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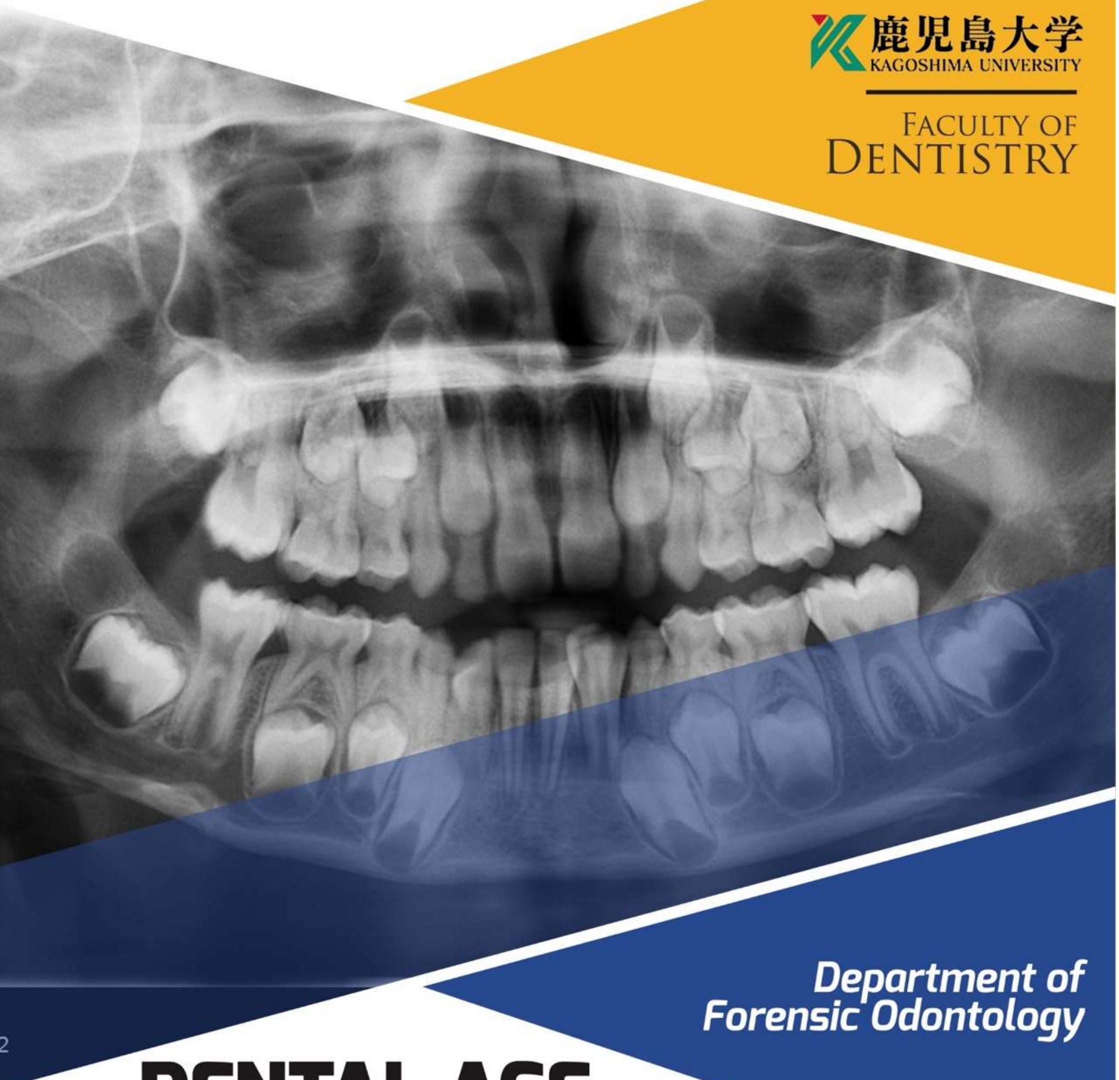
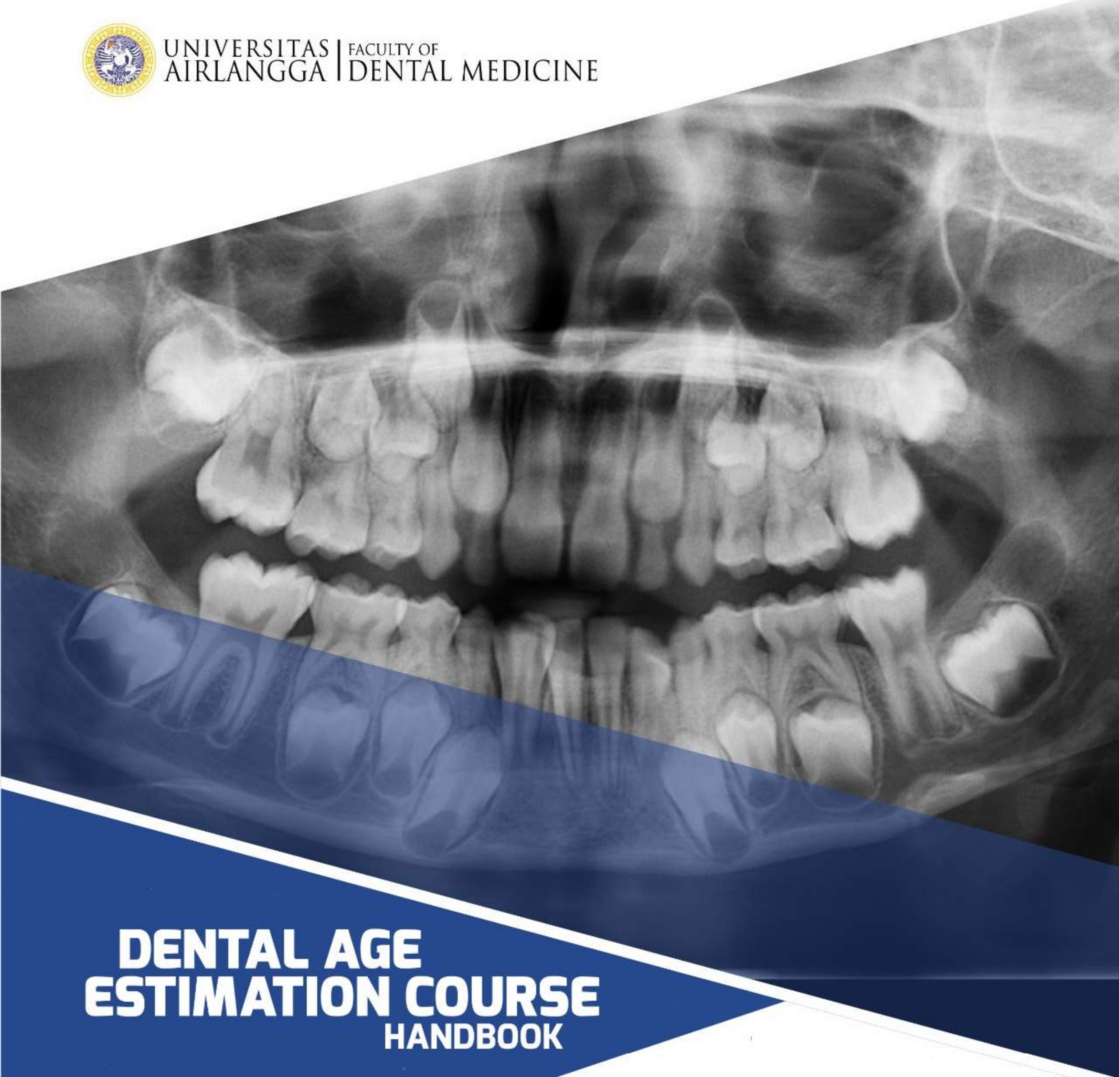


