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Human third molars development: Comparison of 9 country specific populations

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ABSTRACT

The majority of age estimation models based on third molar development are constructed on samples from populations with described and outlined origin. Due to unlike research protocols these studies can rarely be compared for the evaluation of possible geographical or ethnical influences on third molar development. The aim of this study is to evaluate country specific third molar development on standardized collected and analyzed data.

On panoramic radiographs selected from subjects out of 9 country specific populations (Belgium, China, Japan, Korea, Poland, Thailand, Turkey, Saudi-Arabia and South-India) the four third molar scores were registered, according to a modified Gleiser and Hunt methodology. To obtain for each subject a (factor) score which represents the degree of third molar development, a generalized linear mixed model for multivariate ordinal data was fitted on the repeated third molar scores. Differences between countries are analyzed using gender-specific regression models for these factor scores with age and country as predictors.

Comparisons between countries revealed differences in speed and onset of development. However, although reaching statistical significance, differences in actual value were small and not constant over the considered age range. In all countries, at all ages, males were ahead in third molar development compared to females.

1. Introduction

Forensic dental age estimations of living individuals are mostly requested to advice legal authorities in their judgments related to the age of unaccompanied young asylum seekers [1–3]. For these verdicts the age of interest depends on the conceptualized and recognized laws about the age of majority in the country the asylum is solicited. Between the worldwide countries this threshold of adulthood ranges between 9 and 25 years, it can be different for each gender and most commonly it is set at 18 years of age. In this age category dental age estimation techniques based on tooth timing, have to assess third molar(s) development. Although the majority of these dental age estimation methods are developed on samples from populations with described and outlined origin [4–24], the modeled age outcomes of these studies cannot be mutually compared to detect possible geographical (country specific) or ethnical influences. This incomparability originates in unlike research protocols considering the amount, the age distribution and the gender of the subjects included in the samples. Moreover the third molar developmental variables are registered on one, mutual combinations or all present third molars using different scoring or measuring techniques. Additionally, studies differ in the used statistical approach, resulting in diverse age predicting models.

The aim of this study is to compare the degree of third molar(s) development (DTMD) between countries based on a standardized collection and analysis of radiologically obtained third molar data.

2. Materials and methods

Radiologically scored third molar developmental data from 9 country specific samples (Belgium (Be), China (Ch), Japan (Ja), Korea (Ko), Poland (Po), Thailand (Th), Turkey (Tu), Saudi-Arabia (Sa) and South-India (In)), described in detail in a previous study [25], were used to study differences between countries. To ease the comparison of subjects from different countries, an index is needed which quantifies on subject level the degree of development, using information from the four molars, preserving the ordinal character of the scores and handling the presence of missing values. To this purpose, a generalized linear mixed model for multivariate ordinal data is used [26]. The model contains a fixed effect for third molar position (i.e. upper versus lower) and a random subject effect. Fitting this model is similar in spirit as performing a confirmatory factor analysis. For each subject, the empirical Bayes estimate of the random effect can be interpreted as its score on a latent factor underlying and summarizing the developmental stages of the four third molars, i.e. quantifying the overall DTMD. In the remainder, we will refer to this factor score as developmental score (DS). The DS is a normal distributed variable (z-score) with mean and standard deviation respectively equal to zero and one. A DS equal to zero corresponds to a subject with an average DTMD in the

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current study. Due to the exclusion of age, gender and countries as fixed effects in the model, differences in DS between the subjects reflect differences in DTMD between age categories, gender and countries. For males and females separately, a linear regression model with the DS as dependent variable and age and countries as predictors were used to evaluate differences in DTMD between countries. Tukey's adjustments were used for multiple comparisons between countries. An interaction between age and countries was included in the model allowing the differences between countries to depend on age. Inclusion of a quadratic term for age permitted for deviations from linearity.

3. Results

Table 1 presents some examples of patterns of observed third molar scores and their resulting DS.

Pairwise average differences in DS between the countries were maximally 0.43 and 0.52 (z-score) for respectively female and male subjects (Fig. 1). 55% (20/36) of the differences between countries were significant at 5% level for females and 86% (31/36) for males (Table 2). Compared to all other countries female subjects were developing significantly fastest in Belgium. In Japan they were slowest but not significant compared to Poland and South-India. Male subjects in South-India had a significantly lower DTMD than all other countries. The DTMD is significantly higher in Thailand compared to all other countries, except for Belgium Within each country the DS were lower for female than male subjects.

