Original Research Article

Advanced Dental Maturation in New Zealand Maori and Pacific Island Children

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ABSTRACT This study employs Demirjian's (1994: CD Rom. Norwood, MA: Silver Platter Education) method for assessing dental maturation to compare the rates of development in children of three ethnic populations living in New Zealand—Maori, Pacific Island, and European. We test the hypothesis that Maori and Pacific Island children will have significantly advanced dental maturation compared with New Zealand children of European extraction. The study population consists of orthopantomographs of 1,343 children (623 females and 660 males) between the ages of 2.5 and 14 years, and involves three ethnic groups—Maori, European, and Pacific Islander. Bland/Altman plots for the mean chronological age against the age difference suggest that dental age as determined by the Demirjian method is consistently lower than the chronological age of the children examined. A mixed model regression analysis shows that this difference between dental and chronological age is significantly greater in Maori than in European children (regression coefficient = 0.414; $z = 7.01$; $P < 0.001$) and also significantly greater in Pacific Island children than European children (regression coefficient = 0.574; $z = 6.25$; $P < 0.001$). Regression analysis shows that the 50th quantile maturity score of boys and girls differs by 1.49 ($t = -6.18$, $P < 0.01$) and the interaction of sex and age is also significantly different ($t = -2.44$, $P < 0.01$). Similarly, Maori girls show a difference in maturity score of 1.28 ($t = -3.77$, $P < 0.01$). However, the slopes for Maori boys and girls did not differ significantly (age/sex interaction, $t = -1.25$, $P = 0.212$). We conclude that Pacific Island children are advanced in dental maturity compared with Maori children who in turn are more advanced than New Zealand children of European origin. Am. J. Hum. Biol. 20:43–50, 2008. © 2007 Wiley-Liss, Inc.

Human biologists, medical and dental clinicians, physical anthropologists and forensic scientists have long recognized the importance of an understanding of the variation in human growth and development (Smith, 1991). Developing teeth are thought to be a useful indicator of maturation and hence of biological age, because they are less affected than other body tissues by endocrinopathies and environmental insults (Saunders et al., 1993). Dental development may be measured either by tooth eruption or tooth formation. While eruption is a discontinuous and variable measure, affected by factors such as malnutrition, premature loss of primary teeth, crowding and dental decay, tooth formation is seen as a more robust measure with a high heritability, low coefficient of variation, and resistance to environmental effects (Demirjian, 1985; Liversidge and Molleson, 2004; Moorrees and Kent, 1981; Pelsmaekers et al., 1997). Thirty years have passed since Demirjian's (1976) landmark study introduced a uniform and generally accepted method for assessing dental maturation in humans. Importantly, Demirjian based his system upon relative values of objective criteria, rather than on absolute lengths of developing teeth. On the basis of this method, tooth formation data have since been published for a wide range of European, Asian, and North American children (Davis and Hagg, 1994; Koshy and Tandon, 1998; Leurs et al., 2005; Liversidge and Molleson, 2004; McKenna et al., 2002; Solari and Abramovitch, 2002; Staaf et al., 1991; Teivens and Mornstad, 2001). These studies suggest that there may be different patterns of dental maturation among different populations. However, nothing is known about the rates of dental maturation in Polynesian or Maori children.

In an early study, Fry (1981) showed that Polynesian children may have some teeth erupting up to 2 years earlier than children of European ancestry living in the same area. Since then, Yamada et al. (1992) have shown that Cook Island children might be characterized by early dental eruption compared with other ethnic groups. These findings appear to be consistent with the small number of studies that have reported accelerated somatic growth and maturation in Polynesian children (Freeman et al., 2002; Houghton, 1990; Rush et al., 2003).

The obvious question now arises: if there is evidence of precocious maturation in Polynesian children and if they also erupt their teeth earlier, will tooth formation be similarly accelerated? In answer to this question, we determine and contrast the rates of dental development in children of three ethnic populations living in New Zealand—Maori, Pacific Island, and European. We use the Demirjian method (1976) to test the hypothesis that Maori and Pacific Island children will have significantly advanced dental maturation compared with the latter population.