Department of Forensic Odontology

DENTAL AGE ESTIMATION COURSE HANDBOOK

June 20th, 2019

UNIVERSITAS AIRLANGGA | FACULTY OF DENTAL MEDICINE



DENTAL AGE ESTIMATION COURSE
HANDBOOK

CONTRIBUTORS:

PROF. Dr. M. SYLVIA MARGARETHA., drg., Sp. OF (K)
Dr. AGUNG SOSIAWAN, drg., M. Kes.
Dr. HARYONO UTOMO., drg., Sp.Ort
AROFI KURNIAWAN, drg., Ph.D.
AN,NISAA CHUSIDA, drg., M.Kes.
B. SOEGENG HERJADI, drg., MKes.
RIZKY MERDIETIO B., drg., M.ScFOdont.
M. ISTIQOMAH MARINI, drg., M.Si
BETA NOVIA RIZKY, drg

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PREFACE

Glory be to God Almighty for all His blessings that this book is completed. This **Dental Age Estimation Handbook**, serves as a manual to our "Dental Age Estimation Course" for Undergraduate students of Faculty of Dentistry in Kagoshima University, 20th June 2019.

Dental age estimation is one of forensic odontology branch that gives an estimate for a person age, both living and dead. It is an important value for an (future) Odontologist to be able to choose a correct and most accurate method based on its parameters and variables. In the end of the chapter, this book gives an example on how the scientific and statistical sides of forensic odontology can or cannot be applied in the field, especially in mass disaster.

We would like to mention our gratitude to both Dean of Faculty of Dental Medicine, R. Darmawan Setijanto., D.D.S, M.Sc., Ph.D., and Prof. Shouichi Miyawaki, D.D.S., Ph.D., for its support and encouragement. and for all the team that works for writing this book.

We know that this book still has many flaws, and we would love to have a feedback from our reader. We hope that this book will be applied as a reference to do and choose a dental age estimation method for under-graduate students in Kagoshima University.

Surabaya, Mei 2019

Head of Forensic Odontology

Faculty of Dental Medicine Universitas Airlangga

Prof. Dr. Mieke Sylvia M.A.R.,Sp.OF(K)

NIP. 195103151978022001

DENTAL AGE ESTIMATION MODULE HANDBOOK

INTRODUCTION

Age is knowledge, both indispensable and invaluable information for all beings. Age is a measure from birth to a specific time point; it is mostly expressed in years. Combination of age with another form of identity (Name, Nationality, Gender, Date of Birth, etc.) will form a unique combination which can be used in identification. Age can also be a measure of biological and psychological changes.

Attaining specific age information can give information for identification and access to certain rights in Legal Law. Legal law will allow for processing a certain threshold of an age of adultery for administration or penalties for the violation of laws. In a lifetime, age thresholds giving access to certain privileges and to be respected in Legal matters, socioeconomic, cultural, and professional reasons (1).

In Post-Mortem Identification, both ages at death and time of death are essential. The death of a person is officially registered, and a death certificate issued provides information about the identity of the deceased, time, and cause of death. Furthermore, age will close a search gap in a missing person list; and sometimes it can be used for exclusion identification (2). Age information will prove useful in a Mass disaster, especially in an open disaster. In some cases, age will give a victim exclusion for a particular case. Both of these Post-Mortem ages is required for the documents, which will help family members to gain closure and settle the estate.

The age of an individual can be measured or estimated. A measurement of age is a pinpoint value, which can only be obtained in a legal document. Age can be estimated through other methods of measurement, such as biological and social appearance. Human biological age-related variables are observable as it correlates whether it's regressed or progressed in growth. This method of observing a human biological age-related variable will be called an age estimation, due to the nature of the method which will contain a relationship between a parameter and the chosen variable from a sample. This relationship will produce an error rate, which will be expressed as standard deviation (SD). Hence, the results of an age estimation are listed as:

$$y = x \ \pm S.D$$

y is the chosen formula, x is the mean age, and SD is the standard deviation according to the formula chosen in y. The reason for writing this estimated age as listed above is beyond the scope of this workshop.

AGE ESTIMATION IN FORENSICS

Forensics, while it is a close relation to law and closer to science. Age estimation is one of the study branches for forensics. As mentioned above, the legal consequences related to one individual age reaching a certain threshold and whether a body can fall between a specific range of age, making it easier to search in missing person database. INTERPOL suggests that we acquire an age estimation through visual estimation from pathologist and dental related estimation. It is needed that the best practice in identification is achievable. In visual estimation, many factors came at play and made the estimator biased. On the contrary, a method-based estimation using age-related parameter will have a statistical scientific approach. As a Dentist, an age estimation can be found on INTERPOL Chart form 600.

							a	b	c
635	**Specific data**	1 ☐ *Crowns*		2 ☐ *Pontics*		3 ☐ *Implants*			
	01 Specify	4 ☐ *Dentures*		5 ☐ *Other*					
640	**Other findings**	1 ☐ *Occlusion*		2 ☐ *Tooth wear*		3 ☐ *Periodontal status*			
	01 Specify	4 ☐ *Supernumeraries*		5 ☐ *Stains*		6 ☐ *Other*			
645	**Type of dentition**								
	01 Dentition	1 ☐ *Primary dentition*		2 ☐ *Mixed dentition*		3 ☐ *Permanent dentition*			
647	**Estimated age**	*Min*	*Max*	*Min*	*Max*				
	01 Age (Fill either year or month)	________ *year* /	________ *year*	________ *month* /	________ *month*				
650	**Quality check**	*Date:*			*Signature:*				
	FOd 1	*FOd 1 Name:*							
		Date:			*Signature:*				
	FOd 2 (If available)	*FOd 2 Name:*							

Figure 1. Estimated Age on INTERPOL Form 600

DENTAL AGE ESTIMATIONS

In forensics, teeth are a valuable parameter for age estimation. It has proven to have low variability and low external factor exposures (until a certain point). Tissues and tooth growth were used as a base for age estimations, so this approach is widely used both for forensic odontologist and anthropologist. Scientifically, a dental age estimation variable can be obtained from dental growth, tooth morphology, and biochemical changes. Each method will comply with a specific age range. On one human lifetime, each variable will become accurate at some point, and become pointless in the later years. Evaluation of dental age estimation is regarded as an excellent tool for age assessment, due to its strong correlation to age. Age estimation techniques involving these tissues have been widely used in practice and research of forensic odontology.

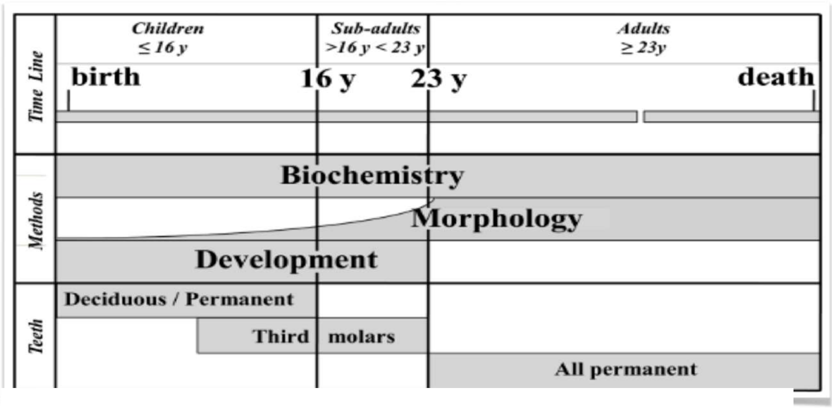

Figure 2. Classification of Age Estimation Methods (Taken from Thevissen; 2013)

TOOTH DEVELOPMENT

Tooth development using the progressive morphological development of the crown, root, and apex of a permanent/deciduous tooth. These combinations of growth, emergence time, and eruption sequence are giving the variable to assess the age. Tooth formation and growth is a noninvasive technique, easily accomplished through radiographic examination. These methods of age estimation are considered most accurate due to combined multiple growth parameters and not prone to an external factor (3). Additionally, these progressive morphological development stays through an interval (staging) and correlation those intervals to chronological age, hence, the researchers have developed dental age estimation techniques (4).

