 2: Comparison between Fishman’s estimation of skeletal age and chronological age in males and females (P significant if <0.05)

| Gender | Age (years) | n  | Mean (SD) | 95% CI of the difference | t statistics | df | t-test (P) | Wilcoxon (P) |
|--------|-------------|----|-----------|--------------------------|-------------|----|------------|-------------|
|        |             |    |           |                          |             |    |            |             |
|        |             |    | CA        | Fishman                  |             |    |            |             |
|        |             |    |           |                          |             |    |            |             |
| Males  | 8–<10       | 9  | 9.41±0.40 | 11.66±1.10               | 1.54±2.96   | 7.27| 8          | 0.000       |
|        | 10–<12      | 58 | 11.11±0.52| 12.09±0.82               | 0.99±1.81   | 0.78| 1.20       | 0.000       |
|        | 12–<14      | 49 | 12.83±0.57| 13.20±1.34               | 0.36±1.17   | 0.03| 0.70       | 0.214       |
|        | 14 years and above | 8 | 14.74±0.87| 15.02±1.46               | 0.28±0.87   | -0.44| 1.01       | 0.92        |
|        | Total       | 124| 11.90±1.39| 12.69±1.38               | 0.79±0.90   | 0.59| 0.98       | 8.02        |
| Females| 8–<10       | 16 | 9.11±0.58 | 10.95±0.53               | 1.84±0.84   | 1.39| 2.28       | 8.74        |
|        | 10–<12      | 61 | 11.02±0.60| 11.98±0.86               | 0.95±0.75   | 0.76| 1.14       | 9.99        |
|        | 12–<14      | 47 | 12.93±0.55| 13.29±1.14               | 0.37±1.07   | 0.05| 0.68       | 2.34        |
|        | 14 years and above | 12 | 14.47±0.35| 14.99±0.51               | 0.52±0.71   | 0.07| 0.97       | 2.52        |
|        | Total       | 136| 11.76±1.59| 12.58±1.41               | 0.82±0.98   | 0.65| 0.98       | 9.68        |

SD=Standard deviation, CI=Confidence interval, CA=Chronological age

Table 3: Comparison between Greulich and Pyle’s estimation of skeletal age and chronological age in males and females

| Gender | Age (years) | n  | Mean (SD) | 95% CI of the difference | t statistics | df | t-test (P) | Wilcoxon (P) |
|--------|-------------|----|-----------|--------------------------|-------------|----|------------|-------------|
|        |             |    |           |                          |             |    |            |             |
|        |             |    |           |                          |             |    |            |             |
| Males  | 8–<10       | 9  | 9.41±0.40 | 9.28±1.60                | -0.13±1.41  | -1.21| 0.95       | -0.27       |
|        | 10–<12      | 58 | 11.11±0.52| 11.37±1.14               | 0.26±1.01   | 0.00| 0.53       | 1.99        |
|        | 12–<14      | 49 | 12.83±0.57| 12.63±1.53               | -0.21±1.35  | -0.59| 0.18       | -1.07       |
|        | 14 years and above | 8 | 14.74±0.87| 14.94±1.15               | 0.20±0.61   | -0.31| 0.71       | 0.92        |
|        | Total       | 124| 11.90±1.39| 11.94±1.79               | 0.05±1.18   | -0.16| 0.25       | 0.43        |
| Females| 8–<10       | 16 | 9.11±0.58 | 9.69±0.93                | 0.58±1.14   | 0.03| 1.18       | 2.02        |
|        | 10–<12      | 61 | 11.02±0.60| 11.65±1.38               | 0.63±1.19   | 0.33| 0.94       | 4.13        |
|        | 12–<14      | 47 | 12.93±0.55| 13.70±1.17               | 0.78±1.00   | 0.48| 1.07       | 5.29        |
|        | 14 years and above | 12 | 14.47±0.35| 15.42±0.79               | 0.95±0.80   | 0.44| 1.45       | 4.12        |
|        | Total       | 136| 11.76±1.59| 12.46±1.99               | 0.70±1.09   | 0.52| 0.89       | 7.53        |

