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Estimating Age in Maori, Pacific Island, and European Children from New Zealand

ABSTRACT: The islands of New Zealand are populated by persons of European, Maori, and Pacific Island extraction. The purpose of this research is to quantify the levels of dental maturation of each of these three populations, in order to obtain data that will be useful in forensic identification and age estimation. The sample consisted of 1383 orthopantomographs (660 males, 723 females) of 477 Maori, 762 European, and 144 Pacific Island children between the ages of 3 and 14 years. Each radiograph was digitized and the stages of mineralization of the seven left mandibular permanent teeth were assessed using the eight stages described by Demirjian. Values for 1, 3, 5, 50, 95, 97, and 99% confidence intervals are listed for each maturity score. Intra-observer reliability was evaluated using Bland–Altman's method on data from re-scoring one out of every 20 radiographs and standard dental maturation curves were constructed for the three populations by means of a quantile regression method. Despite the fact that quantile regression analysis showed that across the age group investigated there were differences between boys and girls, knowledge of the sex does not increase the accuracy of the age estimate, simply because the magnitude of the error of age estimation is greater than the difference between the sexes. Our analysis also shows that population divergence is most marked after the age of 9 years, with a peak difference seen at age 10.

KEYWORDS: forensic science, forensic age estimation, Demirjian, dental maturity

The estimation of age at death from human skeletal remains is a critical aspect in the reconstruction of a biologic profile in both forensic and archaeological contexts (1). Moreover, both in forensic medicine and in the clinical setting, there is a growing demand by courts for appropriate estimations of age in living subjects suspected of being minors without documentation (2). In juvenile forensic cases, age estimation may rely on an evaluation of skeletal maturation, dental eruption, or on tooth formation (3). Of these, tooth formation is probably the method most frequently used (4). This is arguably because tooth formation occurs throughout the growth period, from the middle trimester to adulthood and this extended period provides a useful window for the assessment of growth and maturation. Additionally, developing teeth are known to be less influenced by environmental factors than other growth systems (5). Classically, the investigator assesses crown and root formation stages from dental radiographs and then refers to published reference data of dental maturation to accurately estimate age. While there are a number of methods used to quantify dental maturation, the most commonly used is probably that of Demirjian (6–8).

The importance of dental maturational data is highlighted by the results of numerous recent studies of North American and European children (for review, see 4). However, no such data exist for the Pacific. The population of New Zealand consists of indigenous Maori, the descendants of European migrants referred to as "Pakeha," and recent migrants from the Pacific Islands. This presents an ideal opportunity to gather useful data on dental maturation from a previously undescribed region. The aim of our study was therefore to use Demirjian's dental maturity scores to predict ages for these three populations, to be used both in forensic and clinical dental practice.

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Materials and Methods

Subjects

The sample consisted of 1383 orthopantomographs of 723 females and 660 males from various hospitals and private clinics within New Zealand. Selection was from consecutive hospital records and involved three ethnic groups: Maori, European (Pakeha), and Pacific Island children. The study population consisted of 477 Maori (mean age boys 9.1 years, range 3.6–13.9 years; mean age girls 9.4 years, range 2.6–13.9 years), 762 European (mean age boys 8.5 years, range 2.5–13.9 years; mean age girls 8.7 years, range 2.9–13.9 years), and 144 Pacific Island children (mean age boys 8.6 years, range 3.0–13.8 years; mean age girls 8.0 years, range 3.3–13.8 years). Ethnicity was based on self-declared information on the patient's record cards or by noting obvious Maori or Pacific Island surnames. This research protocol was approved by the University of Otago Ethics Committee.

Methods

Each radiograph was digitized using a Canon 5 Mega pixel powershot camera and subsequently analyzed using Adobe® Photoshop® 7.0. This enabled better contrast of radiographic images and enlargement of the image, which was especially important for assessment of apical closure. A single observer (RT), who was calibrated using Demirjian's CD-ROM tutorial (6), assessed the stages of mineralization of the seven left mandibular permanent teeth using the eight stages described. To avoid observer bias, each radiograph was coded with only a numerical ID number (1–1343). Ethnicity, age, and sex were unknown to the observer. Intra-observer reliability was evaluated by using the Bland–Altman method on data from re-scoring one out of every 20 radiographs (9).