There are multiple systems of age estimations used by a forensic scientist; the most common one is staged (5), atlases (6), tables (3), or diagram (7). It is essential always to be mindful to utilize the appropriate system associated with a given study's data set. As seen in Figure 2, dental development is a maturation process; these techniques use this rational point of view and reserved for cases involving fetuses, infants, children, and sub-adults. These age ranges can also utilize the growth of hand and wrist (8) and clavicle (9). Naturally, as a tooth growth continues, a tooth development will stop growing, and morphological changes should take places for further age estimations.

MORPHOLOGY

Once dental and skeletal growth has ceased, forensic odontologist must use a different approach that involves morphological changes (10). This gross anatomical change is used in observing attrition, periodontal resorption, cementum, apical translucency, and secondary dentine. These methods having (on average) standard deviation of 8 years, compared to tooth development having (on average) 1.5 years deviation. Due to that exemption, morphological changes are used only when it is needed.

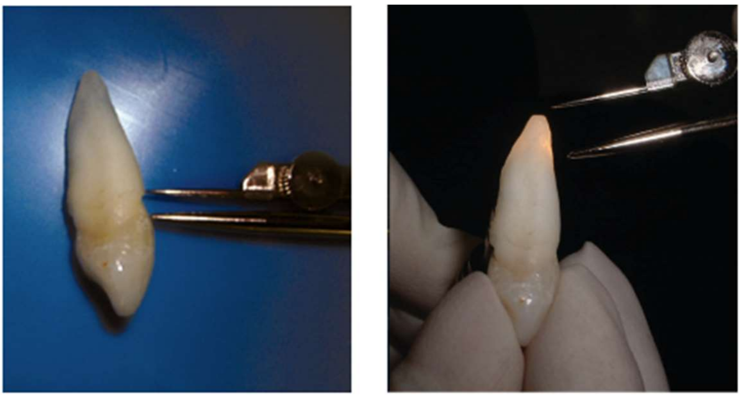

Figure 3. The measurement taken for Lamendin Method (Taken from Senn; 2013)

Although having a high deviation, a morphological dental age estimation can be used both in an invasive or non-invasive way. Invasive techniques will involve a tooth extraction; hence, it cannot be done on a living person. Dalitz (10), Bang & Ramm (11) and Lamendin (12) is a method widely used, especially Bang & Ramm and Lamendin. These methods only use a small number of parameters (1 for Bang & Ramm, 3 for Lamendin) and no sectioning involved. The writer considers this as a method preferably used in a mass disaster situation, which will be covered later.

AGE ESTIMATION FOR CHILDREN

Part I. Demirjian Method
(Adapted from Demirjian, A., A New System of Dental Age Assessment, Human Biology, 45:2, 1973)

The method of Demirjian (13) is useful in estimating the chronological age of children based on their dental age, i.e., of children with unknown birth data which is often true for adopted children or of children committing legal offenses. The advantage of Demirjian`s technique, which is a scoring system based on the use of developmental stages of teeth, is that the predicted dental age is relatively accurate since it is not based on the eruption process of teeth. It is indeed commonly accepted that tooth eruption as an evaluation method for dental age estimation has some limitations since tooth eruption is heavily influenced by environmental factors such as available space in the dental arch, extraction of deciduous predecessors, tipping, or impaction of teeth. Oppositely, the method for dental age estimation using developmental stages of teeth is more useful since environmental factors less influence tooth development.

There are eight stages, A to H, for each tooth together with stage 0 for non-appearance, ranging from the calcification of the tip of a cusp to the closure of the apex. Girls and boys are given different systems of scores. If clinical emergence is used as the criterion for dental age assessment, it can only be applied up to the age of 30 months (completion of the deciduous dentition) and after the age of 6 years (eruption of the first molar). The left side of panoramic radiograph is used to calculate the maturation degree.

Assigning the Stages (Figure 4).

1. The permanent mandibular teeth are rated in the following order: 2nd molar, 1st molar, 2nd bicuspid, 1st bicuspid, canine, lateral incisor, central incisor.
2. All teeth are rated on a scale A to H. The rating is assigned by following the written criteria for each stage carefully, and by comparing the tooth with the diagrams and X-ray pictures given in Figure 1. The illustrations should only be used as an aid, not as the sole source of comparison. For each stage, there are one, two, or three written criteria marked a), b), c). If only one criterion is given this must be met for the stage to be taken as reached; if two criteria are given, then it is sufficient if the first one of them is achieved for the stage to be recorded as reached; if three criteria are given, the first two of them must be met for the stage to be considered reached. At each stage, in addition to the criteria for that stage, the criteria for the previous stage must be satisfied. **In borderline cases, the earlier stage is always assigned**.

3. There is no absolute measurement to be taken. A pair of dividers is sufficient to compare the relative length (crown/root). To determine apex closure stages, no magnifying glass is necessary. The ratings should be made with the naked eye.
4. The crown height is defined as being the maximum distance between the highest tip of the cusps and the cement-enamel junction. When the buccal and lingual cusps are not at the same level, the midpoint between them is considered as the highest point.

Dental Formation Stages

If there is no sign of calcification, the rating 0 is given: The crypt formation is not taken into consideration.

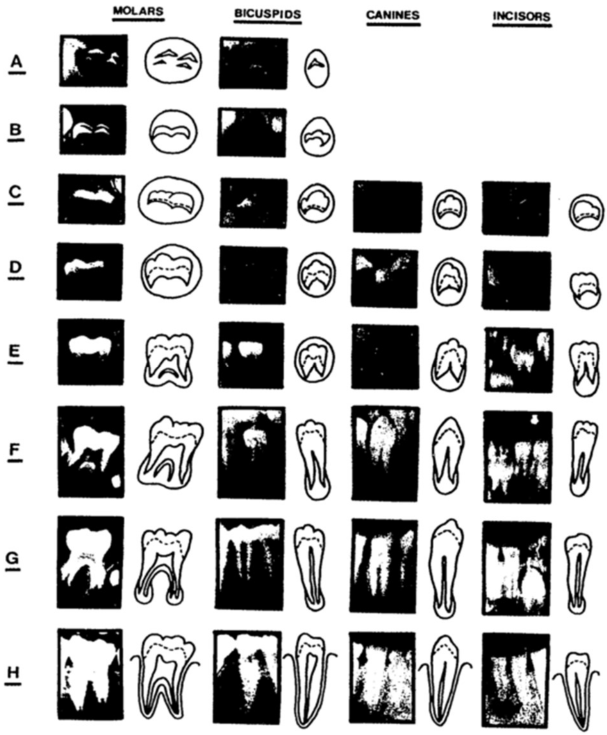

Figure 4. Stage Allocation for Demirjian Method (Taken from Demirjian, 1963)

Stage Description

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 towards the cervical region are seen.

b. The beginning of a dentinal deposit is seen.

c. The outline of the pulp chamber has a curved shape at the occlusal border.

D a. The crown formation is completed down to the cementoenamel junction.

b. The superior border of the pulp chamber in the uniradicular teeth has a definite curved form, being concave towards the cervical region. The projection of the pulp horns if present, gives an outline shaped like an umbrella top. In molars, the pulp chamber has a trapezoidal form.

c. Beginning of root formation is seen in the form of a spicule.

