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Precision and accuracy of commonly used dental age estimation charts for the New Zealand population

Stephanie Baylis[a,*], Richard Bassed[b]

[a] Baylis Dental Services, 41 Maunu Rd, Whangarei, 0110, Northland, New Zealand
[b] Victorian Institute of Forensic Medicine and the Department of Forensic Medicine, Monash University, Melbourne, Australia

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ABSTRACT

Little research has been undertaken for the New Zealand population in the field of dental age estimation. This research to date indicates there are differences in dental developmental rates between the New Zealand population and other global population groups, and within the New Zealand population itself.

Dental age estimation methods range from dental development charts to complex biometric analysis. Dental development charts are not the most accurate method of dental age estimation, but are time saving in their use. They are an excellent screening tool, particularly for post-mortem identification purposes, and for assessing variation from population norms in living individuals.

The aim of this study was to test the precision and accuracy of three dental development charts (Schour and Massler, Blenkin and Taylor, and the London Atlas), used to estimate dental age of a sample of New Zealand juveniles between the ages of 5 and 18 years old (n = 875).

Percentage 'best fit' to correct age category and to expected chart stage were calculated to determine which chart was the most precise for the sample. Chronological ages were compared to estimated dental ages using a two-tailed paired t-test ($P < 0.05$) for each of the three methods. The mean differences between CA and DA were calculated to determine bias and the absolute mean differences were calculated to indicate accuracy.

The results of this study show that while accuracy and precision were low for all charts tested against the New Zealand population sample, the Blenkin and Taylor Australian charts performed best overall.

1. Introduction

Dental age estimation of living and deceased individuals has been the subject of extensive research worldwide. No more so than in relatively recent times as population specific standards are sought to assist in meeting stringent legal requirements [1–10].

As conflict driven movement of people across borders increases from regions where birth registration is not common, it is critical that individuals without accompanying documentation are treated appropriately as either minors or adults [4–7]. The occurrence of mass disasters in regions that do not have population specific reference data to assist in the identification process, can mean delays in the progression of identification of deceased victims and their return to their loved ones [11]. Both issues can have serious, if not devastating, consequences for all involved [12].

Assessment of the development and eruption of the dentition is extremely useful for estimating age of the living and deceased [4,5,13,14]. Teeth develop in a continuous and predictable way and can be evaluated by their degree of mineralization (utilizing radiographic imaging) and by their eruption (also termed emergence) into the oral cavity [15–17]. This continuum spans approximately 20 years from the second trimester [18,19].

Dental age estimation techniques over the years have included the use of maturity scores, atlases and charts, biometric, histological, and gravimetric analysis. Some methods are destructive to tooth tissue [14,20–25] and therefore inappropriate in many instances. Others, while more accurate, are somewhat time consuming [26,27].

Published dental age estimation studies for the New Zealand population are sparse. Leslie (1951)[1] provided estimates of permanent tooth emergence times and showed that New Zealand born children (n = 503) were more dentally advanced than English and American children born overseas. Demirjian's method of age

* Corresponding author.
E-mail address: stephanie1baylis@gmail.com (S. Baylis).

[1] Sample comprised NZ born children of predominantly European origin. Leslie GH. A Biometrical Study of Eruption of the Permanent Dentition of New Zealand Children. Wellington: Government Printer. Cited by Kanagaratnam and Schluter [28].

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estimation [29] has been tested in two contemporary New Zealand studies: i.e. Te Moananui et al [30] and Timmins et al. [31]. Te Moananui used Demirjian maturity scores to predict ages for three population groups within New Zealand and showed Polynesian children matured earlier than Maori and European children (n = 1383) [30]. Timmins however, concluded that Demirjian's method was reliable for predicting chronological age for a randomized sample (n = 200) of children aged 7–16 years old [31]. Kanagaratnam and Schluter studied emergence of permanent teeth in a regional sample of New Zealand children (n = 3466) of different ethnic origins and found differences in median permanent tooth emergence ages among ethnic groups and sexes. The study concluded that emergence of teeth was more advanced in Polynesian children than other ethnic groups sampled [28].

To date, there are no known tests of dental development charts on a New Zealand population sample. This research project sets out to test the accuracy and precision of the Schour and Massler (S&M) [32], AlQahtani (AlQ) et al. [33], and Blenkin and Taylor (B/T) [11] charts, in estimating dental age of a sample of New Zealand children of known age.

2. Methodology

For this cross-sectional study, de-identified OPG radiographs were obtained for a sample of children living in the Northland region of New Zealand. All OPG radiographs were collected in digital format and viewed on computer monitor. Exclusions were applied as follows: bilateral congenitally missing teeth, multiple missing permanent teeth, and OPG radiographs of poor quality. The sample targets were 30 males and 30 females per age category from 5.00–5.99 up to 18.00–18.99 years old. Chronological age (CA) was calculated and individuals were grouped into age categories per sex (Table 1).

