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PAPER

ODONTOLOGY

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Optimal Dental Age Estimation Practice in United Arab Emirates' Children*

ABSTRACT: The aim of the study was to detect whether the Willems model, developed on a Belgian reference sample, can be used for age estimations in United Arab Emirates (UAE) children. Furthermore, it was verified that if added third molars development information in children provided more accurate age predictions. On 1900 panoramic radiographs, the development of left mandibular permanent teeth (PT) and third molars (TM) was registered according the Demirjian and the Kohler technique, respectively. The PT data were used to verify the Willems model and to develop a UAE model and to verify it. Multiple regression models with PT, TM, and PT + TM scores as independent and age as dependent factor were developed. Comparing the verified Willems- and the UAE model revealed differences in mean error of −0.01 year, mean absolute error of 0.01 year and root mean squared error of 0.90 year. Neglectable overall decrease in RMSE was detected combining PM and TM developmental information.

KEYWORDS: forensic science, forensic odontology, dental age estimation, tooth development, Willems model, United Arab Emirates

United Arab Emirates (UAE) legislation categorizes different age thresholds for the judgment of individuals in criminal and civilian offenses (1,2). More specific the ages of 7, 11, 13, 15, 18, and 21 are important references (3). Starting at the age of 7 the UAE legal system provides a different application of judicial punishment than at younger ages. Ages of 11 and 13 signify the end of the custody of a mother to her son and daughter, respectively. Work permission is given at the age of 15 years. Individuals younger than 18 years can be sent during judgment to a rehabilitation center. A judge may pardon the offender for misdemeanor if he/she did not reach the adulthood threshold of 21. UAE legal system has increased its effort to combat under age marriages and human trafficking by acknowledging the age of 18 (4). A need for accurate age estimations exists when the chronological age of the concerned young individual is unknown or cannot be documented. Therefore, the UAE court officials rely on the health authorities to provide specific age estimations in an attempt to reduce inappropriate judicial ruling (5).

To estimate the age in children, Demirjian et al. (6,7) developed maturity scores for the developmental stage of the seven left mandibular permanent teeth. The verification of this method on various samples revealed a consistent over-estimation of the chronological age (8). Willems et al. revisited this method on Belgian children, using a weighted ANOVA. The Willems model was found to provide most accurate dental age estimations in children (9–11). Because most dental age estimation methods developed for children were verified on samples of different origin (8,10), it is important to ascertain whether a UAE-specific model using the Willems method needs to be developed based on a large UAE reference sample.

Dental age estimation methods can be divided into three groups according to the age category of the investigated individual. The first group consists of children (<15 year) and considers the development of permanent teeth except third molars. The second group contains subadults (15–23 year) and evaluates the (late) development of third molars. The last group includes adult individuals (>23 year) and investigates the morphological changes in mature teeth (12–16). Regarding the accuracy of dental age predictions, the different groups can be ranked from high to low in the sequence children, subadults, and adults (17,18). In the children group, combining the developmental information from permanent teeth, and third molars could provide more accurate age predictions.

The study aims were to collect a tooth development sample of UAE children and subadults. Next, the verification of age prediction performances of the Willems model was compared with the verified UAE specific model developed using the Willems method. Lastly, it was assessed if more accurate dental age predictions could be obtained using, in children, third molars development as additional dental age predictor.

Materials and Methods

Retrospectively, 1900 panoramic radiographs of UAE nationals in the age range between 4 and 23 years (F = 950, M = 950) were collected in the period between 2010 and 2011 (Table 1). The panoramic radiographs were collected at various health centers located in UAE, namely Fujairah and Saqer Dental Center under the Ministry of Health, Zayed Military Hospital

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TABLE 1—*Age and gender distribution of the United Arab Emirates sample.*

Group	Age	Male	Female	Total
Children	4	6	6	12
	5	47	48	95
	6	48	44	92
	7	49	54	103
	8	56	49	105
	9	43	49	92
	10	51	51	102
	11	50	49	99
	12	50	50	100
	13	50	49	99
	14	50	53	103
	15	51	52	103
	4–15	532	526	1058
Sub-adults	16	51	55	106
	17	49	53	102
	18	49	42	91
	19	51	59	110
	20	53	55	108
	21	57	38	95
	22	52	48	100
	23	37	46	83
	16–23	418	424	842
Total	4–23	950	950	1900

under the Ministry of Defense, Medical and Health Services Department of Abu Dhabi Police under the Ministry of Interior, Mafraq hospital, Khalifa hospital, and in SEHA, a medical center under Abu Dhabi Health Services, Albadaa Health Center under Dubai Health Authority, and Boston Dental Health Center at the Dubai Healthcare City.

The radiographs were taken with three different types of panoramic X-Ray units, namely: Gendex GXDP-700 Series (Hatfield, PA), Planmeaca ProMax (Helsinki, Finland), and Sirona Orthophos XG 5 (Bensheim, Germany). The obtained digital radiographs were saved in JEPG format. To assure anonymity, the panoramic radiographs had no patient identification details and each radiograph was assigned an alphanumeric serial code. Patients with no medical history and no obvious dental pathology related to the development of permanent teeth or third molars were included in the study.