E Uniradicular teeth:

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.

b. The root length is less than the crown height.

Molars:

a. The initial formation of the radicular bifurcation is seen in the form of either a calcified point or a semi-lunar shape.

b. The root length is still less than the crown height.

F Uniradicular teeth:

a. The walls of the pulp chamber now form a more or less isosceles triangle. The apex ends in a funnel shape.

b. The root length is equal to or greater than the crown height.

Molars:

a. The calcified region of the bifurcation has developed further down from its semi-lunar stage to give the roots a more definite and distinct outline with funnel-shaped endings.

b. The root length is equal to or greater than the crown height.

G The walls of the root canal are now parallel and its apical end is still partially open (Distal root in molars).

H a. The distal end of the root canal is completely closed (Distal root in molars).

b. The periodontal membrane has a uniform width around the root and the apex.

Using the Scoring System

1. Each tooth will have a rating, assessed by the procedure described.

2. This is converted into a score using Table 1 (Appendix) for boys or girls as appropriate. For example, if tooth M1 of a boy is in stage E it is given a score 9.7.
3. The scores for all seven teeth are added together to give the *maturity score*

The maturity score may be converted directly into a dental age either by reading off on the horizontal scale the age at which the 50th centile attains that maturity score value, or by using Table 2 (Appendix) which has been constructed by this means. Thus, a score of 45 for a boy is equivalent to the dental age of 6.9 years.

AGE ESTIMATION FOR CHILDREN

Part II : Willems "Demirjian`s Technique Revisited"
(Adapted from Willems et al. Dental Age Estimation in Belgian Children: Demirjian`s Technique Revisited, Journal of Forensic Sciences, 46:4, 2001)

Willems stated that Demirjian`s method resulted in a consistent overestimation of the dental age for the first Belgian Caucasian sample, amounting to a median of 0.5 years for boys (mean: 0.4; standard deviation: 1.0) and a median of 0.6 years for girls (mean: 0.7; s.d: 1.0) (5). For almost each of 13 age classes of this sample a significant difference was found between the chronological age and the estimated dental age. The most serious overestimations were found in the age class of 9 to 10 years for boys and girls as well as 10 to 11 years for girls.

Demirjian`s stages (Figure 4) are taken and scoring was adapted using a weighted ANOVA on the data of the Belgian Caucasian sample. The result is a higher accuracy scoring and more straightforward to use a method. Firstly, the tooth needs to be staged in Demirjian staging. Secondly, stages were converted to age scoring system (Table 3, Appendix). Finally, the sum taken from Table 3 was the age estimation accompanied by the standard deviation mentioned in the paper.

AGE ESTIMATION FOR CHILDREN AND SUB ADULTS

Part III. Moorrees Method
(Adapted from Moorrees CFA, Fanning EA, Hunt EE. Age Variation of Formation Stages for Ten Permanent Teeth. J Dent Res 1963;42(6):1490–502)

A thorough examination on teeth correlation on physiological ages had been researched by Moorrees et al (3). Using 134 Children (48 M and 51 F), tooth radiograph was examined. Dental age estimation was derived from assigning the corresponding tooth radiograph images to a stage made by Moorrees, it was divided into single rooted teeth and multiple rooted teeth. Similar to Gustafson and Koch (14), this method can be used in single tooth evidence. Although due to its thorough stages (15), this method applies higher dental staging accuracy. Dental stages are coded and divided into 13 and 14 stages for single rooted and multi-rooted teeth, each with its own distinction (Figure 5, Table 1).

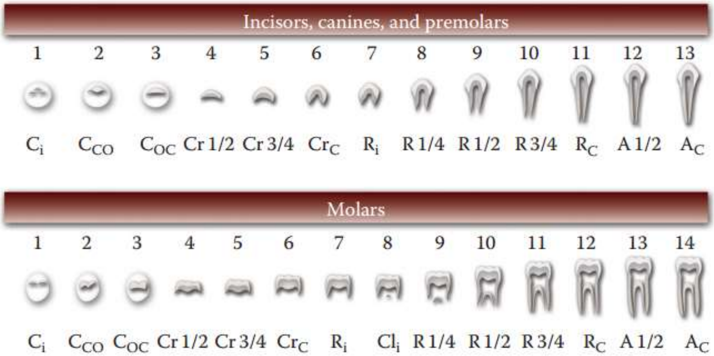

Figure 5. Staging allocation for Moorrees Method (Taken from Senn; 2013)

Single Rooted Teeth Stages		Descriptors	Multirooted Teeth Stages	
C_i	1	Initial cusp formation: Mineralization of cusp tips has begun	C_i	1
C_{CO}	2	Coalescence of cusps: Mineralization centers are beginning to unite	C_{CO}	2
C_{OC}	3	Mineralized cusp outline is complete	C_{OC}	3
Cr 1/2	4	1/2 of estimated crown mineralization is complete	Cr 1/2	4
Cr 3/4	5	3/4 of estimated crown mineralization is complete	Cr 3/4	5
Cr_C	6	Crown mineralization complete; but, root formation has not begun	Cr_C	6
R_i	7	Initial root formation	R_i	7
—	—	Initial cleft formation: Mineralization visible in inter-radicular area	Cl_i	8
R 1/4	8	1/4 of estimated root formation is complete	R 1/4	9
R 1/2	9	1/2 of estimated crown mineralization is complete	R 1/2	10
R 3/4	10	3/4 of estimated crown mineralization is complete	R 3/4	11
R_C	11	Root length complete: Apex remains funnel shaped	R_C	12
A 1/2	12	Apex is 1/2 closed: Root walls are parallel	A 1/2	13
A_C	13	Apical closure is complete	A_C	14

Source: Data modified from Moorrees, C.F.A. et al., *J. Dent. Res.*, 42, 1490, 1963b.

Table 1. Stage Description from Moorrees Staging (Taken from Senn, 2013)

Moorrees dental stages start from the initial formation of the cusp until the root completion. Stage assigned then will be converted to an age estimation complete with its standard deviation (Appendix, Table 5-6). This method can be used for maxillary incisor teeth and all mandibular teeth (including the third molar). Opposite to Demirjian advice on stage confusion, Moorrees allows the method to be averaged **in the same tooth if the assigned tooth is in between a certain stage**.

AGE ESTIMATION FOR CHILDREN AND SUB ADULTS

Part IV. Al-Qahtani Method
(Adapted from AlQahtani, et al., Brief Communication: The London Atlas of Human Tooth Development and Eruption, American Journal of Physical Anthropology, 142: 481-490, 2010)

Atlas is a method of age estimation done through a simple pattern matching and mostly done through radiographic images (16). Al-Qahtani atlas (Figure 1, Appendix)used the modified Moorrees staging (3), and observation was done through the radiographic viewer in 72 post-natal and 104 pre-natal skeletal remains (6). The result was a tooth developmental atlas functional to estimate dental age from 30 weeks in-utero to 23 years old. Both tooth developmental stages in permanent teeth and third molar were illustrated as radiographic representations and clarified by the addition of written descriptions, including the standard deviation (written as midpoint).

AGE ESTIMATION FOR SUB ADULTS

Part V. Gunst and Mesotten Method

(Adapted from Gunst K, Mesotten K, Carbonez A, Willems G. Third molar root development concerning chronological age: A large sample sized retrospective study. Forensic Sci Int 2003;136(1–3):52–7)

Gunst et al. (2003) use large sample involving orthopantomograms of 2513 Belgian Caucasian individuals (1055 males and 1458 females) with known age and gender (17). Gunst main goal was to produce an accurate age estimation using four third molar, which was the only dental age estimation parameter available in the subadults (16-23 years old). OPG radiographs meeting these selection criteria were evaluated using a 10-stage developmental scoring method, as was proposed by Kohler et al. (18). Each of the ten stages relates to a particular developmental phase, as is illustrated in Figure 6. All of the third molars present on the radiograph were given a score corresponding to the stage of root development. In the case of a different developmental stage of the multiple roots of a one-third molar, the least developed root was evaluated and scored based on the stage representation.