SUBJECTS AND METHODS

Subjects

We obtained 1,343 Orthopantomographs (OPG's) of 623 females and 660 males from various hospitals and private clinics within New Zealand. Selection was at random

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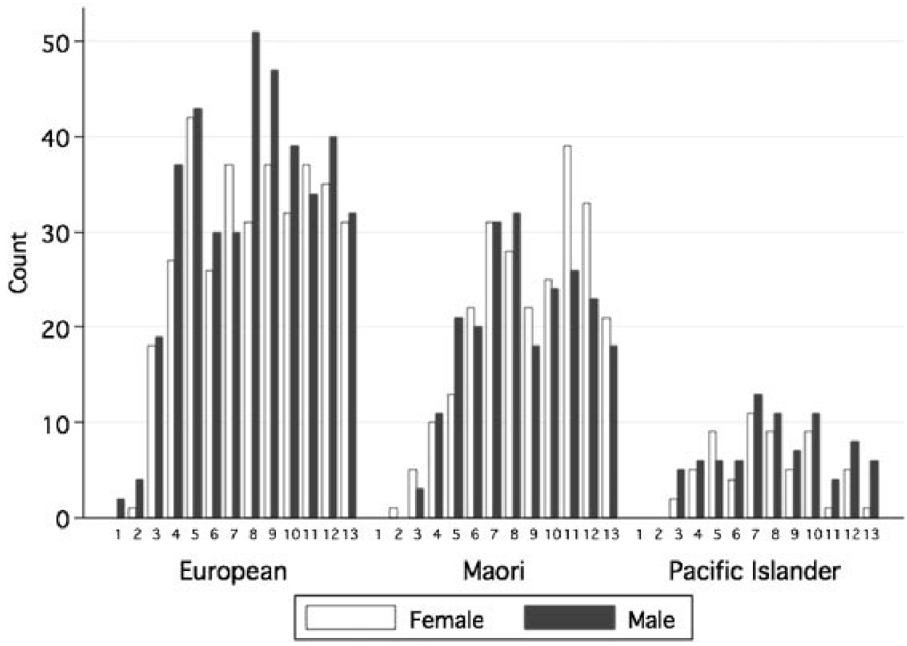

Fig. 1. Age and gender distributions of the three ethnic populations considered.

and involved three ethnic groups; Maori, European, and Pacific Island children. We selected children between the ages of 2.5 and 14 years at the time that the OPG was taken (Fig. 1). 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 1.8–13.9 years; mean age girls 8.7 years, range 2.9–13.9 years) and 144 Pacific Island (mean age boys 8.6 years, range 3.0–13.8 years; mean age girls 8.0 years, range 3.3–13.8 years) children. Inclusion criteria were similar to those of Leurs et al. (2005). In other words, good quality OPG's (resolution, density, and contrast), known birth date and date of radiographic record taken, healthy patients, a complete set of lower left mandibular teeth (excluding mandibular lower third molars), no history of extractions in the lower left quadrant and no agenesis of teeth. Ethnicity was based on self-declared information on patient's record cards or by noting obvious Maori or Pacific Island surnames. The research protocol was approved by the Otago University Ethics Committee.

Methods

Each OPG 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 image, which was especially important for assessment of apical closure. A single observer (RT), who was calibrated using Demirjian's CD-ROM tutorial (Demirjian, 1994), assessed the stages of mineralization of the seven left mandibular permanent teeth using the eight stages described (Demirjian, 1985). To avoid observer bias, each OPG 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 means of Dahlberg's (1940) statistic.

Analysis

Dental and chronological age values were compared for each ethnic group, by sex and for each year of age, and these data were then evaluated by means of a mixed model regression analysis. Because the use of correlation coefficients has been criticized on the grounds that they measure the relations between two variables rather than the agreement between them (Altman and Bland, 1983), we also used Bland–Altman plots in our study. This is a graphical method in which the differences between two populations are plotted against the averages of the populations (Altman and Bland, 1983; Bland and Altman, 1986, 1999; Gardner and Altman, 1986).

Finally, we calculated standard dental maturation curves for the three populations by means of a quantile regression method as described by Wei et al. (2005). An advantage of this approach is that it makes no parametric assumptions of the distribution of the data, for example, one need not assume that these are equally distributed about the mean.

RESULTS

Reliability

Rescoring one out of every 20 radiographs produced 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% (Dahlberg, 1940).