Based on age, the radiographs were divided into two groups: the children (n = 1058) aged between 4 and 15.99 year and the subadults (n = 842) aged between 16 and 23.99 year. In both groups, the Kohler et al. technique was used to stage the third molars development. In pluri-radicular third molars, the least developed root was staged (19,20). In the children group, the Demirjian technique was applied to stage the development of the mandibular left seven permanent teeth. Various tools of Adobe Photoshop CS (Adobe Systems Incorporated, San Jose, CA) were utilized to optimize the image properties of the imported radiographs to allow optimal staging.

For inter- and intra-examiner reliability, the first and a second examiner staged two sets of 100 randomly selected radiographs from both groups (21) and weighted Kappa statistics were applied.

The Willems model was verified on the collected UAE children. Next, the UAE children sample was randomly and stratified on age and gender divided into a referential sample (n = 470, F = 240, M = 245) and a test sample (n = 485, F = 234, and M = 236). The referential sample was used to develop a UAE-specific model using the Willems method and the UAE-specific model was verified with the test sample. For both verifications, the difference between the chronological age and estimated age (chronological age – estimated age) was calculated and for calibration expressed in mean error (ME), indicating the direction of the error (over- vs. underestimation), mean absolute error (MAE), expressing the magnitude of the error, and root mean squared error (RMSE), informing about the variance of the error.

Third molar and permanent tooth information were fitted in different regression models separately and combined to calculate the related RMSE to evaluate their age prediction performances. All analyses were performed separately for males (M) and females (F). All statistical analyses were performed in SAS software version 9.2 (SAS Institute Inc., Cary, NC).

Results

The weighted kappa values (Intra = 0.99, Inter = 0.91) indicated a high agreement in staging by both examiners. An overall (M + F) ME, MAE, and RMSE of −0.01, 0.71, and 0.90 year, respectively, were detected verifying the Willems model on the UAE children sample.

The differences in ME and MAE between the verified Willems and UAE-specific model were insignificant ($p < 0.05$): difference in ME −0.12 year (F), 0.12 year (M), and difference MAE −0.07 year (F), and 0.02 year (M). The RMSE decreased 0.08 year (F) and increased 0.01 year (M) in the verified UAE-specific model compared with the verified Willems model (Table 2).

The regression model combining the seven left mandibular permanent teeth and four-third molars presented similar RMSE values compared to the model including the seven left mandibular permanent teeth alone (RMSE: 0.89 year and 0.91 year, respectively [M] and 0.87 year and 0.88 year, respectively [F]; Table 3). In the age group between 8 and 10 years, a small decrease in RMSE was detected in both sexes (RMSE decrease M = 0.04 year, F = 0.03 year).

TABLE 2—*Mean error (ME), mean absolute error (MAE) and root mean squared error (RMSE) from the Willems and the United Arab Emirates (UAE)-specific model verified on the test sample.*

	Willems Model			UAE-Specific Model		
Gender	ME	MAE	RMSE	ME	MAE	RMSE
Female	0.12	0.71	0.89	0.00	0.64	0.81
Male	−0.08	0.67	0.87	0.04	0.70	0.88

Mean of E, AE, and RMSE expressed in years.

TABLE 3—*Root mean square error (RMSE) from the regression models with only permanent teeth (PT), only third molars (TM) and PT and TM as predictors and age as response.*

	Female			Male		
Age Category	RMSE PT	RMSE TM	RMSE PT + TM	RMSE PT	RMSE TM	RMSE PT + TM
<8 years	0.93	1.69	0.79	1.00	1.58	0.78
8–10 years	0.83	1.07	0.80	0.78	1.15	0.74
10–12 years	0.86	1.91	0.92	0.92	2.07	1.09
12–14 years	0.80	1.55	0.88	0.77	1.64	0.79
Overall	0.88	1.60	0.87	0.91	1.67	0.89

Mean of RMSE expressed in years.

Discussion

Maber et al. (11) analyzed the accuracy in dental age predictions of different methods applied in children and concluded that the Willems model provided best results. As this method was developed on a Belgian reference sample, its age predicting performance on a UAE sample was verified. Verifying the UAE-specific and the Willems model revealed very small overall differences in reported errors for both males and females. These findings support that ethnic difference between Arab and European descendents are insignificantly influencing tooth development and its related age estimations. Therefore, it is suggested that the Willems model can be applied on a UAE children population. For the age thresholds of specific forensic importance in the UAE (7, 11, 13, and 15 year), the same trend was detected.

In children, the accuracy of dental age predictions is high due to the presence of seven permanent developing teeth (22,23). To apply the Willems model, seven permanent mandibular teeth need to be staged according the Demirjian technique. It relies on the examiner to be well informed about and trained in this staging technique. Calibrating the observers is a part of the quality assurance in age estimation. In the present study, a high-weighted Kappa was reported for intra- and inter-examiner reliability, indicating the feasibility of a high reproducibility of the Demirjian as well as the Köhler staging technique.

Third molar development is the only dental age predictor in the subadult age group (24–28). As third molars start developing in the children group, in the present study, third molars were staged in this group according the Köhler technique. This allowed to combine permanent teeth with third molars development information. The added third molar information provides for the age categories younger than 10 years a negligible decrease in RMSE (maximal decrease of 0.04 year). Related to the ages of forensic importance in UAE, it is unnecessary to systematically integrate third molar development in the dental age assessments of children.

Conclusion

The application of the Willems model in a UAE sample was verified, and it was found that the Willems model, although based on a Belgian reference sample can be used for dental age estimations in UAE children. A negligible gain in age prediction accuracy was obtained adding third molars development information in children.

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