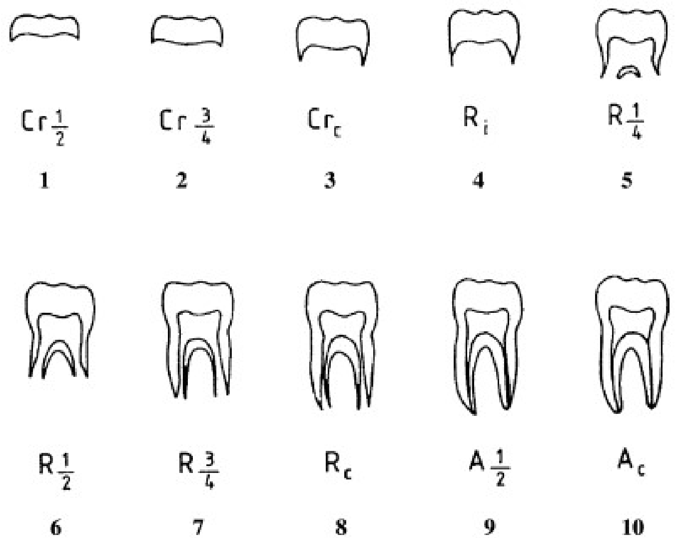

Figure 5. Kohler staging allocation for Gunst Method (Taken from Gunst, 2013)

Subsequently, the assigned stage was calculated using the formula available in Appendix Table 7**.** By choosing the amount of third molar available (n) and which third molar available (UL = Upper Left, UR = Upper right, LR = Lower right, LL = Lower left), the outcome is an estimated age with their respective standard deviation. Gunst's method can also be used to determine whether a subject is over or under 18 years old (Appendix table 8) this proven useful in a court case or an asylum seeker in juveniles. The problem persists in the method where multicollinearity is present; the author suggests in the formula table (Appendix Table 8) that one third molar may have the same information with a particular third molar, making the information gathered from 4 teeth sometimes will have the same outcome as with the three teeth.

DENTAL AGE ESTIMATIONS; ADAPTING TO MASS DISASTERS

Taken from **Palu Earthquake and Tsunami Victim Identification; Forensic Odontologist Perspective (Boedi; 2018)**

In forensic odontology, the uniqueness of human dentitions is the basis of the identification process of the victims. As mentioned in the chapter before, there are multiple approaches on age estimation and it is important to be mindful about the subject and the situations.

On September 28th, 2018, earthquake hits Central Celebes (7.4 Magnitude), located in 26km North of Donggala triggering a tsunami, liquefaction, and landslide. Approximately 2.256 victims and 1.309 remain missing. The dry tropical climate in Palu made tissue decayed quickly and combined with seawater exposure, bodies enter a putrefaction state quicker, and visual identification was not possible. In this matter, odontological aspects are essential.

Figure 6. Anterior upper maxillary with ABFO No. 2 Scale

Biological age is measured through growth and maturational milestones in a different biological system as the skeleton, dentition or soft tissues. (19) Teeth do survive inhumation well, which helps in identifying decayed victims and show less variability than skeletal age. (6) Age estimation is great importance for the identification of victims for closing age search range and giving a scientifically proven age estimation method rather than just a visual age identification. Anyhow, dental age estimation based scientifically proven parameters and calculations are mandatory, and not based on an assumption.

Dental age estimation differs from between children, sub-adults, and adults. In children and sub-adults, tooth development is more reliable than other developmental parameters available for age estimation up until it reached fully developed dentition. (20) This method typically employs a method described by the researcher to register the observed status development and convert it to age estimation in a different way. After reaching a fully developed dentition in adult age, parameter for age estimation changes to forms of tooth morphology changes including attrition, transparency of root, tooth cementum annulation, and apposition of secondary dentine. (21)

Radiological evidence and measurement are invaluable during identification both for dental charting and age estimation. Staging systems and ratio measurement methods needs radiograph images to be taken, and under these circumstances, radiographic images are not possible to be made due to the number of bodies. Morphological methods considered was taking time to prepare, teeth need to be sectioned labio-lingually for Dalitz and Johanson method. (10,21) Due to these limitations and reducing time consumption taken for each body, many age estimation methods are not feasible.

Tooth eruption is a parameter of tooth development which, unlike tooth mineralization, can be determined in two ways: by clinical examination or by evaluation of dental radiographs. (22) Clinical observation of tooth eruption with AlQahtani London Atlas was used. (6) AlQahtani (2014) reported that AlQahtani

Atlas (2010) shows excellent reproducibility compared to Schour and Massler (23) and Ubelaker, (24) Kappa values were 0.879, 0.838, and 0.857, respectively. (16) London Atlas considered being a valid tool for age estimation in a victim with multiple missing teeth, (19), which is found numerous times in the victim. Age estimation was made in both children and sub-adult age estimation on eruption timing.

Al-Qahtani (2010) stated that the London Atlas was using alveolar eruption. (6) Determining a tooth eruption parameter problem be consistent, which is an eruption is made if penetrating the alveolar or penetrating the gingiva due to decomposition variability in victims' body. The examination was mixed between gingival eruption (if the soft tissue still exists) or alveolar eruption (if the soft tissue was already decomposed). This alveolar eruption problem can be easily avoided with a radiological image which cannot be taken. Until this article is written, the year timing difference between the gingival and alveolar eruption were not yet researched.

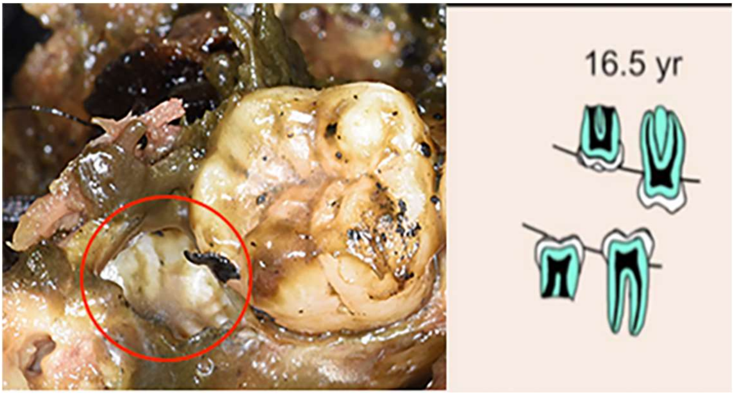

Figure 7. Lower right third molar in clinical eruption with alveolar eruption due to gingiva already decayed (red circle, left) shows a match with AlQahtani (2010) Atlas (right). Age estimation result was 16.5±1year old.