SD=Standard deviation, CI=Confidence interval, CA=Chronological age

Table 4: Comparison between Demirjian’s estimation of dental age and chronological age in males and females

| Gender | Age (years) | n  | Mean (SD) | 95% CI of the difference | t statistics | df | t-test (P) | Wilcoxon (P) |
|--------|-------------|----|-----------|--------------------------|-------------|----|------------|-------------|
|        |             |    |           |                          |             |    |            |             |
|        |             |    |           |                          |             |    |            |             |
| Males  | 8–<10       | 9  | 9.41±0.40 | 10.93±2.35               | 1.53±2.09   | -0.08| 0.13       | 2.19        |
|        | 10–<12      | 58 | 11.11±0.52| 11.78±1.20               | 0.68±1.10   | 0.39| 0.96       | 4.69        |
|        | 12–<14      | 49 | 12.83±0.57| 13.59±1.63               | 0.75±1.51   | 0.32| 0.19       | 3.48        |
|        | 14 years and above | 8 | 14.74±0.87| 15.04±1.24               | 0.30±1.44   | -0.91| 1.50       | 0.58        |
|        | Total       | 124| 11.90±1.39| 12.64±1.86               | 0.74±1.38   | 0.50| 0.99       | 5.99        |
| Females| 8–<10       | 16 | 9.11±0.58 | 10.15±1.05               | 1.04±1.19   | 0.40| 1.68       | 3.48        |
|        | 10–<12      | 61 | 11.02±0.60| 12.07±1.20               | 1.05±1.08   | 0.78| 1.33       | 7.62        |
|        | 12–<14      | 47 | 12.93±0.55| 13.55±1.05               | 0.62±0.90   | 0.36| 0.89       | 4.73        |
|        | 14 years and above | 12 | 14.47±0.35| 15.03±0.91               | 0.56±0.97   | -0.05| 1.18       | 2.01        |
|        | Total       | 136| 11.76±1.59| 12.62±1.70               | 0.86±1.04   | 0.68| 1.04       | 9.66        |

SD=Standard deviation, CI=Confidence interval, CA=Chronological age

Statistical results were found to be similar (nonsignificant difference for Greulich and Pyle, compared to CA) in Groups 1, 2, and 3, while in Group 4, results of the two methods, Fishman and Greulich and Pyle, suggest that difference is not significant between CA and SA.

**Comparison between chronological age and different methods of skeletal age estimation in females [Tables 2 and 3]**

Both methods of SA exhibit higher mean values for the whole sample with higher value for Fishman’s, as
compared to CA (12.46 ± 1.99 years for Greulich and Pyle and 12.58 ± 1.41 years for Fishman). In both assessment methods, the difference between SA and CA is significant.

Only in the 1st group (8–10 years), statistical difference was not significant when comparing CA to SA as assessed with Greulich and Pyle’s method.

**Comparison between chronological age and different methods of dental age estimation in males [Tables 4 and 5]**

In the whole male sample, both methods of DA estimation provided higher mean value. However, DA assessment, according to Demirjian, showed higher difference (12.64 ± 1.86 years) with CA, than Willem’s mean value (12.08 ± 1.66 years). Difference between CA and Willem’s DA was statistically insignificant. As for age groups, the results of Willem’s method in all groups suggested a statistically insignificant difference when compared to CA; in Groups 1 and 4, Demirjian’s method as well as Willem’s method showed insignificant difference with CA.

**Comparison between chronological age and different methods of dental age estimation in females [Tables 4 and 5]**

DA assessment according to both Demirjian (12.62 ± 1.70 years) and Willem’s (11.84 ± 1.77 years) methods overestimated age in the female sample, but the mean difference with CA as reported by Willem’s method is more reduced (+0.082 for Willems and +0.86 for Demirjian), and the statistical difference in the latter was insignificant. In all age groups, results of the Willem’s method provided statistically insignificant difference with CA, whereas only in the Group 4, Demirjian’s method showed insignificant difference.

Results are summarized graphically in Figure 3, showing mean age differences (using the four methods of dental and skeletal estimations for both genders).