Dental maturity scores were calculated using Demirjian's method. We then calculated standard dental maturation curves for the three populations by means of a quantile regression method as described by Wei et al. (10). An advantage of this approach is that it makes no non-parametric assumptions of the distribution of the data; for example, one need not assume that these are equally distributed about the mean.

Results

Reliability

Figure 1 gives the Bland–Altman plot (9) of differences between re-scored and original data against average of measurement values. The mean difference was 1.9, with a confidence interval of −4.9 to 8.7, suggesting that there was no significant difference between the two sets of measurements. Re-scoring one out of every 20 radiographs produced an intra-class correlation coefficient of 0.96 and an agreement of 87% for the scoring of teeth, with a random yield (the standard error of the difference between the two sets of measurements) of 0.17 for both male and female maturity scores, which represents an index of reliability of greater than 93%.

Predicted Ages

Median maturity curves and their 95% confidence intervals for children of European, Maori, and Pacific Island extraction are given in Figs. 2, 3, and 4. From these data, it is clear that a maturity score of 30 would yield a median age of 4.5 for European and Maori children, but 4.0 for a Pacific Island child. Figure 5 shows the differences between dental ages of European and Maori, and also between European and Pacific Island children, from which it is clear that population divergence is most marked after the age of 9 years, with a peak difference seen at age 10.

Sex Differences

Our quantile regression analysis showed that across the age group investigated, there are differences between boys and girls; however, knowledge of the sex does not increase the accuracy of

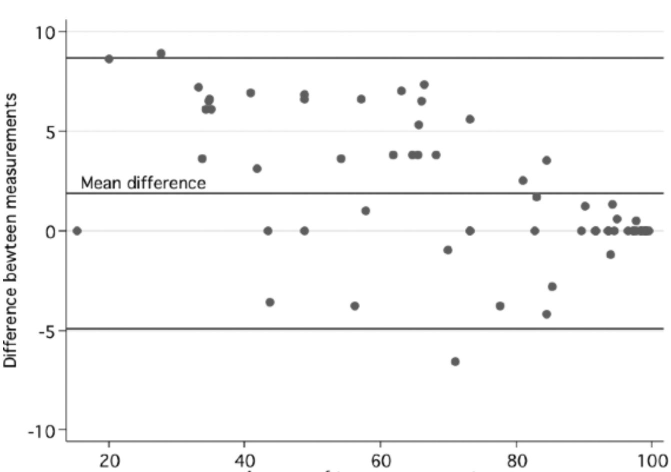

FIG. 1—*Bland–Altman plot for the differences between repeated measurements and the original data. An average difference of 1.9, with a confidence interval of −4.9 to 8.7, suggests that there is no significant difference between the two sets of measurements.*

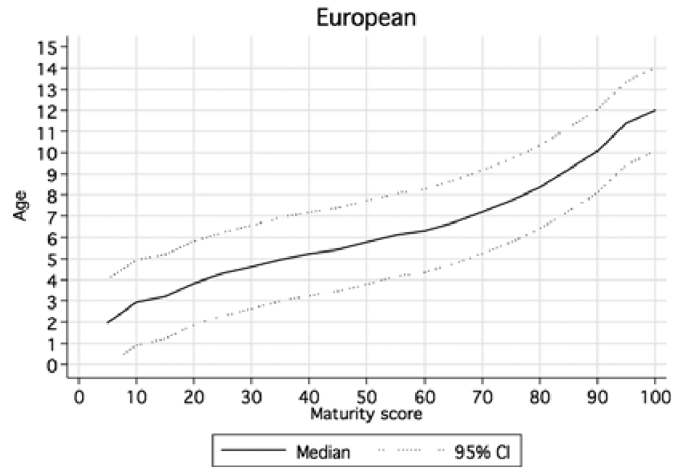

FIG. 2—*Dental ages plotted against maturity scores for New Zealand children of European ancestry.*