In sub-adult, the third molar clinical eruption was used (figure 3). AlQahtani (2010) gives data on his Atlas about third molar development. Third molar development was the only teeth in development in sub-adult. (17) Levesque et al. (1981) examined clinical eruption pattern and sexual dimorphism in mandibular third molar development between 4640 panoramic radiographs using Demirjian staging. (20,25) It was reported that mean year of alveolar emergence in the male is 17.2 years old and 17.7 years old in a female, (25), and compared to AlQahtani (2010) Atlas, alveolar emergence is between 16.5 and 17.5 years old. The third molar played an essential role for age estimation in sub-adult after all tooth is thoroughly developed, and age estimation in sub-adult victims can be made. (26)

In adult, most of the methods considered were not feasible due to tooth preparation time and limited tools. (10,21) Transparency of the root value can be taken prepared and unprepared from apical parts, which are visible through light exposure both (figure 4). Transparency increases with age and not related to pathologic conditions or treatment. (14) The method used for age estimation measuring the transparency of the root is simple and could be quickly done without extensive training. (11) Bang and Ramm (1970) presented an age estimation based on the length of transparency of the root in millimeters. They are differentiated through different teeth position and how the teeth are prepared. Based on a large sample, the authors were able to present a second-degree polynomial regression:

$$\text{Age} = B_0 + (B_1 * X) + (B_2 * X^2) \qquad (1)$$

It was further differentiated based on the total transparency of the root length. For total length smaller than or equal to 9mm, equation (1) was used. For total length larger than 9mm, a first-degree polynomial regression formula in equation (2) was used. Regression constant and the regression coefficients used are referred to Bang and Ramm (1970). (11)

$$\text{Age} = B_0 + (B_1 * X) \qquad (2)$$

The regression model was tested on 24 known-age individuals (168 intact teeth) ranging in age from 26.0 to 85.9 years and have shown similar or better results, (27) from 24 individuals, 14 (58.3%) fell within the theoretical 35% confidence interval (CI). (±4.2 to ±4.7 year(6)); 19 (79.2%) fell within the theoretical 65% C.I (±9.2 to ±10.5years); and 22 (91.7%) fell within the theoretical 95% C.I (±18.6 years to ±21.0 years). The average deviation was 6.47 years, with 19 estimated within ten years of known age and 14 estimated within five years of known age when compared to other methods. (27)(28) This method helps in making the age estimation fast and still scientifically acceptable. Care has to be taken to measure the value to the total length of the translucent zone presence, and boundaries between opaque and translucent dentine were irregular, making the evaluation more or less subjective. (27,29). Transparency of the root was taken using ABFO No.2 scale, analog measurement of root transparency length is keeping the methods established before digital processing software became widespread. (11,12).

Figure 6. Transparency of the root was seen on maxillary first incisor

Another age estimation method that is preferable to use is dental attrition. As researched from Lovejoy (1985), it used a large sample of 332 adult dentitions from Libben Population. (30) This method was used as an age estimation parameter, although it depends on sample populations and age group. Distinguishing children, sub-adult and adult using dental attrition is valid, and it is unreliable to distinguish an adult age 30-year-old from a 40-year-old individual, attrition is no more reliable than suture closure. (30) Dental attrition also affected by many external factors. Bartlett et al. (2011) studied its relationship with dietary habit and tooth wear was statistically significant to dietary habits, which is highly varied in every population. (31) Seligman et al. (1988) studied the prevalence of multiple factors associated with dental attrition. It was reported that attrition scores did not differ significantly between age groups (Males $p<0.06$ and females $p<0.07$), another factor such as gender (Men had higher attrition score than women, $p <0.01$), and molar relation ($p<0.05$ for class II and class III angle). (32) This made an age estimation method from dental attrition was considered not feasible in dental age estimation for Palu victims.

In conclusion, a dental age estimation with a single variable to determine an estimated age from tooth is preferable in a Mass disaster situation. Although it is depending to the corresponding country involved, started from their forensic expert experience, technological advancement in both AM and PM data storage, and their respond to the disaster itself.

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APPENDIX

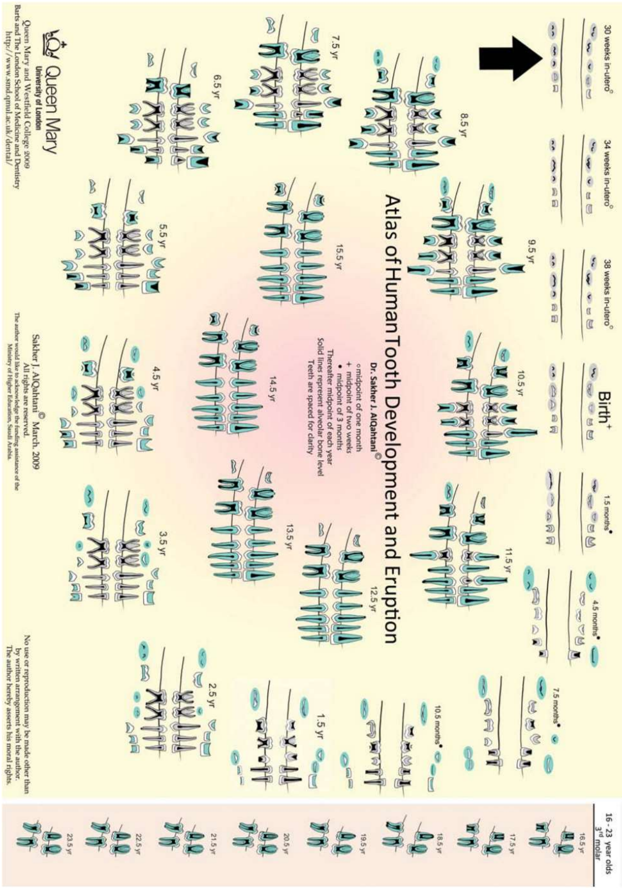

Figure 1. Atlas of Human Tooth Development and Eruption by Al-Qahtani. The Arrow Indicates the Starting Point. The Dentine are Presented in Gray for Deciduous Teeth and in Green for Permanent.

Self-Weighted Scores for Dental Stages
7 Teeth (Mandibular Left Side)

Boys									
	Stage								
Tooth	0	A	B	C	D	E	F	G	H
M_2	0.0	2.1	3.5	5.9	10.1	12.5	13.2	13.6	15.4
M_1				0.0	8.0	9.6	12.3	17.0	19.3
PM_2	0.0	1.7	3.1	5.4	9.7	12.0	12.8	13.2	14.4
PM_1			0.0	3.4	7.0	11.0	12.3	12.7	13.5
C				0.0	3.5	7.9	10.0	11.0	11.9
I_2				0.0	3.2	5.2	7.8	11.7	13.7
I_1					0.0	1.9	4.1	8.2	11.8

Girls									
	Stage								
Tooth	0	A	B	C	D	E	F	G	H
M_2	0.0	2.7	3.9	6.9	11.1	13.5	14.2	14.5	15.6
M_1				0.0	4.5	6.2	9.0	14.0	16.2
PM_2	0.0	1.8	3.4	6.5	10.6	12.7	13.5	13.8	14.6
PM_1			0.0	3.7	7.5	11.8	13.1	13.4	14.1
C				0.0	3.8	7.3	10.3	11.6	12.4
I_2				0.0	3.2	5.6	8.0	12.2	14.2
I_1					0.0	2.4	5.1	9.3	12.9

NB: Stage 0 is no calcification

Table 1. Demirjian Scoring System for Boys and Girls

Conversion of Maturity Score to Dental Age (7 Teeth)