Population differences

Mean differences between the chronological and dental ages for the three population groups as calculated by Demirjian's method, are given in Table 1. In children of European descent, the differences ranged from −0.84 to

TABLE 1. Differences between chronological and dental ages as calculated by Demirjian's (1994) method for Maori, European and Pacific Island boys and girls

Age	Sample size	Mean chronological age (±SD)	Mean dental Age (±SD)	Mean difference (SD)	95% CI
European Boys					
3	10	3.15 (0.25)	3.44 (0.59)	−0.28 (0.55)	−0.67 to 0.11
4	32	4.03 (0.28)	4.57 (1.00)	−0.53 (0.99)	−0.89 to −0.17
5	46	5.02 (0.27)	5.72 (0.83)	−0.69 (0.69)	−0.92 to −0.47
6	35	6.02 (0.30)	6.80 (0.71)	−0.78 (0.52)	−1.05 to −0.50
7	27	7.00 (0.27)	7.67 (0.57)	−0.68 (1.05)	−0.86 to −0.50
8	36	8.07 (0.25)	8.49 (0.71)	−0.41 (0.70)	−0.65 to −0.17
9	45	9.00 (0.29)	9.25 (1.22)	−0.31 (1.18)	−0.66 to −0.43
10	46	10.00 (0.28)	10.65 (1.15)	−0.64 (0.96)	−0.96 to −0.32
11	35	11.02 (0.27)	11.67 (1.11)	−0.65 (0.97)	−1.02 to −0.28
12	37	12.02 (0.25)	12.87 (0.99)	−0.84 (1.01)	−1.16 to −0.51
13	32	13.00 (0.31)	13.30 (1.07)	−0.37 (1.06)	−0.76 to −0.00
14	13	13.68 (0.14)	13.78 (0.59)	−0.09 (0.54)	−0.43 to −0.23
European Girls					
3	9	3.17 (0.17)	3.40 (1.25)	−0.22 (1.34)	−1.25 to 0.80
4	26	4.00 (0.28)	4.11 (0.76)	−0.10 (0.73)	−0.39 to 0.19
5	32	5.06 (0.24)	5.70 (0.64)	−0.63 (0.65)	−0.87 to 0.40
6	29	5.86 (0.27)	6.32 (0.71)	−0.46 (0.69)	−0.72 to −0.19
7	25	6.92 (0.29)	7.44 (0.74)	−0.52 (0.73)	−0.82 to −0.21
8	46	7.97 (0.27)	8.43 (0.91)	−0.48 (0.84)	−0.73 to −0.23
9	25	9.02 (0.32)	9.40 (1.04)	−0.37 (0.89)	−0.74 to −0.00
10	45	9.92 (0.26)	10.50 (1.33)	−0.57 (1.25)	−0.94 to −0.19
11	29	11.02 (0.29)	12.60 (1.02)	−1.57 (1.10)	−1.99 to −1.16
12	41	11.98 (0.30)	13.42 (1.00)	−1.44 (1.01)	−1.76 to −1.12
13	33	12.94 (0.30)	13.57 (0.83)	−0.84 (0.84)	−0.93 to −0.32
14	6	13.65 (0.16)	13.98 (0.82)	−0.33 (0.91)	−1.28 to −0.62
Maori Boys					
4	7	4.01 (0.30)	4.48 (0.73)	−0.47 (0.48)	−0.92 to −0.25
5	17	5.03 (0.29)	6.05 (0.68)	−1.02 (0.70)	−1.39 to −0.66
6	17	5.94 (0.32)	6.82 (0.74)	−0.88 (0.72)	−1.25 to −0.51
7	26	6.97 (0.28)	7.83 (0.85)	−0.85 (0.53)	−1.07 to −0.64
8	34	7.95 (0.27)	8.77 (0.92)	−0.81 (0.94)	−1.14 to −0.48
9	21	8.86 (0.26)	10.00 (1.23)	−1.13 (1.17)	−1.66 to −0.60
10	23	9.88 (0.28)	11.49 (1.15)	−1.60 (1.05)	−2.06 to −1.15
11	26	10.98 (0.32)	12.21 (1.41)	−1.22 (1.41)	−1.79 to −0.65
12	25	12.01 (0.30)	13.32 (0.84)	−1.31 (0.85)	−1.66 to −0.95
13	15	12.87 (0.26)	13.78 (0.72)	−0.90 (0.70)	−1.30 to −0.51
14	9	13.64 (0.12)	13.90 (0.93)	−0.25 (0.91)	−0.95 to −0.45
Maori Girls					
3	2	3.00 (0.59)	2.80 (0.14)	+0.19 (0.73)−	6.40 to −6.80
4	6	3.90 (0.41)	4.65 (1.35)	−1.88 (1.08)	−1.88 to −0.38
5	17	4.97 (0.25)	5.72 (0.63)	−0.75 (0.57	−1.05 to −0.46
6	17	6.01 (0.26)	7.04 (0.80)	−1.03 (0.74)	−1.41 to −0.64
7	25	7.04 (0.26)	7.79 (0.76)	−0.74 (0.73)	−1.05 to −0.44
8	33	7.97 (0.26)	8.82 (1.06)	−0.84 (1.06)	−1.22 to −0.46
9	24	9.00 (0.29)	10.00 (1.32)	−0.99 (1.20)	−1.50 to −0.48
10	24	9.97 (0.29)	10.92 (1.22)	−0.94 (1.20)	−1.45 to −0.43
11	26	10.98 (0.61)	12.47 (1.20)	−1.20 (1.20)	−1.97 to −0.99
12	39	11.91 (0.29)	13.48 (1.05)	−1.57 (1.02)	−1.19 to −1.24
13	22	12.84 (0.30)	13.78 (1.12)	−0.93 (1.11)	−1.42 to −0.43
14	6	13.71 (0.18)	14.20 (0.97)	−0.49 (1.01)	−1.55 to −0.57
Pacific Island Boys					
4	5	3.78 (0.20)	4.70 (1.56)	−0.91 (1.39)	−2.64 to −0.81
5	7	5.01 (0.27)	6.20 (0.60)	−1.18 (0.35)	−1.51 to −0.86
6	8	5.95 (0.23)	7.15 (0.63)	−1.19 (0.51)	−1.62 to −0.75
7	5	7.05 (0.32)	7.86 (0.19)	−0.81 (0.39)	−1.30 to −0.31
8	13	7.85 (0.27)	8.89 (0.92)	−1.03 (0.91)	−1.59 to −0.48
9	10	8.84 (0.26)	10.02 (1.16)	−1.17 (1.06)	−1.93 to −0.41
10	10	10.00 (0.18)	11.65 (1.13)	−1.65 (1.02)	−2.38 to −0.91
11	6	10.70 (0.25)	12.33 (1.20)	−1.62 (1.24)	−2.92 to −0.32
12	7	12.02 (0.37)	13.55 (0.75)	−1.53 (0.79)	−2.26 to −0.79
13	1	12.98 (0.32)	13.41 (0.65)	−0.42 (0.00)	−1.08 to −0.23
Pacific Island Girls					
4	3	4.00 (0.25)	5.50 (1.56)	−1.50 (1.34)	−4.83 to −1.83
5	8	5.04 (0.25)	5.55 (0.81)	−0.50 (0.66)	−1.05 to −0.04
6	7	5.85 (0.33)	6.91 (0.57)	−1.05 (0.58)	−1.59 to −0.51
7	11	7.05 (0.20)	7.88 (0.52)	−0.83 (0.60)	−1.23 to −0.42
8	2	7.91 (0.23)	8.05 (0.63)	−0.13 (0.86)	−7.94 to −7.67
9	10	8.91 (0.26)	10.34 (0.98)	−1.42 (0.94)	−2.10 to −0.74
10	7	9.94 (0.28)	11.50 (0.62)	−1.55 (0.51)	−2.03 to −1.07
11	4	10.79 (0.16)	13.57 (0.45)	−2.78 (0.55)	−3.66 to −1.90
12	6	12.21 (0.35)	13.80 (0.98)	−1.59 (1.14)	−2.79 to −0.38

