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# Age estimation charts for a modern Australian population

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ABSTRACT

Calculation of the biological age of an individual has application in many fields of dentistry. It can be used to determine the appropriate timing of interventionist treatment for example in orthodontics; to analyse the developmental stage of an individual relative to the general population in the management of genetic or congenital conditions which disturb growth; and to estimate the age of a living or deceased person for forensic purposes.

Many of the techniques used to estimate age can be quite time consuming to complete. This time component is a major disadvantage in a forensic context when age estimations in mass disasters are required as part of the post-mortem examination process. Consequently, forensic practitioners have tended to use the simpler but less reliable atlas style techniques of Schour and Massler and Ubelaker in these situations.

For mass disaster situations, such as the recent Victorian Bushfires, it would be advantageous to have access to Australian specific data in the convenient Schour and Massler format.

This project reinterpreted the Australian data previously collected by Blenkin and other relevant studies and applied it to a schematic similar to that of Ubelaker to develop a reliable, convenient and contemporary reference for use in age estimation.



## 1. Introduction

Calculation of the biological age of an individual has application in many fields of dentistry. It can be used to determine the appropriate timing of interventionist treatment for example in orthodontics; to analyse the developmental stage of an individual relative to the general population in the management of genetic or congenital conditions which disturb growth; and to estimate the age of a living or deceased person for forensic purposes.

While accurate, many of the techniques based on the analysis of dental development do require training and experience to ensure precision and the process can be quite time consuming to complete. This time component is a limitation in a forensic context when age estimations in mass disasters are required as part of the post-mortem examination process. Consequently, forensic practitioners have tended to use the simpler but less reliable atlas style techniques of Schour and Massler [1] and Ubelaker [2] in these situations.

Valid criticisms of the Schour and Massler charts include the fact that, although augmented by additional data, they were based on the work of Logan and Kronfeld [3] and as such suffer from similar limitations of a small sample size of chronically ill, institutionalised children with no differentiation between male and female. In assigning a different diagram to each year of growth, the range about a mean age can only be ±6 months, a range too small to be credible. Being an 'atlas type' system any comparison is subject to a higher degree of inter-observer disagreement when compared to systems that rely on objective physical measurements. However, the wide applicability, despite the sample on which it is based, may be testament to the relative stability of the pattern and rate of dental development regardless of the impact of environmental factors or disease on growth. Finally, the fact that the published images are of solid teeth, yet are most often compared to radiographs of the case at hand for assessment can prove problematic.

More recently, Ubelaker [2] modified and improved upon the chart produced by Schour and Massler. Using data from numerous population studies he modified the stages of tooth development and position within the existing diagrams and included new additional diagrams. The population basis for this work was American Indian and other 'nonwhite' populations. Owing to issues with identification of sex of the sub-adult samples, no differentiation in the data was made between males and females.

The current study is aimed at addressing many of these shortfalls.

## 2. Materials and methods

The charts developed by Ubelaker were examined in detail. Each diagram within these charts was analysed using the modified Demirjian method as described by

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Blenkin [4]. In essence, each diagram was treated as a 'case' that needed an age estimate. Each tooth of the right mandibular quadrant, excepting the third molar (41–47) was assessed and rated according to the Demirjian system. These ratings were converted to numerical scores and estimates of age, including range at the 95% confidence interval, were made using Blenkin's standards. For those diagrams representing ages below the utility of the Blenkin method, data from Fanning were used to estimate the age of the cases depicted [5]. For those diagrams representing ages older than the utility of the Blenkin method, data collected on the development of mandibular third molars by the authors and Dr Bassed et al. were used [6].

The confidence intervals of each of the depicted stages of development varies according to the source of the data from which the age estimates were derived. The first four diagrams up to the age of 1.4 years were assessed using the work of Fanning [5] and as such represent the stage of development attained between the 10th and 90th percentiles. The next six diagrams up to the age of 6.3 years (6.7 years for females) were assessed using Blenkin's data, the 95% confidence intervals of which had been calculated using the standard error of estimate for each age group [7]. The next five diagrams up to the age of 13.8 years (14 years for males) were assessed using Blenkin and Evans' data, the 95% confidence intervals of which had been calculated using the residual error from the ANOVA output in order to provide a simplified and uniform confidence interval from across the sample age groups [4]. The detail regarding the distribution of the sample by age can be found in Blenkin's paper, with the overall $n = 3261$ ($m = 1637$, $f = 1624$). The diagram depicted as 15 years (14.5 yrs for males) was assessed using the same data collected by Blenkin above, but where the least squares method was used to regress only the development data on third molars for both sexes individually ($n = 1526$ with $f = 816$, $m = 710$), the 95% confidence interval have been calculated using the residual error from the ANOVA output. The last two diagrams were assessed using data collected by Bassed et al. [6], the percentiles represent the percentage of individuals of the given ages who had attained that specific stage of development. Again, the age distribution of the sample population can be found in Bassad's paper with the overall $n = 973$.

Each pictogram was then assigned an 'Australian' age, and diagrams which represented stages with inadequate differentiation were removed.