The model indicated that the differences between countries depend on age ($p = 0.004$ for females and $p < 0.0001$ for males). Lines depicting in each country the change of the DS over age were indeed not parallel (Fig. 2), but no clear patterns of differences in DS could be distinguished between the countries. Indeed over the different ages the DS differences between countries changed in an unordered way. For females the shape of the regression lines representing the relation between DS and age was similar for all countries, except for Turkey. As a result the highest DS were detected in the youngest and oldest ages in Turkey. In all other age ranges the DS was for Belgium and Japan respectively highest and lowest. For males a constant finding over the different ages was the almost persistently lowest DS value for India. Further on the differences between countries tended to be smaller around 18 year. The pairwise differences in average DS between the countries calculated at all full years in the range between 16 and 22 years were significant ($p < 0.05$) in18% (45/252) and 32% (80/252) of respectively the female and male subjects (results not shown). For the total age range and at each full year separately, the countries were ranked based on their average DS (Table 3). The ranking

Table 1
Developmental scores for some patterns of observed third molar scores.

Row number	Observed third molar scores				DS
	UR	UL	LL	LR	
1	3	3	3	3	−2.54
2	3	3	4	4	−2.11
3	4	4	4	4	−1.84
4	5	5	5	5	−1.34
5	6	6	6	6	−0.86
6	7	7	7	7	−0.46
7	8	8	8	8	−0.11
8	9	9	9	9	0.25
9	9	9	9	10	0.34
10	10	10	10	10	1.06
11	*	10	10	10	1.05
12	*	*	10	10	1.03
13	*	*	*	10	0.91
14	9	8	*	*	0.004

UR: upper right, UL: upper left, LL: lower left, LR: lower right, DS: Developmental score, *: missing third molar. The factor analysis provided for all possible combinations of four observed third molar scores (based on the modified 10 point scoring system of Gleiser and Hunt) a corresponding DS representing the degree of third molar(s) development (DTMD). Rows 11–13 illustrate that the DS differed according to the appearance and position of missing third molars. The pattern of four observed third molar scores with a DS nearest to zero, thus corresponding to a subject with an average DTMD in the total dataset, is listed in row 14.

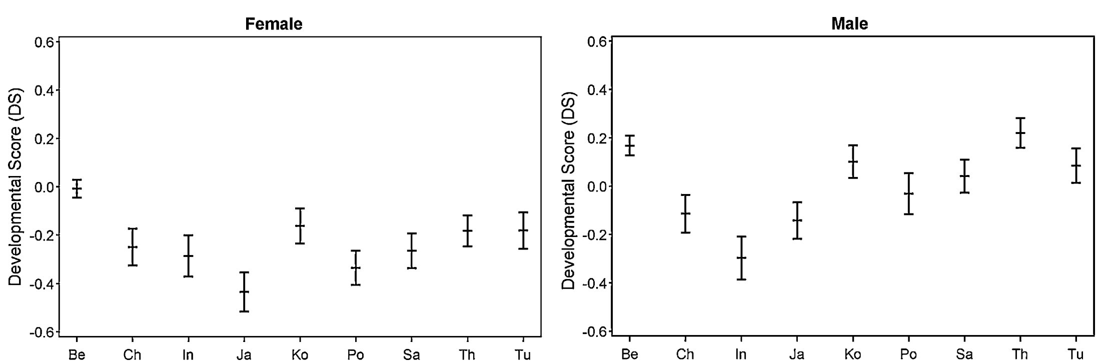

Fig. 1. Least-squares means and 95% confidence intervals obtained from the linear regression model assuming that differences between countries do not depend on age. Be: Belgium, Ch: China, Ja: Japan, Ko: Korea, Po: Poland, Th: Thailand, Tu: Turkey, Sa: Saudi-Arabia, and In: South-India.

Table 2
Comparison of developmental score between pairs of countries, irrespective the age.