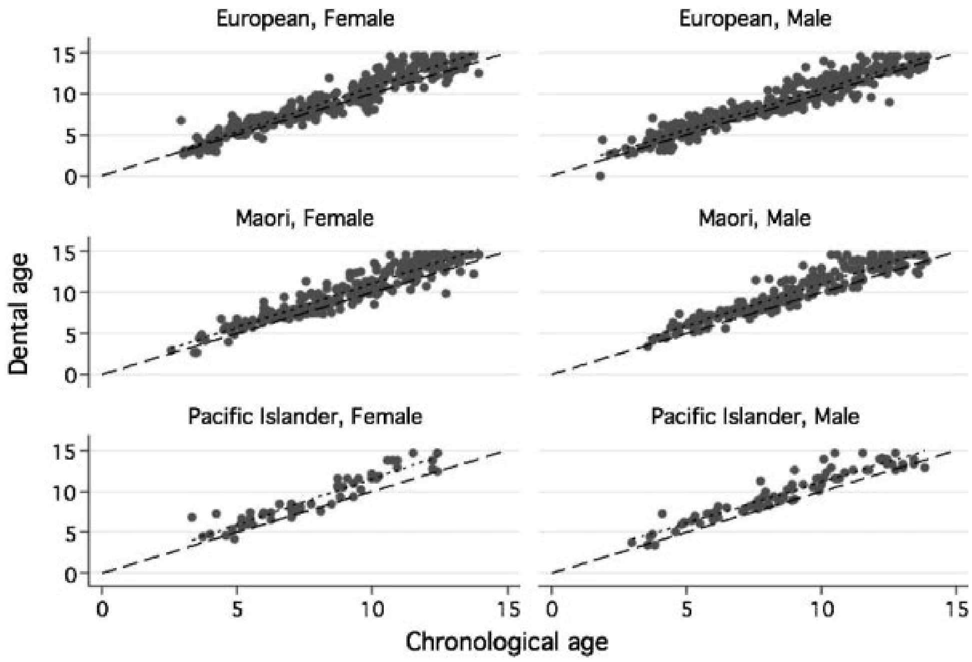

Fig. 2. Correlations between chronological age and dental age calculated according to Demirjian (long dashes are line of identity, dots are regression line).