Spearman’s correlation coefficient (Rho) between CA and SA (Fishman–Greulich and Pyle) and between chronological age and dental age (Demirjian–Willem’s method) is shown in Table 6. It shows a strong statistically significant correlation of the two SAs and the two DAs with the CA.

**Discussion**

SA assessment allows the clinician to determine relative maturity of patients, hence to evaluate those

---

### Table 5: Comparison between Willem’s estimation of dental age and chronological age in males and females

| Gender | Age (years) | n  | CA Mean (SD) | Willems Mean (SD) | Willems-CA Mean (SD) | 95% CI of the difference | t statistics | df | t-test (P) | Wilcoxon (P) |
|--------|-------------|----|--------------|-------------------|----------------------|--------------------------|--------------|----|------------|--------------|
| Males  | 8–<10       | 9  | 9.41±0.40    | 10.62±2.00        | 1.22±1.69            | −0.08±2.52               | 2.16         | 8  | 0.063      | 0.051        |
|        | 10–<12      | 58 | 11.11±0.52   | 11.30±1.14        | 0.20±1.01            | −0.07±0.46               | 1.49         | 57 | 0.143      | 0.117        |
|        | 12–<14      | 49 | 12.83±0.57   | 12.89±1.37        | 0.06±1.26            | −0.30±0.42               | 0.33         | 48 | 0.746      | 0.538        |
|        | 14 years and above | 8  | 14.74±0.87   | 14.39±1.32        | −0.35±1.69           | −1.76±1.06               | −0.59        | 7  | 0.577      | 0.401        |
|        | Total       | 124| 11.90±1.39   | 12.08±1.66        | 0.18±1.24            | −0.04±0.40               | 1.62         | 123| 0.108      | 0.081        |
| Females| 8–<10       | 16 | 9.11±0.58    | 9.47±0.91         | 0.36±1.17            | −0.27±0.98               | 1.22         | 15 | 0.241      | 0.224        |
|        | 10–<12      | 61 | 11.02±0.60   | 11.25±1.29        | 0.22±1.17            | −0.08±0.53               | 1.49         | 60 | 0.141      | 0.416        |
|        | 12–<14      | 47 | 12.93±0.55   | 12.75±1.17        | −0.18±0.98           | −0.47±0.11               | −1.26        | 46 | 0.215      | 0.137        |
|        | 14 years and above | 12 | 14.47±0.35   | 14.49±1.20        | 0.02±1.24            | −0.77±0.81               | 0.06         | 11 | 0.953      | 0.875        |
|        | Total       | 136| 11.76±1.59   | 11.84±1.77        | 0.08±1.12            | −0.11±0.27               | 0.85         | 135| 0.395      | 0.900        |

**SD=Standard deviation, CI=Confidence interval, CA=Chronological age**

**Table 6: Correlations (Spearman’s rho) between chronological age and skeletal age (Fishman–Greulich and Pyle) and between chronological age and dental age (Demirjian–Willem’s method)**

|                  | Fishman | Greulich and Pyle | Demirjian | Willems |
|------------------|---------|-------------------|-----------|---------|
|                  | Males   | Females           | Both      |         |
| Fishman          | 0.659** | 0.833**           | 0.768**   |         |
| Greulich and Pyle| 0.696** | 0.843**           | 0.776**   |         |
| Demirjian        | 0.680** | 0.805**           | 0.748**   |         |
| Willems          | 0.684** | 0.792**           | 0.740**   |         |

**Correlation is significant at the 0.01 level (two tailed)**

---

Figure 3: Mean age difference (at 95% confidence interval) of the four estimation methods for both males and females. Chronological age: blue for Demirjian, green for Willem’s, yellow for Greulich and Pyle, and red for Fishman’s methods.
with advanced or delayed stages of puberty. In normal individuals, SA varies from CA on a ±10% average.[11] Some factors might lead to growth deficiency or delay, such as nutritional or metabolic alterations. Similarly, large variations in dental development have prevented the use of DA as an overall measure of maturation.