	Be	Ch	Sa	Th	Tu	Ko	Po	Ja	In
									Male
Be		<0.0001	<0.0001	0.22	0.002	<0.0001	<0.0001	<0.0001	<0.0001
Ch	<0.0001		0.013	<0.0001	0.002	<0.0001	0.55	0.005	0.019
Sa	<0.0001	0.68		<0.0001	0.033	0.44	0.069	<0.0001	<0.0001
Th	<0.0001	0.058	0.043		0.007	<0.0001	<0.0001	<0.0001	<0.0001
Tu	<0.0001	0.035	0.002	0.11		0.002	0.16	<0.0001	<0.0001
Ko	<0.0001	0.35	0.044	0.17	0.34		0.001	<0.0001	<0.0001
Po	<0.0001	0.25	0.25	0.004	0.001	0.033		0.007	0.001
Ja	<0.0001	0.004	0.008	<0.0001	<0.0001	<0.0001	0.3		0.003
In	<0.0001	0.33	0.43	0.2	0.056	0.09	0.43	0.1	
	Female								

Be: Belgium, Ch: China, Ja: Japan, Ko: Korea, Po: Poland, Th: Thailand, Tu: Turkey, Sa: Saudi-Arabia, In: South-India lower and upper off-diagonal part refer to female and male respectively. p-values are obtained after applying a correction for multiple testing (Tukey's adjustment).

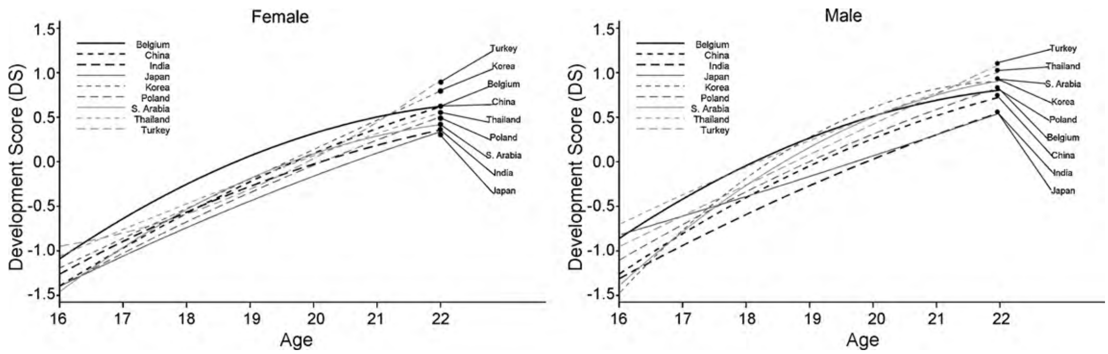

Fig. 2. Country specific relations between age and DS obtained from the regression model with an interaction between country and age, for female and male subjects separately.

fluctuated strongly between the age categories, again illustrating that differences between countries were not following a clear trend (Table 3). Note also that there was a lack of correspondence between the rankings observed for females and males, for patterns of rankings within a country as well as for patterns of differences between countries.

The detected statistically significant differences in DS between countries turned out to be small observed clinical differences. First, the difference in DS can be expressed as a difference in age. In the slowest developing country (Japan, females) the maximal difference in average DS corresponding to a one-year increase equals 0.46 (z-score). Hence, the maximal DS difference between countries observed at any age (0.52 z-score) would correspond to a difference of 14 months (Fig. 1). Secondly, the difference in DS can be expressed as a difference in pattern of third molar scores. To this purpose, the DS is compared between subjects with succeeding patterns of equal repeated third molar scores (Table 1) (for example: the DS of a subject with all four modified Gleiser and Hunt (GH) scores [27] 4 compared with the DS of a subject with all GH scores equal to 5). The maximal and minimal detected difference in DS were 0.81 (pattern 9999 compared to 10101010) and 0.35 (pattern 7777 and 8888) respectively. The mean difference in DS equals 0.51. As such, the maximal observed difference between countries in average DS (0.43 z-score) for females and (0.52 z-score) for males is in line with differences between the aforementioned succeeding patterns.

4. Discussion

The collected data provided information regarding the third molar scores following the modified GH technique [27] and concerning the position and amount of the missing third molars. The factor score analysis allowed to compress all this information in a single numbered DS, permitting to detect the DTMD of the included subjects. Therefore, in contrast to the methodology used by Gunst et al. [8,9] in this study one age related regression model could be developed for each gender. In fact previous authors were obligated to develop divers regression models on the one hand depending on appearing multicollinearity between the observed GH scores of different third molars within a subject and on the other hand related to the amount of available third molars per subject.