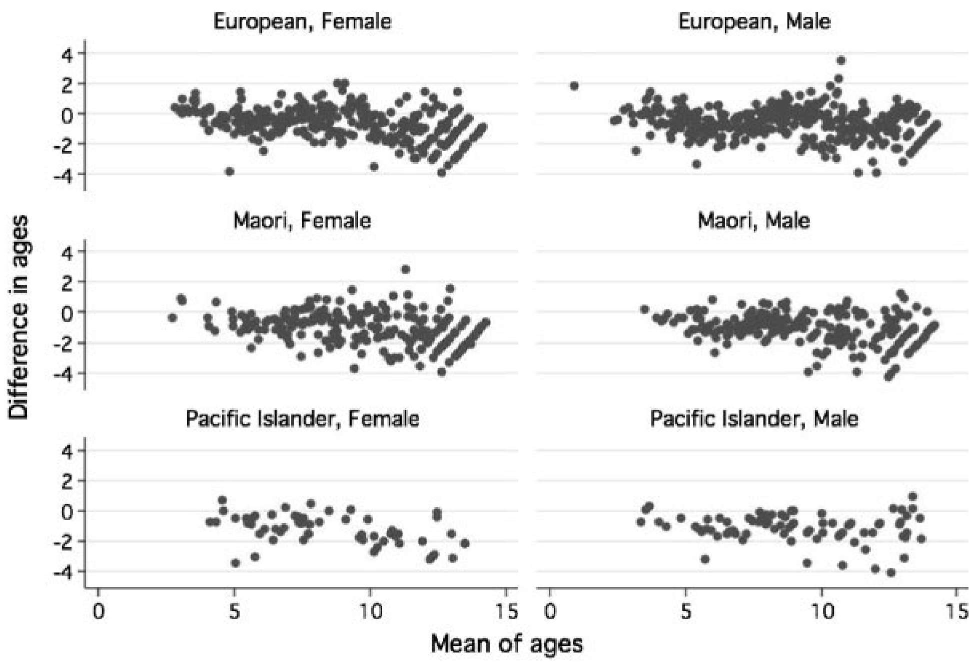

Fig. 3. Bland/Altman plots for mean age against age differences in males and females of the three populations examined.

−0.09 (mean difference (MD) −0.57 95% confidence interval (CI) −0.67 to −0.48) in boys and from −1.57 to −0.10 (MD −0.67 95% CI −0.78 to −0.57) in girls. In Maori children, the ranges were from −1.31 to −0.25 (MD −1.03 95% CI −1.17 to −0.89) in boys and from −1.88 to −0.49 (MD −1.04 95% CI −1.17 to −0.91) in girls, and in Pacific island children from −0.42 to −1.65 (MD −1.14 95% CI −1.35 to −0.93) in boys and from −0.13 to −2.78 (MD −1.26 95% CI −1.50 to −1.01) in girls. There were no discernible trends in the standard deviations across year intervals for each population. With the exception of 3-year-old Maori girls ($n = 2$), all were dentally advanced relative to Demirjian's standard. The upper limit of the 95% confidence intervals of all other ages fell below zero,

