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Application of third molar development and eruption models in estimating dental age in Malay sub-adults

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ABSTRACT

The third molar development (TMD) has been widely utilized as one of the radiographic method for dental age estimation. By using the same radiograph of the same individual, third molar eruption (TME) information can be incorporated to the TMD regression model. This study aims to evaluate the performance of dental age estimation in individual method models and the combined model (TMD and TME) based on the classic regressions of multiple linear and principal component analysis. A sample of 705 digital panoramic radiographs of Malay sub-adults aged between 14.1 and 23.8 years was collected. The techniques described by Gleiser and Hunt (modified by Kohler) and Olze were employed to stage the TMD and TME, respectively. The data was divided to develop three respective models based on the two regressions of multiple linear and principal component analysis. The trained models were then validated on the test sample and the accuracy of age prediction was compared between each model. The coefficient of determination (R^2) and root mean square error (RMSE) were calculated. In both genders, adjusted R^2 yielded an increment in the linear regressions of combined model as compared to the individual models. The overall decrease in RMSE was detected in combined model as compared to TMD (0.03–0.06) and TME (0.2–0.8). In principal component regression, low value of adjusted R^2 and high RMSE except in male were exhibited in combined model. Dental age estimation is better predicted using combined model in multiple linear regression models.

1. Introduction

The study on third molar developmental (TMD) stages and eruption (TME) as regard to age estimation has been extensively documented and published. While most authors agree to adopt developmental stages as a method of choice in dealing with third molars to estimate dental age, the eruptional study receives a far less overwhelming fate. The TMD model is considered more robust especially in estimating dental age for inter-ethnic variation. The eruption or emergence of third molar on the other hand, has been claimed to be most susceptible to skeletal pattern as well as local factors that includes poor spacing in the retro-molar area, between the distal of the second molar, and the anterior border of the ascending ramus of the mandible.[1,2] However, by carefully limiting the factors that may disrupt the TME process, the eruptional staging may offer a great potential to achieve more precision in dental age estimation.

On the legal perspective, the age of criminal responsibility in most countries is 18 years and therefore third molar provides a legal platform to assess the person's chronological age based on the dental developmental age boundary. However, due to its high variability, estimation error may occur to some extent according to the technique used.[3] To reduce this setback, several studies have proposed a combination of variables added into existing third molar regression model. Although no significant results were obtained, adding the information on all seven permanent mandibular teeth to the third molar model has clearly giving low estimation error especially on specific age categories level.[4–7] In order to increase the accuracy of age estimation in criminal proceeding for

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determining whether an individual is of criminally responsible age or whether adult criminal law is applicable, an updated recommendation has been adopted by the members of Study Group on Forensic Age Diagnostics.[8]

The aim of this study is twofold. Firstly, to develop dental age estimation models based on the information of only TMD, only TME and combination of both information; secondly, to validate the performance of all three models as well as the model developed by Gunst and his team[9] and thus to evaluate the prediction accuracy on all different models.

2. Materials and methods

Digital panoramic radiographs of 705 Malay individuals (336 males and 369 females) with known chronological age and gender were retrospectively selected for this study. The chronological age of individuals was calculated from the date of birth verified by the national identity card. Individuals were classified as Malaysian citizen and Malay based on the same means and data record retrieval. The age of sub-adults for this collected sample ranged from 14.1 to 23.8 years old (Table 1). The sampling was performed at the radiology unit in Faculty of Dentistry of University Teknologi MARA (UiTM) Malaysia from the year 2007 through July 2013. Although the majority of individuals came as outpatients, several selection criteria such as good image quality and no medical evidence or pathology affecting tooth development on the panoramic radiographs had been imposed to prevent any confounding to the data. The authors were retrospectively cross-checking the panoramic radiographs with assessment reports to meet the set of inclusion and exclusion criteria in this study. In addition, criteria to prevent the local factors that may influence the eruption of third molar have been established in this study. The third molar exhibited with horizontal or vertical impaction and angulation between long axis of third molar and long axis of second molar is $> 10^\circ$ were considered the exclusion criteria for this study. A specific criterion was applied to the mandibular third molar. The available mandibular retro-molar space was measured in addition to third molar crown width. The available retro-molar space was defined as the distance between the distal border of the second molar and the anterior border of the ramus measured on the occlusal plane, in proportion to the width of the third molar crown. The ratio of retromolar space to crown width was calculated according to the method described by Olive and Basford[10] and later modified by Ganss et al.[11] Should the ratio was found to be less than 1.1, the subject would be excluded.