Age estimation was performed by the first author alone. Comparison was made between the seven mandibular right side teeth[2] (4th quadrant; FDI 47-41[3]) of each individual against the charts to give estimation of dental age (DA) for each method.

Intra-observer reliability of DA estimation was calculated using the Kappa statistics on a random sample (n = 90) of the study pool, retested after 4 months. Data was analyzed in Microsoft Office Excel Worksheet 2013.

Percentage 'best fit' to correct age category and to expected chart stage were calculated to determine which chart was the most precise for the New Zealand sample. For the Schour and Massler and the Blenkin and Taylor charts, the correct age group was defined by the error ranges provided for each chart stage e.g. using the Schour and Massler chart: a child with a DA of 5 year and a CA within 4.25–5.75 years (5 year ± 9 months) was considered to be in the correct age category. The correct age group, for the AlQahtani London Atlas, was defined as being within the age range of the chronological age category i.e. a child with a DA of 5.5 year and a CA within 5.00–5.99 year was considered in the correct age category.

CA and DA (calculated for every individual using each of the charts) were also compared using a two-tailed paired t-test,[4] with a significance level of $P < 0.05$, to analyze accuracy and reliability. Mean differences between CA and DA, standard deviations and standard errors of the mean differences between CA and DA, and variance of the CA and DA for each age group were also calculated for each age category, for each method. The mean differences between CA and DA were calculated to determine bias and the absolute mean differences were calculated to indicate accuracy. This statistical data was calculated for immature individuals only and tabulated separately for sex. All individuals over the age of 15 year needed to be eliminated due to the difficulty in assigning appropriate stages without reference to third molars, once all seven root apices had closed.

Table 1
Number of males and females for each age category.

Age (years)	Total males	Total females
5.00–5.99	13	11
6.00–6.99	21	23
7.00–7.99	31	32
8.00–8.99	40	41
9.00–9.99	34	34
10.00–10.99	36	33
11.00–11.99	35	38
12.00–12.99	36	30
13.00–13.99	33	33
14.00–14.99	31	34
15.00–15.99	33	39
16.00–16.99	29	31
17.00–17.99	34	30
18.00–18.99	30	30

3. Results

The Schour and Massler (S&M) [32] and the two Blenkin and Taylor (B/T) charts[5] [11] have identical drawings. Ages and error ranges of each stage for the latter having been adjusted for the Australian population and sexual dimorphism. The Australian charts also have fewer earlier stages. None of these charts are accompanied by written criteria for stages of tooth development. In contrast, the AlQahtani London Atlas (AlQ) is accompanied by Moorrees' stage descriptions, with diagrams, used for identifying tooth developmental stages and root resorption of single and multi-rooted teeth [33].

During the analysis of the radiographs, chart diagram anomalies became apparent at specific developmental stages. For example, tooth 44 at stage 6 year ± 9 months, in the Schour and Massler chart (B/T—F: 5.5 ± 1.3 year; M: 5.75 + 1.6 year), shows root formation more advanced than stage 7 year ± 9 months (B/T—F: 6.3 ± 1.3 year; M: 6.7 ± 1.4 year). Tooth 45 shows greater tooth development at 10 year ± 9 months than at 11 year ± 9 months for the same chart (B/T—F: 9.9 ± 1.8 year; M: 10.3 ± 1.8 year versus F: 10.8 ± 1.8 year; M: 11.1 ± 1.8 year). The overall eruption pattern of both teeth, and root resorption of the corresponding deciduous teeth, show advancement. Although these differences were noted, they did not affect stage placement for individuals. The Schour and Massler chart also has a large jump in tooth development between stages 12 year ± 6 months (range = 11.5–12.5 years) and stage 15 year ± 6 months (range = 14.5–15.5 years). This jump also occurred in the Blenkin and Taylor charts, however the stage age ranges are much larger and overlap i.e. 13.8 ± 1.8 year (range = 12–15.6 years) and 15.0 ± 3.7 year (range = 11.3–18.7 years) for females (B/T male stages 14.0 ± 1.8 years: range = 12.2–15.8 year and 14.5 ± 3.7 years: range = 10.8–18.2 years). Further issues with these charts occurred in determining whether root apices were open or closed and whether the periodontal ligament (PDL) was wide or of normal width. Reference was made to tabled figures constructed by Schour and Massler to assist in chart interpretation [18].

The London atlas also included diagrammatic anomalies. For example, there is no difference in root development of tooth 46

[2] Age estimation was also carried out for lower left third molar in all cases, but were not used in calculation of overall age estimation of each individual due to their considerable variability.
[3] FDI—Fédération Dentaire Internationale tooth numbering system.
[4] Assuming unequal variance.
[5] Separate male and female charts.