In this study, two methods of DA evaluation (Demirjian and Willems) and two methods of SA evaluation (Greulich and Pyle and Fishman) were used to assess their applicability in a sample of Lebanese growing population. Greulich and Pyle’s method is widely used for evaluation of patients’ SA in Lebanese individuals, thus the need to test its accuracy. No specific DA method is reported as reference for the same population.

**Skeletal assessment**

Both methods delivered overestimated results in male sample; however, Greulich and Pyle assessment is closer (11.94 ± 1.79 years) to mean CA (11.90 ± 1.39 years), in comparison to Fishman’s values for the whole sample. In all age groups, Greulich and Pyle method showed nonsignificant difference.

Overestimation with significant differences to mean CA (11.76 ± 1.59 years) were shown in results of female sample for the two methods as well, with the exception of Group 1 for Greulich and Pyle; higher mean value was recorded in Fishman’s assessment (12.58 ± 1.41 years) than that of Greulich and Pyle’s method (12.46 ± 1.99 years).

Different ways of bone age prediction are found in literature such as the Roche–Wainer–Thissen method,[12] assessing SA on a radiograph of knee joint, or Sauvegrain method,[13] based on elbow radiograph. Some authors[11,14,15] developed methods based on examination of standard radiographs of left hand and wrist. Skeletal maturity depicts several ossification centers in a specific order in the hand and the wrist, which is clearly described in Fishman’s method.

Although none of these described methods is uniformly accepted or used in clinical practice, the Greulich and Pyle method is one of the most popular and routinely used methods. A recent survey of the Society for Pediatric Radiology found that 27% of respondents were using a hemiskeleton method for infants, while 70% used the Greulich and Pyle method.[16] Percentage of the latter grows up to 97% when assessment is made on 3–18-year-old patients.

A study conducted on a multiethnic sample of 2614 individuals concluded that Greulich and Pyle method is reproducible and accurate with small difference between bone age and CA.[17] Similar results with significant correlation (r = 0.86) between skeletal and CA were found by Mohammed et al. in a population of South Indian (Andhra) children.[18]

In opposition, this method overpredicted SA in South Turkish children from 10 to 15 years in males and 10 to 18 in females, as reported by Gungor et al.[19] Recently, ultrasonography and MRI were preconized for successful replacement of radiography in bone age assessment as presented by Greulich and Pyle.[20,21] The aim of such procedures was to avoid irradiation during this examination.

A study performed by Bagherpour et al.[22] found a significant correlation only in males between dental development stages of mandibular left and right canines as prescribed by Demirjian and skeletal maturity index (Fishman’s SMI 4) corresponding to ossification of sesamoid bone. The author concluded that different skeletal maturity patterns between genders might be perceptible. Camacho-Basallo et al.[23] tested two hand wrist methods and showed that correlation coefficients for CA were statistically significant only for Fishman’s method.

Fishman’s method has been successfully applied on a sample of South Indian population. The study’s results concluded that it can be used as a reliable choice for predicting biological age.[24] Mean age difference was minimal, hence 0.4 year in males and 0.3 year in females, indicating that SA is underestimated with this method. These results were not concordant with those of this study with mean age difference of 0.79 year in males and 0.82 year in females, indicating that SA is overestimated when Fishman's method is used.

**Dental assessment**

In male sample, Demirjian’s method delivered higher mean value (12.64 ± 1.86 years) and significant difference in comparison to CA (11.90 ± 1.39 years), whereas the mean value obtained from Willems’s method was 12.08 ± 1.66 years. The mean age difference was 0.18 year for Willems’s method.

Similar overestimations were observed in female sample, but more reduced in Willems’s method (11.84 ± 1.77 years) than in Demirjian’s results (12.62 ± 1.70 years) with significant difference in the latter. The mean age difference was 0.08 years for Willem’s method.

For males and females, statistical difference was insignificant in all age groups.

Pratyusha et al.[25] studied the applicability of Demirjian’s method and modified Cameriere’s method in children.
aged from 9 to 14 years. Estimation age with the latter method was closer to CA. These results were not similar in a research assessing the same methods. Demirjian’s method showed more appropriate results for the investigated population.

