Journal of Forensic and Legal Medicine 26 (2014) 61–64

Contents lists available at ScienceDirect

Journal of Forensic and Legal Medicine

journal homepage: www.elsevier.com/locate/jflm

Original communication

# Dental age estimation: The role of probability estimates at the 10 year threshold

Victoria S. Lucas*, Fraser McDonald, Monica Neil [a], Graham Roberts

*Department of Orthodontics, King's College London Dental Institute, Floor 22 Tower Wing, Guy's Hospital, London SE1 9RT, UK*

ARTICLE INFO

*Article history:*
Received 7 April 2014
Accepted 2 June 2014
Available online 28 June 2014

*Keywords:*
Dental age estimation
Dental age assessment
Dental development
Tooth development stages
Probability
NORMDIST function

ABSTRACT

*Introduction:* The use of probability at the 18 year threshold has simplified the reporting of dental age estimates for emerging adults. The availability of simple to use widely available software has enabled the development of the probability threshold for individual teeth in growing children.
*Materials and methods:* Tooth development stage data from a previous study at the 10 year threshold were reused to estimate the probability of developing teeth being above or below the 10 year threshhold using the NORMDIST Function in Microsoft Excel. The probabilities within an individual subject are averaged to give a single probability that a subject is above or below 10 years old. To test the validity of this approach dental panoramic radiographs of 50 female and 50 male children within 2 years of the chronological age were assessed with the chronological age masked. Once the whole validation set of 100 radiographs had been assessed the masking was removed and the chronological age and dental age compared. The dental age was compared with chronological age to determine whether the dental age correctly or incorrectly identified a validation subject as above or below the 10 year threshold.
*Results:* The probability estimates correctly identified children as above or below on 94% of occasions. Only 2% of the validation group with a chronological age of less than 10 years were assigned to the over 10 year group.
*Conclusions:* This study indicates the very high accuracy of assignment at the 10 year threshold. Further work at other legally important age thresholds is needed to explore the value of this approach to the technique of age estimation.


*"To us, probability is the very guide of life" Cicero (106–43 BC) attributed*

## 1. Introduction

The main purpose and justification for age estimation is to ensure that 'separated children in Europe'[1] receive appropriate care and support. The issue of whether or not a child is either above or below a specific age threshold has most effectively been dealt with by estimating the dental age (DA) of the subject.[2–4] The result of this has been very satisfactory, providing an estimate usually within, or close to, 3 months of the chronological age (CA). An alternative way to approach this issue is to calculate the probability that a subject of unknown date of birth is either above or below a specific age threshold. This concept was first presented in a publication relating to the third molar.[5] It was reported that the presence of a lower left third molar, LL8 stage H, indicated the probability of the subject being aged greater than 18 years was 0.9220 [92.2%] for females, and 0.9010 [90.10%] for males. These are compelling results that support the application of the principle of probability for providing age assignments at a specific threshold. This has been shown using multiple developing teeth in children.[6] Results expressed as probability are easily converted to percentages that are straightforward for non-clinicians to understand. This is particularly important for solicitors, barristers, social workers and the subjects involved.

The use of specific thresholds is important in the UK. Ten years is the age of criminal responsibility,[2] 13 years is the age below which sexual intercourse with a child is deemed to be statutory rape,[3] 16 years is the age below which a child is not legally able to give permission for sexual activity.[4]

* Corresponding author. Tel.: +44 020 7188 4432; fax: +44 020 7188 4415.
*E-mail addresses:* victoria.s.lucas@kcl.ac.uk (V.S. Lucas), graham.j.roberts@kcl.ac.uk (G. Roberts).
[a] The Department of Paediatric Dentistry, The Eastman Dental Hospital, 256 Gray's Inn Road, London, WC1X 8LD, UK.

http://dx.doi.org/10.1016/j.jflm.2014.06.002
1752-928X/

The purpose of this investigation is to explore the potential role of probability estimates in determining whether a child is above or below a specific age. In this study this is the 10 year threshold.

## 2. Materials and methods

The Reference Data Set (RDS) for this study has been established by the DARLInG research group at King's College London.[7] (see Appendix A.) Ethical approval was granted by the NRES Committee South Central – Oxford C/Reference Number 12/SC/0029. All the radiographs used were archive material in Departments of Dental Radiology from London. The validation samples comprised 50 females and 50 males, age range 8–12 years. These were separate from the radiographs comprising the RDS. The validation sample radiographs were examined in random order after the chronological age was masked.

The process of estimating the probability that a subject was below the 10 year threshold is as follows.

i The radiograph of the subject of unknown date of birth is examined. In this study the date of birth is known but masked from the examiner carrying out the TDS assessments and not revealed until the chronological age and dental age are compared. The maturity of the *developing* teeth on the left side and the appropriate corresponding scores are assessed after Demirjian et al. (1973)[8] (Fig. 1 and Table 1). Each of the 16 Tooth Morphology Types on the left side is assigned a letter from A to H.