Age	Score	Age	Score	Age	Score	Age	Score
			Boys				
3.0	12.4	7.0	46.7	11.0	92.0	15.0	97.6
.1	12.9	.1	48.3	.1	92.2	.1	97.7
.2	13.5	.2	50.0	.2	92.5	.2	97.8
.3	14.0	.3	52.0	.3	92.7	.3	97.8
.4	14.5	.4	54.3	.4	92.9	.4	97.9
.5	15.0	.5	56.8	.5	93.1	.5	98.0
.6	15.6	.6	59.6	.6	93.3	.6	98.1
.7	16.2	.7	62.5	.7	93.5	.7	98.2
.8	17.0	.8	66.0	.8	93.7	.8	98.2
.9	17.6	.9	69.0	.9	93.9	.9	98.3
4.0	18.2	8.0	71.6	12.0	94.0	16.0	98.4
.1	18.9	.1	73.5	.1	94.2		
.2	19.7	.2	75.1	.2	94.4		
.3	20.4	.3	76.4	.3	94.5		
.4	21.0	.4	77.7	.4	94.6		
.5	21.7	.5	79.0	.5	94.8		
.6	22.4	.6	80.2	.6	95.0		
.7	23.1	.7	81.2	.7	95.1		
.8	23.8	.8	82.0	.8	95.2		
.9	24.6	.9	82.8	.9	95.4		
5.0	25.4	9.0	83.6	13.0	95.6		
.1	26.2	.1	84.3	.1	95.7		
.2	27.0	.2	85.0	.2	95.8		
.3	27.8	.3	85.6	.3	95.9		
.4	28.6	.4	86.2	.4	96.0		
.5	29.5	.5	86.7	.5	96.1		
.6	30.3	.6	87.2	.6	96.2		
.7	31.1	.7	87.7	.7	96.3		
.8	31.8	.8	88.2	.8	96.4		
.9	32.6	.9	88.6	.9	96.5		
6.0	33.6	10.0	89.0	14.0	96.6		
.1	34.7	.1	89.3	.1	96.7		
.2	35.8	.2	89.7	.2	96.8		
.3	36.9	.3	90.0	.3	96.9		
.4	38.0	.4	90.3	.4	97.0		
.5	39.2	.5	90.6	.5	97.1		
.6	40.6	.6	91.0	.6	97.2		
.7	42.0	.7	91.3	.7	97.3		
.8	43.6	.8	91.6	.8	97.4		
.9	45.1	.9	91.8	.9	97.5		

Table 2. Demirjian Scoring Conversion System for Boys

Conversion of Maturity Score to Dental Age 7 Teeth (Mandibular Left Side)

Age	Score	Age	Score	Age	Score	Age	Score
			Girls				
3.0	13.7	7.0	51.0	11.0	94.5	15.0	99.2
.1	14.4	.1	52.9	.1	94.7	.1	99.3
.2	15.1	.2	55.5	.2	94.9	.2	99.4
.3	15.8	.3	57.8	.3	95.1	.3	99.4
.4	16.6	.4	61.0	.4	95.3	.4	99.5
.5	17.3	.5	65.0	.5	95.4	.5	99.6
.6	18.0	.6	68.0	.6	95.6	.6	99.6
.7	18.8	.7	71.8	.7	95.8	.7	99.7
.8	19.5	.8	75.0	.8	96.0	.8	99.8
.9	20.3	.9	77.0	.9	96.2	.9	99.9
4.0	21.0	8.0	78.8	12.0	96.3	16.0	100.0
.1	21.8	.1	80.2	.1	96.4		
.2	22.5	.2	81.2	.2	96.5		
.3	23.2	.3	82.2	.3	96.6		
.4	24.0	.4	83.1	.4	96.7		
.5	24.8	.5	84.0	.5	96.8		
.6	25.6	.6	84.8	.6	96.9		
.7	26.4	.7	85.3	.7	97.0		
.8	27.2	.8	86.1	.8	97.1		
.9	28.0	.9	86.7	.9	97.2		
5.0	28.9	9.0	87.2	13.0	97.3		
.1	29.7	.1	87.8	.1	97.4		
.2	30.5	.2	88.3	.2	97.5		
.3	31.3	.3	88.8	.3	97.6		
.4	32.1	.4	89.3	.4	97.7		
.5	33.0	.5	89.8	.5	97.8		
.6	34.0	.6	90.2	.6	98.0		
.7	35.0	.7	90.7	.7	98.1		
.8	36.0	.8	91.1	.8	98.2		
.9	37.0	.9	91.4	.9	98.3		
6.0	38.0	10.0	91.8	14.0	98.3		
.1	39.1	.1	92.1	.1	98.4		
.2	40.2	.2	92.3	.2	98.5		
.3	41.3	.3	92.6	.3	98.6		
.4	42.5	.4	92.9	.4	98.7		
.5	43.9	.5	93.2	.5	98.8		
.6	45.2	.6	93.5	.6	98.9		
.7	46.7	.7	93.7	.7	99.0		
.8	48.0	.8	94.0	.8	99.1		
.9	49.5	.9	94.2	.9	99.1		

Table 3. Demirjian Scoring System for Girls

Tooth	A	B	C	D	E	F	G	H
Central incisor	...	...	1.68	1.49	1.5	1.86	2.07	2.19
Lateral incisor	...	...	0.55	0.63	0.74	1.08	1.32	1.64
Canine	...	...	...	0.04	0.31	0.47	1.09	1.9
First bicuspid	0.15	0.56	0.75	1.11	1.48	2.03	2.43	2.83
Second bicuspid	0.08	0.05	0.12	0.27	0.33	0.45	0.4	1.15
First molar	...	...	...	0.69	1.14	1.6	1.95	2.15
Second molar	0.18	0.48	0.71	0.8	1.31	2	2.48	4.17

Table 4. Weighted Anova System by Willems et al. for Demirjian Staging for Boys

Tooth	A	B	C	D	E	F	G	H
Central incisor	...	...	1.83	2.19	2.34	2.82	3.19	3.14
Lateral incisor	...	...	...	0.29	0.32	0.49	0.79	0.7
Canine	...	...	0.6	0.54	0.62	1.08	1.72	2
First bicuspid	−0.95	−0.15	0.16	0.41	0.6	1.27	1.58	2.19
Second bicuspid	−0.19	0.01	0.27	0.17	0.35	0.35	0.55	1.51
First molar	...	...	...	0.62	0.9	1.56	1.82	2.21
Second molar	0.14	0.11	0.21	0.32	0.66	1.28	2.09	4.04

Table 5. Weighted Anova System by Willems et al. for Demirjian Staging for Boys

Table 5. Stage to Dental Age conversion for Moorees Method for Girls

	Girls																			
	Maxillary Incisors				Mandibular Incisors				Mandibular Posterior Teeth											
	UI1		UI2		LI1		LI2		C		P1		P2		M1		M2		M3	
Stage	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
C_i									0.5	0.12	1.7	0.24	2.9	0.35	0.1	0.05	3.5	0.41	9.6	1.00
C_{CO}									0.7	0.15	2.2	0.28	3.5	0.40	0.2	0.09	3.8	0.43	10.1	1.05
C_{OC}									1.2	0.18	2.9	0.35	4.1	0.47	0.7	0.14	4.3	0.49	10.7	1.11
Cr 1/2									1.9	0.25	3.5	0.41	4.7	0.53	1.0	0.17	4.8	0.54	11.3	1.17
Cr 3/4									2.9	0.35	4.2	0.49	5.3	0.59	1.4	0.20	5.4	0.59	11.7	1.20
Cr_C	4.9	0.54	5.7	0.62					3.9	0.45	5.0	0.56	6.2	0.66	2.2	0.28	6.2	0.68	12.3	1.27
R_i									4.7	0.52	5.7	0.63	6.7	0.73	2.6	0.32	7.0	0.75	12.9	1.32
Cl_i															3.5	0.41	7.8	0.83	13.5	1.39
R 1/4	6.0	0.66	6.6	0.71	4.5	0.51	4.7	0.53	5.3	0.57	6.5	0.69	7.5	0.79	4.6	0.52	9.1	0.96	14.9	1.53
R 1/2	6.6	0.71	7.2	0.76	5.1	0.57	5.9	0.65	7.1	0.75	8.1	0.86	8.7	0.92	5.1	0.57	9.8	1.01	15.8	1.62
R 2/3	7.1	0.76	7.7	0.82	5.6	0.62	6.3	0.68												
R 3/4	7.6	0.81	8.3	0.87	6.1	0.66	6.7	0.72	8.3	0.88	8.8	0.97	10.0	1.05	5.5	0.60	10.5	1.09	16.4	1.67
R_C	8.2	0.86	9.1		6.6	0.72	7.6	0.80	8.8	0.93	9.9	1.03	10.6	1.12	5.9	0.63	11.0	1.13	17.0	1.71
A 1/2	8.9	0.93	9.6	0.99	7.4	0.79	8.1	0.86	9.9	1.03	11.0	1.15	12.0	1.24	6.5	0.71	12.0	1.23	18.0	1.82
A_C					7.7	0.82	8.5	0.89	11.3	1.18	12.1	1.26	13.6	1.40	8.0	0.85	13.8	1.43	20.1	2.01

Source: Data adapted from Harris, E.G. and Buck, A., *Dent. Anthropol.*, 16, 15, 2002.