Several studies on applicability of Demirjian or Willem’s methods on Middle Eastern populations have been published. Nour El Deen et al. found a consistent overestimation using Demirjian method on Saudi population. Another study tested the applicability of this method on a sample of Tunisian children. It concluded that Demirjian’s method underestimates age between 9 and 16 years.

A meta-analysis based on 26 studies using Demirjian method concluded that CA was overestimated, thus “the need of population-specific standard for better estimation” while Willem’s method was found less accurate than Demirjian’s one for DA estimation in Thai children.

However, different conclusions were found in a comparison between Willem’s and Demirjian’s methods conducted on a Chinese sample. These findings were in accordance with the results of the present study and those of Ambarkova on a Macedonian sample with bigger overestimation in Demirjian’s method.

All the above results should be analyzed cautiously, in light of ethnical specificity, multiple disparities into the same population, and sample size that might affect research interpretation.

**Conclusions**

Results of the present study suggest that a strong correlation exists between both dental and skeletal assessment methods and CA; Willem’s method is more suitable to assess DA in both genders for Lebanese population; Greulich and Pyle method is accurate for SA assessment in males and females between 8 and 10 years, while it significantly overestimates age in all the other female groups.

Contemporary history of Lebanon witnessed periodical conflicts and violence that left behind numerous unknown and/or unidentified victims. Consequently, the present study is needed to evaluate CA of human remains, in addition to its application in odontology and pediatrics. It contributes as well as widens our knowledge on growth variability and dental maturity on Lebanese population, in comparison to neighboring ones.

Further investigations with larger sample would improve these findings and suggest specific charts applicable to Lebanese individuals.

**Financial support and sponsorship**

Nil.

**Conflicts of interest**

There are no conflicts of interest.

**References**

1. Thompson DT. On Growth and Form. 9th ed. Cambridge: Cambridge University Press; 1971.
2. Greulich WW, Pyle SI. Radiographic Atlas of Skeletal Development of the Hand and Wrist. 2nd ed. Stanford: Stanford University Press; 1959.
3. Tanner JM, Whitehouse RH, Marshall WA, Carter BS. Prediction of adult height from height, bone age, and occurrence of menarche, at ages 4 to 16 with allowance for midparent height. Arch Dis Child 1975;50:14-26.
4. Björk A, Helm S. Prediction of the age of maximum pubertal growth in body height. Angle Orthod 1967;37:134-43.
5. Fishman LS. Radiographic evaluation of skeletal maturation. A clinically oriented method based on hand-wrist films. Angle Orthod 1982;52:88-112.
6. Hurme VO. Ranges of normalcy in the eruption of permanent teeth. J Dent Child 1949;16:11-5.
7. Nolla C. The development of the permanent teeth. J Dent Child 1960;27:254-66.
8. Moorrees CF. Dental development – A growth study based on tooth eruption as a measure of physiologic age. Rep Congr Eur Orthod Soc 1964;40:92-106.
9. Demirjian A, Goldstein H, Tanner JM. A new system of dental age assessment. Hum Biol 1973;45:211-27.
10. Willens G, Van Olmen A, Spiessens B, Carels C. Dental age estimation in Belgian children: Demirjian’s technique revisited. J Forensic Sci 2001;46:893-5.
11. Gilsanz V, Ratib O. Hand Bone Age: A Digital Atlas of Skeletal Maturity. New York: Springer-Verlag; 2005.
12. Roche AF, Wainer H, Thissen D. The RWT method for the prediction of adult stature. Pediatrics 1975;56:1027-33.
13. Sauvegrain J, Nahum H, Bronstein H. Study of bone maturation of the elbow. Ann Radiol (Paris) 1962;5:542-50.
14. Eklöf O, Ringertz H. A method for assessment of skeletal maturity. Ann Radiol (Paris) 1967;10:330-6.
15. Tanner JM, Whitehouse RH, Marshall WA, Healy MJ, Goldstein H. Assessment of Skeletal Maturity and Prediction of Adult Height (TW2 Method). London: Academic Press; 1975.
16. Breen MA, Tsai A, Stamm A, Kleinman PK. Bone age assessment practices in infants and older children among Society for Pediatric Radiology members. Pediatr Radiol 2016;46:1269-74.
17. Chaumoître K, Paneul M, Saliba-Serre B, Adalier P, Signoli M, Leonetti G, et al. Forensic use of the Greulich and Pyle atlas: Prediction intervals and relevance. Eur Radiol 2017;27:1032-43.
18. Mohammed RB, Rao DS, Goud AS, Sailaja S, Thetay AA, Gopalakrishnan M. Is Greulich and Pyle standards of skeletal maturation applicable for age estimation in South Indian Andhra children? J Pharm Bioallied Sci 2015;7:218-25.
19. Gungor OE, Celikoglu M, Kale B, Gungor AY, Sari Z. The reliability of the Greulich and Pyle atlas when applied to a Southern Turkish population. Eur J Dent 2015;9:251-4.
20. Hajalioghi P, Tazamani MK, Arami S, Fouladi DF, Ghojazadeh M. The utility of ultrasonographic bone age determination in detecting growth disturbances; a comparative study with the conventional radiographic technique. Skeletal...
21. Urschler M, Krauskopf A, Widek T, Sorantiin E, Ehammer T, Borkenstein M, et al. Applicability of Greulich-Pyle and Tanner-Whitehouse grading methods to MRI when assessing hand bone age in forensic age estimation: A pilot study. Forensic Sci Int 2016;266:281-8.