The third molar development and eruption were scored according to the Gleiser and Hunt technique[12] modified by Kohler[13] and Olze technique,[14] respectively. The former technique devised ten developmental stages based on third molar maturity and the latter technique formulated on four third molar eruptional stages. After three weeks, one-hundred randomized panoramic radiographs were extracted and scored by second examiner and rescored by primary examiner for kappa inter-observer and intraobserver reliability. The non-scores were treated as missing values.

The accumulation of individual dataset was then split into two groups. A dental age estimation model was developed on the training dataset and performance for this model was tested on the test dataset. The former utilized 70% of accumulated dataset for model development and the remaining 30% were used for testing. Males and females were treated in different models.

The panoramic images were kept without compression as JPEG file of 2.5 Mb and dimension of 2400 × 1280 pixels. Precautions measure to avoid bias has been taken by randomly re-label all images and all related information was made anonymous prior to data scoring. Image assessments were performed using Adobe®-Photoshop® CS2 version 9.0 software (Adobe Systems Incorporated, San-Jose CA, USA), enabling image enhancement and improvement of the image quality during data collection. Ethics approval to collect radiographs for human subjects has been obtained by the Ethics Committee for Research Involving Human Subjects of UiTM.

Table 1
Age and sample distribution of Malay sub-adults.

Age group	Males	Females	Total
14-14.9	21	20	41
15-15.9	37	39	76
16-16.9	31	34	65
17-17.9	29	41	70
18-18.9	30	41	71
19-19.9	38	46	84
20-20.9	43	40	83
21-21.9	36	32	68
22-22.9	46	42	88
23-23.9	25	34	59
Total	336	369	705

Age groups in years.

3. Statistical analysis

The missing data rate was relatively low (12.4%) and the 'completer' or 'complete' case analysis approach to manage missing data was used. Multiple linear regression (MLR) analysis based on the method of least squares was performed to evaluate the relationship between chronological age as response and all four permanent third molar based on its developmental stages[9] and eruptional stages[15] as predictors. The first part of the study dealt with two important statistics that were employed to develop the TMD, TME, and combine model; selection of variables and multicollinearity. In order to ensure the most reliable prediction, the selection of variables in stepwise regression analysis was carried out by calculating the Mallows' Cp statistic, which is a measure of the bias of the prediction equation.[16] This method provides a single combination of variables for each equation. The model size and fitting criteria are fixed since the optimum Cp value must be close to the number of variables involved in the model. Regression coefficients and their standard deviations were calculated. As for multicollinearity, the principal collinearity diagnostics for dependency measurement includes: the variance inflation factor (VIF), condition index and variance decomposition proportions. If none of the VIFs are greater than 10, collinearity is not a problem. Multicollinearity is a concern when the VIF exceeds 10. The condition index and variance proportions were used to identify which variables were involved. Principal component regression (PCR) was carried out to establish orthogonal predictors (uncorrelated components) and thus removing the problem of multicollinearity. The minimum eigenvalue to retain the number of components was set at 1 based on Kaiser criterion.[17] The conventional multiple linear regression and PCR models developed from the training dataset were compared to each other to assess prediction accuracy. The second part quantified the performance of the trained prediction model by root mean square error (RMSE) in test dataset. The error of age prediction was defined as the difference between chronological age and estimated age (chronological age − estimated age). All *p* values reported are two-tailed. Statistical significant was set at 0.05 and analyses were conducted using RStudio version 0.97.551 - © 2009–2012 RStudio, Inc. software. The *prcomp* function was used to develop PCR in RStudio.