Table 6. Stage to Dental Age conversion for Moorees Method for Boys

	Boys																			
	Maxillary Incisors				Mandibular Incisors				Mandibular Posterior Teeth											
	UI1		UI2		LI1		LI2		C		P1		P2		M1		M2		M3	
Stage	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
C_i									0.5	0.11	1.8	0.24	3.0	0.37	0.0	0.09	3.7	0.41	9.2	0.98
C_{CO}									0.8	0.15	2.3	0.31	3.5	0.42	0.2	0.11	4.0	0.43	9.7	1.01
C_{OC}									1.2	0.19	2.9	0.36	4.2	0.48	0.5	0.11	4.8	0.49	10.3	1.07
Cr 1/2									2.1	0.27	3.6	0.43	4.7	0.53	1.0	0.17	5.1	0.54	10.9	1.14
Cr 3/4									2.9	0.35	4.4	0.52	5.3	0.59	1.5	0.21	5.7	0.59	11.6	1.20
Cr_C	5.3	0.59	5.9	0.64					4.0	0.46	5.2	0.58	6.2	0.69	2.1	0.29	6.5	0.68	12.0	1.24
R_i									4.8	0.55	5.8	0.64	6.9	0.74	2.7	0.34	7.1	0.75	12.7	1.32
Cl_i															3.5	0.41	8.1	0.83	13.6	1.41
R 1/4	6.3	0.68	6.9	0.75			5.3	0.60	5.7	0.63	6.8	0.74	7.8	0.83	4.7	0.53	9.3	0.96	14.6	1.50
R 1/2	6.9	0.74	7.6	0.80	5.2	0.59	6.2	0.68	8.0	0.86	8.5	0.91	9.4	0.99	5.1	0.57	10.1	1.01	15.1	1.54
R 2/3	7.6	0.80	8.1	0.86	5.8	0.64	6.8	0.74												
R 3/4	8.1	0.85	8.7	0.91	6.4	0.70	7.4	0.78	9.6	1.00	9.9	1.04	10.8	1.13	5.4	0.61	10.8	1.09	15.9	1.62
R_C	8.6	0.90	9.6	1.01	7.0	0.75	8.0	0.84	10.2	1.06	10.3	1.09	11.5	1.21	5.8	0.64	11.3	1.13	16.3	1.67
A 1/2					7.7	0.81	8.5	0.90	11.8	1.23	11.9	1.24	12.7	1.30	6.9	0.75	12.2	1.23	17.6	1.79
A_C					8.1	0.85	9.3	0.98	13.0	1.35	13.3	1.38	14.2	1.46	8.5	0.91	14.2	1.43	19.2	1.95

Source: Data adapted from Harris, E.G. and Buck, A., *Dent. Anthropol.*, 16, 15, 2002.

n	TM present	R^2	Regression formulae	S.D.
Male				
1	UR/UL/LR/LL		Too few numbers of observations	
2	UR*–UL(*)	0.41	13.9911 + 0.6895 UR	1.48
	UR(*)–UL	0.40	14.2486 + 0.6595 UL	1.50
	UR–LL/UR–LR/UL–LR		Too few numbers of observations	
	UL(*)–LL*	0.49	12.2999 + 0.8765 LL	1.22
	LL**–LR	0.41	14.8622 + 0.5823 LR	1.34
3	UR(*)–UL*–LL**	0.37	13.3882 + 0.7466 UL	1.40
	UR*–UL(*)–LL**	0.36	13.5689 + 0.7201 UR	1.41
	UR*–UL(*)–LR	0.56	12.2212 + 0.6032 UR + 0.3132 LR	1.26
	UR**–LR(*)–LL*	0.62	12.2915 + 0.8849 LL	1.37
	UR**–LL(*)–LR*	0.61	12.3395 + 0.8791 LR	1.39
	UL*–LL(*)–LR**	0.61	13.0453 + 0.7832 UL	1.16
	UL*–LL**–LR(*)	0.61	13.0453 + 0.7832 UL	1.16
4	UR(*)–UL*–LR**–LL*	0.45	11.5886 + 0.4493 UL + 0.4525 LL	1.49
	UR*–UL(*)–LR**–LL*	0.45	11.5419 + 0.4426 UR + 0.4651 LR	1.49
Female				
1	UR	0.27	16.0204 + 0.4957 UR	1.97
	UL	0.43	15.5403 + 0.5640 UL	1.37
	LL	0.61	15.0536 + 0.6494 LL	1.19
	LR		Too few numbers of observations	
2	UR(*)–UL*	0.53	13.9365 + 0.7031 UL	1.46
	UR*–UL(*)	0.48	13.9392 + 0.6979 UR	1.54
	UR–LL/UR–LR		Too few numbers of observations	
	UL–LR/UL–LL		Too few numbers of observations	
	LL(*)–LR*	0.37	15.4518 + 0.5451 LR	1.31
	LL*–LR(*)	0.36	15.3779 + 0.5529 LL	1.32
3	UR*–UL(*)–LL**	0.29	15.9468 + 0.4912 UR	1.33
	UR(*)–UL*–LL**	0.28	16.0947 + 0.4732 UL	1.34
	UR(*)–UL**–LR*	0.31	16.0558 + 0.5026 LR	1.61
	UR**–UL(*)–LR*	0.31	16.0558 + 0.5026 LR	1.61
	UR**–LL(*)–LR*	0.33	13.7186 + 0.7335 LR	1.64
	UR–LL**–LR*	0.29	13.8418 + 0.7086 UR	1.68
	UL**–LR(*)–LL*	0.42	13.8227 + 0.6928 LL	1.33
	UL**–LR*–LL(*)	0.34	14.2609 + 0.6314 LR	1.42
4	UR(*)–UL*–LL**–LR	0.42	13.0484 + 0.3056 UL + 0.4736 LR	1.51
	UR*–UL(*)–LR–LL**	0.42	13.0725 + 0.4773 LR + 0.3010 UR	1.50

Table 7. Regression formula for males and females based on the number of present wisdom tooth (n) and respective location. TM present: third molar present; R^2: root square; S.D.: standard deviation. *: These teeth may not be used in the same model because of multicollinearity. (*): These teeth may not be used in the same model because of multicollinearity and therefore this tooth is omitted. **: No significant contribution to the regression model and thus omitted. UR = Upper Right | UL = Upper Left | LR = Lower Right | LL = Lower Left

	Male	Female
UR = 10	82	87.3
UL = 10	82.6	87.2
LL = 10	94.8	94.5
LR = 10	96.4	93.1
UR + LL = 10	82.7	88.2
LR + LL = 10	96.6	94.0
UR + UL + LL + LR = 10	96.3	95.1

Table 8. Probability for an individual to be older than 18 years in case of full third molar development.

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