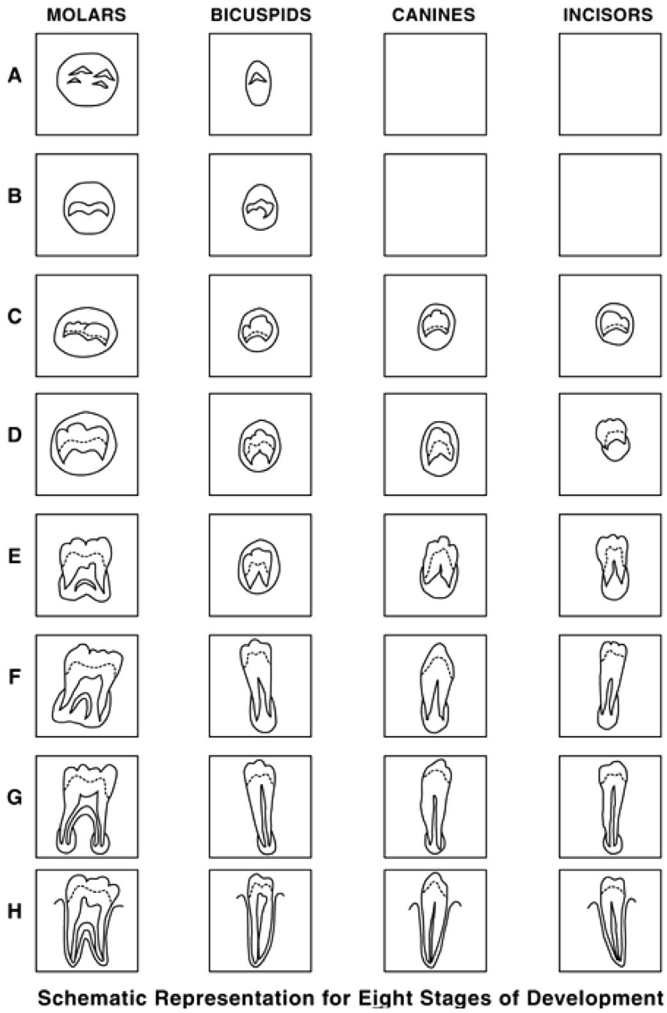


**Fig. 1.** Schematic representation of the Tooth Development Stages after Demirjian.[8]

**Table 1**
Descripitons of Tooth Development Stages by Demirjian et al. (1973).[8]

| Tooth development stage (TDS) | Single multi-rooted teeth [Descriptions] |
|---|---|
| **A** | In both uniradicular and multiradicular teeth, a beginning of calcification is seen at the superior level of the crypt in the form of an inverted cone or cones. There is no fusion of these calcified points |
| **B** | Fusion of the calcified points forms one or several cusps, which unite to give a regularly outlined occlusal surface |
| **C** | a Enamel formation is complete at the occlusal surface. Its extension and convergence toward the cervical region is seen<br>b The beginning of a dentine deposit is seen<br>c The outline of the pulp shape has a curved shape at the occlusal border |
| **D** | a Crown formation is complete down to the cemento-enamel junction<br>b The superior border of the pulp chamber in uniradicular teeth has a definite curved form, being concave towards the cervical region. The projection of the pulp horns, if present, gives an outline like an umbrella top. In molars, the pulp chamber has a trapezoid form<br>c Beginning of root formation is seen in the form of a radiopaque spicule |
| **E** | Uniradicular teeth<br>a The walls of the pulp chamber now form straight lines, whose continuity is broken by the presence of the pulp horn, which is larger than in the previous stage<br>b The root development is still less than the crown<br>Multiradicular teeth<br>a Initial formation of the radicular bifurcation is seen in the form of either a calcified point or a semilunar shape<br>b The root length is still less than the crown height |
| **F** | Uniradicular teeth<br>a The walls of the pulp chamber now form a more or less isosceles triangle. The apex ends in a funnel shape<br>b root development is equal to or greater than the crown<br>Multiradicular teeth<br>a The calcified region of the bifurcation has developed further down from its semilunar stage to give the roots a more definite and distinct outline, with funnel shaped endings<br>b The root length is equal to or greater than the crown height |
| **G** | a The walls of the root canals are now parallel (distal root of molars)<br>b The apical ends of the root canals are still partially open |
| **H** | a The apical end of the root canal is completely closed (distal root in molars)<br>b The periodontal membrane has a uniform width around the root and apex |

The data extracted from the RDS for one subject are shown in the spreadsheet comprising Table 2. This spreadsheet contains in column **I** the data derived in relation to the Tooth Development Stages (TDSs) in Fig. 2. Column **II** shows all the TDSs; there is no data for UL1, UL2, LL2, and LL1 because growth is complete and the root apices are closed. Column **III**, n-tds, shows the number of teeth in the RDS that have attained a given stage. For example, UL3 stage G n-tds is 26 which means that 26 upper left canines have attained stage F and are recorded in the DARLInG database. Column **IV**, x-tds, is the mean age of attainment of the TDS. For example, for the UL3, the mean age of attainment of stage F in the RDS is 9.23 years. Column **V** is the standard deviation. Column **VI** is the standard error which is calculated from Column **III** (n-tds) and Column **V** (sd-tds). Column **VII** is the calculated probability for each of the developing teeth in Column **I**. the probability is calculated using the NORM.DIST function in Microsoft Excel[9] (see Fig. 3).