All considerations related to DTMD in this research count on the maturation of these teeth in subjects aged between 16 and 22 years. Accordingly GH scores of third molars lower than, or equal to, 3 had a very low prevalence, implicating that mainly third molars root development is evaluated.

The quantification of the discovered maximal pair wise average difference in DS between countries related to age reveal that individuals from different countries with an equal DTMD differ maximally 14 months in age. The impact of this finding on the performance of age predictions has to be considered in relation to the high human variability inherent physiological age indicators [28] such as third molars development. Accordingly the errors in dental age predictions based on third molars information from another country are, as described in an earlier study [25], negligible. Another important observation related to forensic age estimation is that third molars development especially for male subjects is most clustered for all not boarder countries in the chronological age category between 17 and 19 years. This finding accentuates the inter country-specific similar age prediction outcomes appropriate for the adult–juvenile discrimination set at an 18 years threshold [25].

The tests for the interaction between country and age on the pair wise average differences in DS, indicate that the DTMD among countries varies as a function of age. These differences depend on

Table 3
Ranking of countries based on the DS for the whole age range and at various age categories.

Country	Age															
	Female								Male							
	16y	17y	18y	19y	20y	21y	22y	T	16y	17y	18y	19y	20y	21y	22y	T
Be	3	1	1	1	1	1	3	1	3	2	1	2	3	5	6	2
Ch	6	7	6	5	3	4	4	5	6	8	8	7	7	7	7	7
Ja	7	9	9	9	9	9	9	9	2	4	7	8	8	8	9	8
Ko	4	4	3	3	2	2	2	2	9	6	3	1	1	1	4	3
Po	8	8	8	8	8	7	6	8	5	5	6	6	6	6	5	6
Th	2	2	2	4	5	5	5	4	1	1	2	3	2	2	2	1
Tu	1	3	7	7	6	3	1	3	4	3	4	5	5	3	1	4
Sa	9	7	4	2	4	6	7	6	8	7	5	4	4	4	3	5
In	5	5	5	6	7	8	8	7	7	9	9	9	9	9	8	9

Be: Belgium, Ch: China, Ja: Japan, Ko: Korea, Po: Poland, Th: Thailand, Tu: Turkey, Sa: Saudi-Arabia, In: South-India, y: year, T: age range between 16 and 22 year. Countries are ranked from highest (1) to lowest (9) mean developmental score (DS).

changes in slope between country specific linear models and cannot be considered as a shift in DTMD value between countries. This indicates that comparisons of the DTMD between countries have to be assessed at well described moments in life.

An overall higher DTMD for males compared to females is observed within each country at different ages evaluating the distribution of the DS and comparing the country specific regression outcomes. This implicates that the quantity of difference in DTMD between genders depends on the age of the subjects. In the literature this general finding is detected by several authors evaluating populations of countries not included in this study [15,16,29,30] as on integrated countries such as Be [7–9], Ja [10,12], Tu [17,18] and Ch [22].

The DTMD between ethnical or biological related individuals could be searched by classifying the studied countries in accordingly groups. Since no common developmental trends between countries were detected the same conclusion can be drawn considering the evaluation of associated country groups containing information from the Caucasian (Be, Po, and Tu) and the Mongoloid (Ch, Ja, Ko, and Th) populations. Future interest lies in further country specific data collection, especially from the Negroid and Australian group. Olze [31] found, comparing Caucasian, Mongoloid and (black) African samples that at the same DTMD the Caucasians occupied a middle position with the Mongoloid subjects on average older and the African subjects younger. Harris [32] reported on mandibular third molar evaluation that American blacks have a higher DTMD than American whites. This finding is in agreement with the conclusions made by Blankenship [33] comparing all third molars, except for males in the latest developing stages. These results fit into the country specific DTMD described in this study if the assumption that third molars timing is faster in Negroid populations compared to all other country specific populations is valid. Further research on an extended data collection has to clear out this assumption as well as the for current study unusual gender specific finding discovered by Liversidge [34] namely that black girls are on average timing earlier than black boys.

5. Conclusion

The DTMD is summarized for each subject using a factor score. Analyses of these summary scores reveal many significant differences between countries. However, the differences between countries are not constant over age and vary in an unordered way. Moreover, the magnitude of the differences turns out to be small. As such, there is no evidence for important differences in DTMD between the countries. An overall lower DTMD in female compared to male subjects was detected in the different country specific samples.

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