22. Bagherpour A, Poustit M, Adelianfar E. Hand skeletal maturity and its correlation with mandibular dental development. J Clin Exp Dent 2014;6:e275-9.

23. Camacho-Basallo P, Yáñez-Vico RM, Solano-Reina E, Iglesias-Linares A. Five radiographic methods for assessing skeletal maturity in a Spanish population: Is there a correlation? Acta Odontol Scand 2017;75:106-12.

24. Mohammed RB, Kalyan VS, Tirouveluri S, Vegesna GC, Chirla A, Varma DM. The reliability of Fishman method of skeletal maturation for age estimation in children of South Indian population. J Nat Sci Biol Med 2014;5:297-302.

25. Pratyusha K, Prasad MG, Radhakrishna AN, Saujanya K, Raviteja NV, Chandrasekhar S. Applicability of Demirjian’s method and modified Cameriere’s methods for dental age assessment in children. J Clin Diagn Res 2017;11:ZC40-3.

26. Wolf TG, Briseño-Marroquín B, Callaway A, Patyna M, Müller VT, Willershausen I, et al. Dental age assessment in 6- to 14-year old German children: Comparison of Cameriere and Demirjian methods. BMC Oral Health 2016;16:120.

27. Nour El Deen RE, Alduaiji HM, Alajlan GM, Aljabr AA. Development of the permanent dentition and validity of Demirjian and Goldstein method for dental age estimation in sample of Saudi Arabian Children (Qassim Region). Int J Health Sci (Qassim) 2016;10:21-8.

28. Aissaoui A, Salem NH, Mougou M, Maatouk F, Chadly A. Dental age assessment among Tunisian children using the Demirjian method. J Forensic Dent Sci 2016;8:47-51.

29. Yan J, Lou X, Xie L, Yu D, Shen G, Wang Y. Assessment of dental age of children aged 3.5 to 16.9 years using Demirjian’s method: A meta-analysis based on 26 studies. PLoS One 2013;8:e84672.

30. Duangto P, Janhom A, Prasitwattanaseree S, Mahakkanukrauh P, Lamaroon A. New prediction models for dental age estimation in Thai children and adolescents. Forensic Sci Int 2016;266:583.e1-5.

31. Ye X, Jiang F, Sheng X, Huang H, Shen X. Dental age assessment in 7-14-year-old Chinese children: Comparison of Demirjian and Willems methods. Forensic Sci Int 2014;244:36-41.

32. Ambarkova V, Galic I, Vodanovic M, Biocina-Lukenda D, Brkic H. Dental age estimation using Demirjian and Willems methods: Cross sectional study on children from the Former Yugoslav Republic of Macedonia. Forensic Sci Int 2014;234:187-e1-7.