A validation study was undertaken using a sample of 204 OPGs ($m = 100$, $f = 104$). The distribution of the sample by chronological age is given in Table 1.

The cases were randomly selected from cases at the Victorian Institute of Forensic Medicine, the Oral Health Centre of Western Australia and Private Orthodontic practice in Australia. All cases had been previously de-identified prior to use in this study. Each case was blindly assessed and given an age estimate by two assessors who discussed and agreed upon the estimate based on the charts provided here. Each estimate was then compared to the chronological age for each respective case in order to establish the validity of the method.

A study of inter observer error was undertaken. One assessor was the author, the other, a general practitioner dentist with some forensic experience. The results of their individual age assessment for each of the 204 cases used in the validation study, were compared and analysed using the kappa statistic. Intra observer error was assessed by way of the author reassessing 50% of the sample ($n = 102$) after an intervening period of 8 weeks.

**Table 1**
Age distribution of the validation sample.

| Age | Male | Female | Total |
|---|---|---|---|
| 0* | 19 | 18 | 37 |
| 1 | 6 | 4 | 10 |
| 2 | 4 | 3 | 7 |
| 3 | 2 | 1 | 3 |
| 4 | 1 | 1 | 2 |
| 5 | 2 | 1 | 3 |
| 6 | 3 | 1 | 4 |
| 7 | – | 3 | 3 |
| 8 | 3 | 4 | 7 |
| 9 | 5 | 2 | 7 |
| 10 | 6 | 6 | 12 |
| 11 | 5 | 6 | 11 |
| 12 | 12 | 12 | 24 |
| 13 | 12 | 19 | 31 |
| 14 | 6 | 11 | 17 |
| 15 | 5 | 5 | 10 |
| 16 | 7 | 5 | 12 |
| 17 | 1 | – | 1 |
| 18 | – | 1 | 1 |
| 19 | 1 | – | 1 |
| 22 | – | 1 | 1 |
| Total | 100 | 104 | 204 |

* Each age group is represented by the midpoint of the range. For example age = 1 represents the range 0.51–1.5 years of age.

## 3. Results

The completed charts are depicted in Figs. 1–4.

By way of example, a male child with erupted and occluded first molars and maxillary central incisors, lateral incisors erupted but not yet in occlusion, and deciduous molars and canines still present would be assessed as being $8.8 \pm 1.8$ years, or of the age range of 7–10.6 years. A further example: 69% of females aged 22 years will have reached the stage of apex closure of the permanent third molars.

The validation study resulted in the correct estimation of age range of the case at hand in 84% of the female cases and in 79% of the male cases. While 13–14% of cases had their the age ranges underestimated, overestimates of age range occurred in only 7% of cases (3% in females). Importantly, none of the incorrect age range estimates were greater than one diagram removed form the correct one. Table 2 summarises these results.

The analysis of inter-observer error resulted in a kappa statistic of 0.74 for female cases and 0.70 for males. The analysis of intra-observer error resulted in a kappa statistic of 0.8 for both sexes. These statistics represent levels of 'substantial reliability' according to Landis and Koch [8].

## 4. Discussion

Up until the landmark study by Logan and Kronfeld in 1933 it was generally held that the calcification of all the permanent teeth began at the same time [3]. This assumption was based upon tables produced 40 years earlier by Legros and Magitot [9].

Today we know that the development of the dentition commences at differing stages in the growth of the child dependent on the teeth in question. It is recognised that there is a degree of variation in the actual timing due to the inherent biological variability of human beings, hence the use of ranges rather than discrete timings. It is also widely acknowledged that the teeth develop through a succession of stages that are common to all humans and that all teeth, both deciduous and permanent, normally pass through all these stages of development. These stages are predictable and observable and it is the observation of these stages that many methods of age estimation are based upon.

The study by Logan and Kronfeld in 1933 was a cross sectional study using histological sectioning and radiographic examination of 0–15 year olds. The study was based on the examination of 25 fresh post-mortem specimens, however, 19 of these were under 2 years-of-age. From the data the authors published a detailed account of the positioning and relative development of the human dentition.

In 1941, Schour and Massler published an important study that summarised the development of the human dentition in an 'atlas style' chart [1]. It was based on the data collected by Logan and Kronfeld and other histological studies of the developing dentition undertaken by Schour around the same time. The summary of this information into a pictorial or 'atlas type' chart provided the profession with a tool that would not only be used in every day practice, but would also prove useful in estimating the age of an individual in a forensic context. The method involves comparison of a radiograph of, preferably, the entire maxillary and mandibular dentitions against diagrams depicting the stage of the development of the dentition representative of each year of age. By matching the radiographic image to a specific diagram the estimated age of the child is that listed with the associated diagram.

The advantages of using this system to estimate the age of an individual are that it is non-destructive, being able to conduct the assessment on radiographs of the jaws; it is simple and does not require any specialised training to recognise specific stages of development, as required in many of the more recently developed systems; and it does not require the use of specialised equipment beyond an X-ray apparatus.