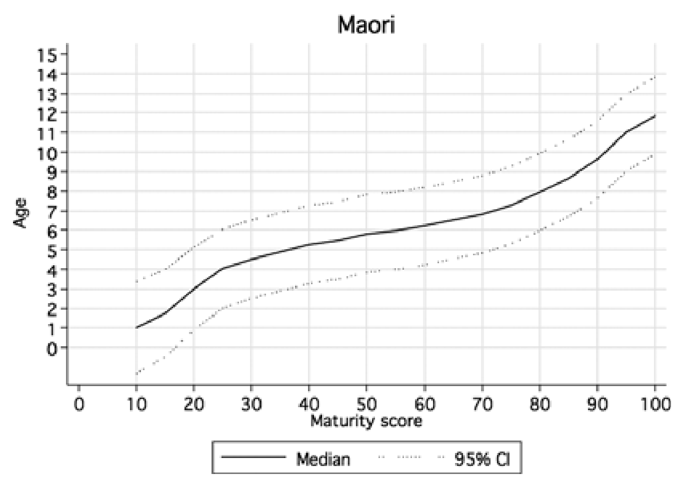

FIG. 3—*Dental ages plotted against maturity scores for New Zealand Maori children.*

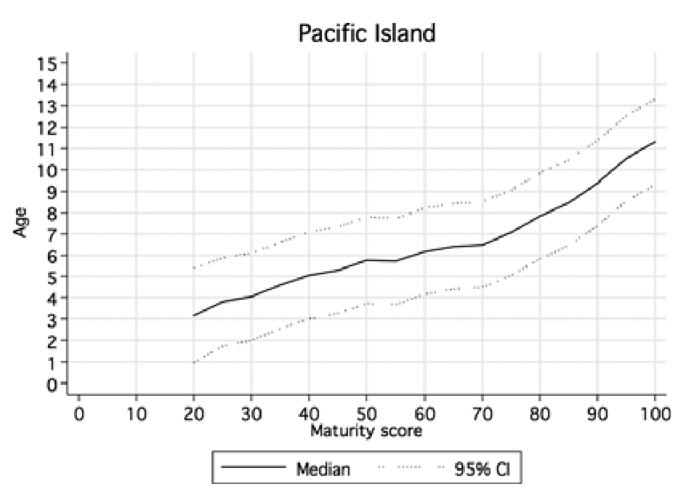

FIG. 4—*Dental ages plotted against maturity scores for New Zealand Pacific Island children.*

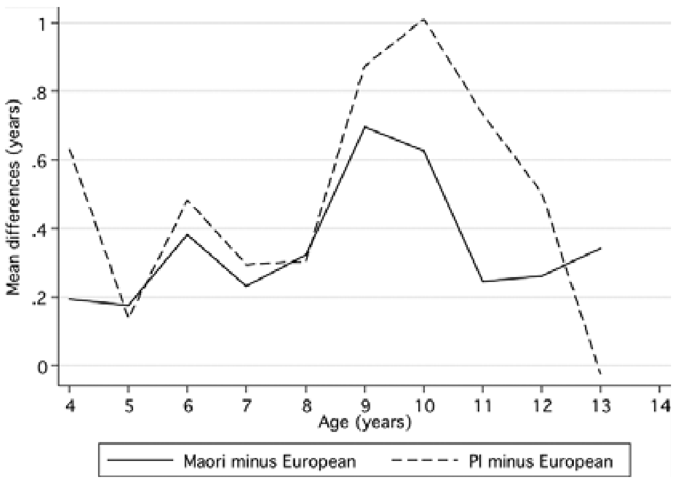

FIG. 5—*Differences between dental ages of European and Maori children, and also between European and Pacific Island children.*

the age estimate, simply because the magnitude of the error of age estimation is greater than the difference between the sexes. For instance, despite a statistically significant difference between European boys and girls (p = 3.67; <0.01), there is only a 0.3 of a year difference between males and females at the 50th centile level, a level of measurement which is not forensically realistic.