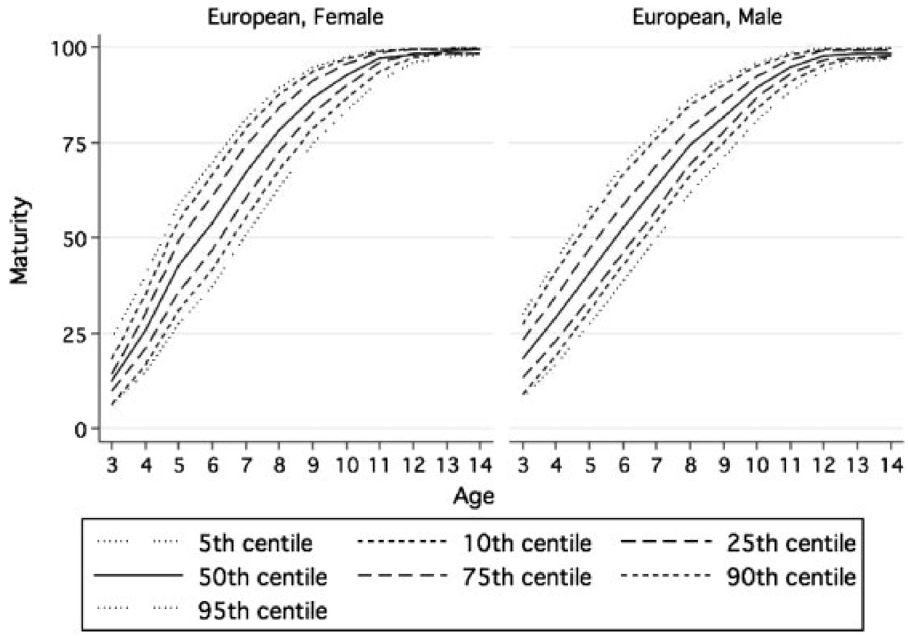

Fig. 4. Standard quantile regression curves for dental maturation for male and female New Zealand children of European descent.

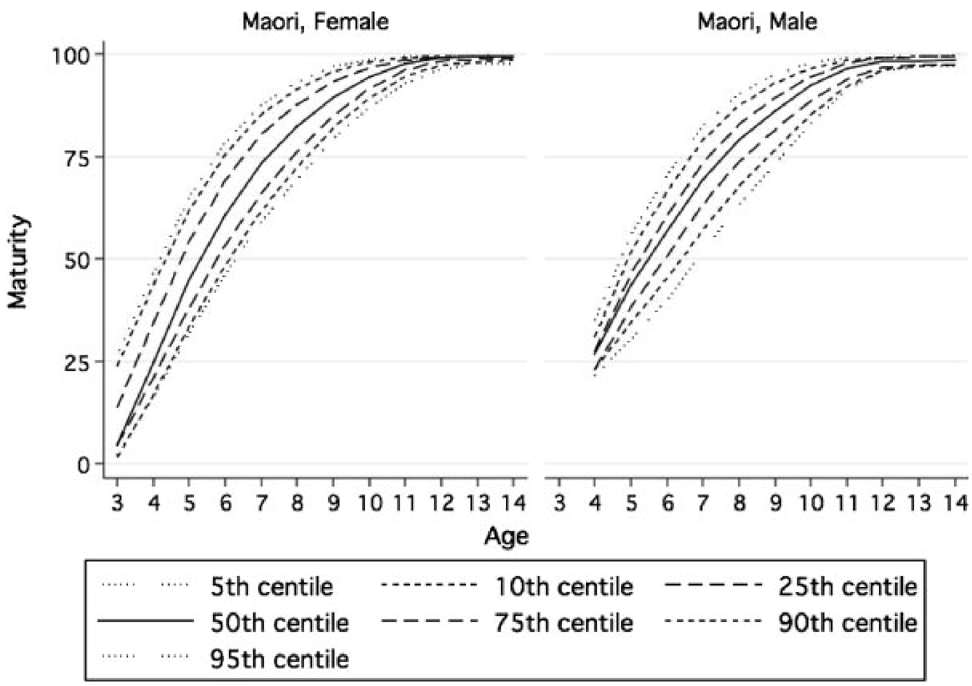

Fig. 5. Standard quantile regression curves for dental maturation for male and female New Zealand children of Maori descent.

hence the differences between the chronological and dental ages were statistically significant.

The linear relationship between chronological age and dental age as calculated by Demirjian's (1985) method is given in Figure 2. Inspection shows that the lines of identity ($y = x$) in each of the populations diverges from the least square regression line for males and females. Bland/Altman plots for the mean chronological age against the age difference are given in Figure 3, from which it appears that more than half the data points are below the zero line and that this trend is more marked in Maori and Polynesian children. This implies that the dental age as determined by the Demirjian method was consistently lower than the chronological age of the children examined. A mixed model regression analysis (Fig. 2) shows that the difference between dental and chronological age is significantly greater in Maori than in European children (regression coefficient $= 0.414$; $z = 7.01$; $P < 0.001$) and

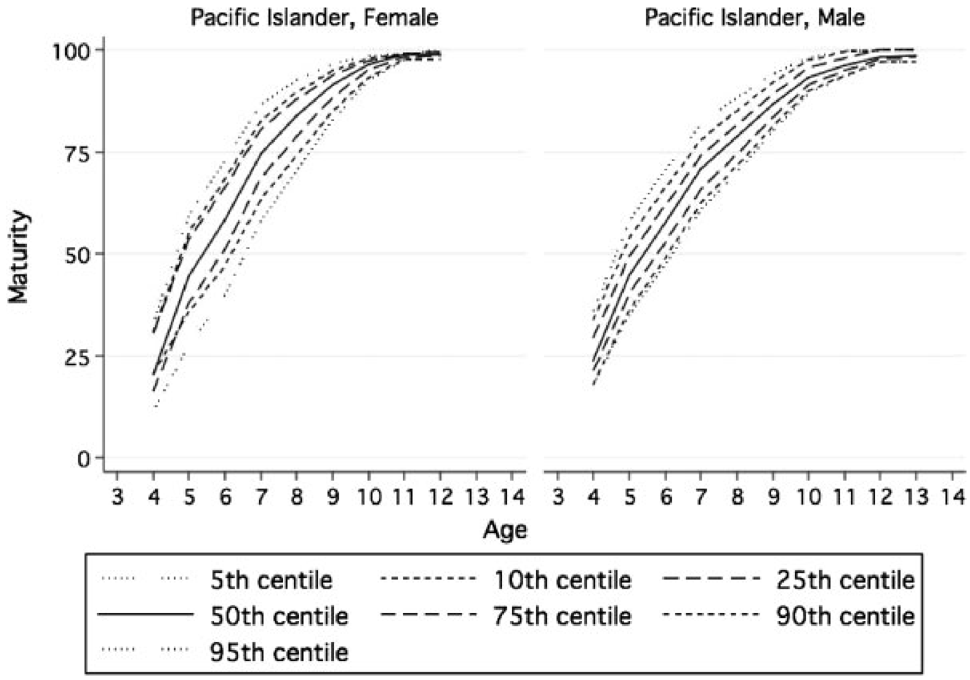

Fig. 6. Standard quantile regression curves for dental maturation for male and female New Zealand children of Pacific Island descent.

also significantly greater in Pacific Island children than European children (regression coefficient = 0.574; z = 6.25; $P < 0.001$).

Dental maturity for Maori, Polynesian, and New Zealand European children

Dental maturation curves for the males and females of each of the three populations, as calculated by a quantile regression method (Wei et al., 2005), are given in Figures 4–6. The mixed model is an extension of linear regression that allows for lack of independence in the observations, such as more than one measurement on the same individual (eg. estimated and actual age). Figure 7 gives a comparison of the 50th percentile graphs of boys and girls in the three populations studied. It is clear that Pacific Island children mature faster than either Maori or European children. That girls mature faster than boys is confirmed by the results of a quantile regression analysis, which shows that the 50th quantile maturity score differs by 1.49 ($t = -6.18$, $P < 0.01$) and the interaction of sex and age (in other words, the slopes of the two graphs) is also significantly different ($t = -2.44$, $P < 0.01$). Similarly, Maori girls show a difference in maturity score of 1.28 ($t = -3.77$, $P < 0.01$). However, the slopes for Maori boys and girls did not differ significantly (age/sex interaction, $t = -1.25$, $P = 0.212$).

DISCUSSION

The aim of the present study was to use the Demirjian method (Demirjian and Goldstein, 1976) to determine and contrast the dental development of Maori, Pacific Island, and European children living in New Zealand. It is clear from our data that their dental age, as determined by this method, was consistently advanced (Fig. 3). Interestingly, it has also been shown that Pacific Island children are taller for their chronological age than European children, and that they enter puberty earlier (Gordon et al., 2003; Salesa et al., 1997). However, there are no significant differences in weight or crown-rump length at birth (Simmons, 1994), nor in adult height (Russell et al., 1999). These results suggest that there might be different trajectories of growth between European and Pacific Island children. Recently, Grant et al. (2005) showed that prepubertal Pacific Island children have larger skeletons and greater bone mineral content than European children. These findings, together with those of our present investigation, appear to support the small number of studies that have recorded accelerated somatic growth and maturation in Polynesian children (Freeman et al., 2002; Houghton, 1990; Rush et al., 2003). Of course, one might assume that the conditions are less favorable for indigenous people than for those of European extraction. So, for instance Ibrahim et al. (2003) have argued that the issue of access to care includes a complex mix of cultural factors and individual preferences of patients, ethnic characteristics and practices of healthcare professionals (including bias, stereotyping or racism), as well as the system of delivery of healthcare (including location of facilities, cost of access and allocation of resources), all of which could have marked effects on maturation.