Discussion

The identification of unknown human remains begins with the creation of a profile that traditionally includes sex, ethnicity, individual features, and age. Yet the ascertainment of age at death from skeletal material is controversial. Firstly, the degree of accuracy of the age estimate is inversely proportional to the length of time lived (11) and hence, biologic estimations of age are the most accurate in the early phases of development. Secondly, there are only two types of macroscopic parameters that are useful indicators of biological age: firstly, epiphyseal closure throughout the skeleton and secondly, dental age (12). Unfortunately, skeletal maturation is not well correlated with chronological age, nor are its underlying genetic processes well buffered, as they are known to be influenced by environment, lifestyle, and activity (e.g. 13,14). In contrast, the developing dentition is thought to be a useful indicator of maturation and hence of biological age, because teeth are less affected than other body tissues by environmental insults (15,16).

Dental development may be measured either by tooth eruption or tooth formation. Tooth formation is thought to be a less variable measure than eruption, unaffected by factors such as malnutrition, premature loss of primary teeth, crowding, and dental decay. Moreover, tooth formation has a high heritability, low coefficient of variation, and is more resistant to environmental effects (5,17,18). In the past few decades, a great deal of knowledge has accumulated on dental maturity in North America, Europe, and Asia (see Table 1). However, there are no such data available for Maori, Pacific Island, or New Zealand children of European descent.

The aim of this paper was to present developmental maturity standards for Maori, European, and Pacific Island children and to provide maturity curves (Demirjian's score as a function of age) that may be useful for forensic dentists.

When the differences in dental age between European and Maori, and also between European and Pacific Island children were plotted (Fig. 4), the population difference diverged most markedly

TABLE 1—*Studies using Demirjian's dental maturity scale.*

Country	Province	Reference	Sample Size (n) Boys	Girls	Study type*	Age (years)
Australia	Adelaide	19	288	327	C	4.9–16.9
	Perth	20	690	760	C	4–16
Belgium	Leuven	21	1029	1087	C	1.8–18
	Leuven	22	1255	1268	C	2–18
Brazil	São Paulo	23	321	368	C	6–14.9
China	Chengdu	24	465	438	C	3–16
	Hong Kong	25	101	103	C	5–7
Finland	Helsinki	26	349	389	C + L	2.5–16.5
	Helsinki	27	50	40	C	4–15
	Kuhmo	27	181	214	C	4–15
	Helsinki + Turku	28	506	556	C	2.5–17.2
	Southern	29	(1651)		C + L	2–25
	Southern	21	1119	1094	C	2–19
France	Southern France	30	470	561	C	2–18
	Venissieux	31	98	108	C	3.5–14.5
	Venissieux	32	(1610)		C	3.5–?16
Germany	Freiburg	33	489	514	C	2–20
Holland	Nymegen	34	232	254	C + L	4–14
Hungary	Pecs	35	9	104	C	2.9–17.5
India	Manipal	36	93	91	C	5–15
	Belgaum	37	94	103	C	6–13
Italy	Rome	38	(157)		C	5–14
Korea	Kwangju	39	173	137	C	3–17.2
Norway	Oslo	40	128	133	L	5.4–12.7
Sweden	Regional	41	243	242	C	2.6–17.2
UK	London	42	263	258	C	4–9
	Sheffield	43	42	39	C	2.6–15.8
	Sheffield (Somali)	44	42	39	C	2.6–15.8
International	Australia, Belgium, England, Finland, France, Korea, Sweden	45	4835	4742	C	2–24

*C, cross-sectional; L, Longitudinal. Table adapted from Ref. (4).

around 9–11 years, which is much earlier than the maximum difference calculated for Belgian children, at 12 years of age (22). This suggests that Polynesian children mature earlier than European children (46) and highlights the importance of using population-specific standards in forensic age determination. As stated earlier, there are two types of macroscopic parameters that are useful indicators of biologic age: epiphyseal closure throughout the skeleton and secondly, dental mineralization. Unfortunately, the former has been shown to be insensitive to ethnicity (but sensitive to socio-economic status [45], again underlining the importance of dental development as an ageing criterion in forensics.

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