Liversidge (2003) recently reviewed variation in modern human dental development. She highlighted the fact that the most widely used method of assessment of dental maturity was that of Demirjian et al. (1973). While numerous studies around the world have shown advancement in dental maturation compared with Demirjian's original Canadian standard, few studies compared maturity directly between population groups. In the first of these, Liversidge et al. (1999) compared dental maturity in Bangladeshi and white children living in London, UK. This study, limited to children between the ages of 4 and 8.99 years,

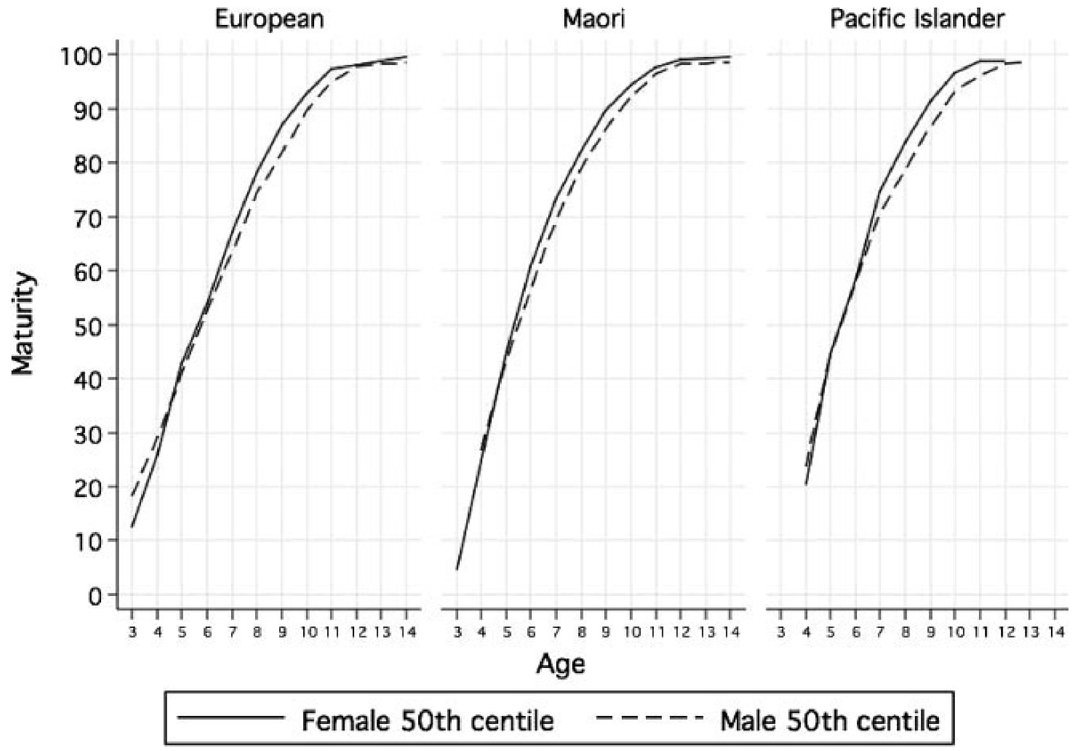

Fig. 7. Gives a comparison of the 50th percentile graphs of boys and girls in the three populations studied.

showed no significant difference between the groups. From a small study of Somali children living in Sheffield, UK, Davidson and Rodd (2001) reported a 9-month advancement in dental maturity compared with white children living in the same area. Teivens and Mörnstad (2001) investigated dental maturation in a large group of Korean children and found an advancement of a few months compared with Swedish children. The present study is the first to address differences in dental maturation between three ethnic groups in the Pacific island, New Zealand. Our most important finding is that Pacific Islanders are advanced in dental maturity compared with Maori children who in turn are more advanced than New Zealand children of European origin. Earlier, Fry (1981) had shown that Polynesian children may have some teeth erupting up to 2 years earlier than children of European ancestry living in the same area, and Yamada et al. (1992) showed that Cook Island children had early dental eruption compared to other ethnic groups.

It is clear, however, that recording difference in dental maturation between groups using a single score such as Demirjian, fails to clarify exactly where and how these differences occur. Any system that expresses maturity as a single value has advantages and disadvantages. The advantage is the ease and clinical usefulness of assessing maturity. The most important disadvantage is that while differences in maturity can be measured, the actual reason for these differences between groups or individuals is not explained.

A future approach to this question would be to analyze the timing of formation stages of individual teeth. Demirjian's method relies on weighted scores of tooth formation stages of seven individual teeth. Differences in the timing of one or more of these stages of individual teeth relative to other stages or teeth are hidden and could be explored by calculating and comparing the timing of individual stages of individual teeth for these groups.

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