J Forensic Sci, Mar. 2003, Vol. 48, No. 2
Paper ID JFS2002274_482
Available online at: www.astm.org

Marjatta Nyström,[1] Ph.D., D.D.S. and Helena Ranta,[2] Ph.D., D.D.S.

Tooth Formation and the Mandibular Symphysis During the First Five Postnatal Months

ABSTRACT: Schedules based on tooth development are useful in age assessments of children, but in early infancy they are based on only a few studies. The radiographic appearance of the mandibular symphysis during the first postnatal months has not gained attention. The present study describes the formation of teeth and the development of fusion between the mandibular halves during the first five postnatal months, as seen in panoramic tomograms taken in medicolegal autopsies of 29 ethnic Finns, 19 boys and 10 girls, at the Department of Forensic Medicine, University of Helsinki. In the majority of the infants, the criteria of sudden infant death (SID) were fulfilled. The stages of tooth formation used were those applied by Moorrees et al. (5) with one modification (Nyström et al. (7)).

Mineralization of all primary teeth proceeded rapidly during the first postnatal months, the change being on average two developmental stages in four months. Considerable variation in tooth development existed in infancy. The mandibular halves were separated at birth. Complete fusion had occurred in the majority of infants aged four months, and the tomograms of the remaining infants showed a thin vertical line in a part of the symphysis. The marked changes, which during the first postnatal months occur in the radiographical appearance of the mandibular symphysis, and in the formation of primary teeth, provide valuable information for age assessments of infants.

KEYWORDS: forensic science, forensic odontology, tooth mineralization, tooth development, mandibular symphysis, panoramic radiography

Mineralization of teeth is not environmentally sensitive and is therefore useful in age assessments. Little information exists regarding the development of most teeth in healthy infants (1). Studies on mineralization of human teeth during the first postnatal year include small numbers of individuals (2,3) or cover only part of the dentition (4–7). Data on the development of primary teeth during the first postnatal months are especially scarce (6,8).

Present knowledge on timing of tooth development in infancy is mainly based on histological (2,8) and radiological (5,6,9) observations of teeth at various developmental stages. One approach has been to use chronological incremental markers in fully developed teeth to provide timetables for dental development within individuals (3,10). Calcium and phosphorus contents (4) and tooth weights (11) and heights (12,13) have also been measured in order to construct schedules of tooth development. Timetables obtained by different methods are not, however, exactly the same. Radiographic assessment of any tooth's maturity always gives a later age than does histological assessment, because time is required to accumulate a mass of mineral sufficient to register above the absorbence of the alveolar bone plates (4,14,15). Furthermore, criteria for stages of tooth mineralization, especially for completion of crown development, are not identical in histology and radiography (14). Schedules of normal development should therefore be based on information acquired by several methods, because when age estimation is needed, only one method may be available.

The mandibular symphysis is an area where distinct changes occur shortly after birth (16), but very little exact information exists as to the timing of the fusion of this symphysis (17).

[1] Department of Pedodontics and Orthodontics, Institute of Dentistry.
[2] Department of Forensic Medicine, University of Helsinki, Helsinki, Finland.

Received 17 August 2002; and in revised form 3 Sept. 2002; accepted 5 Oct. 2002; published 3 Feb 2003.

We had an opportunity to study the development in the whole dentition in early postnatal life in a rare sample of human radiographs. We could also observe the development, that occurs in the mandibular symphysis during the first postnatal months. Such radiographic information has not been previously presented. The specific aims of the present study were to provide data suitable for age assessments based on:

- mineralization of all primary and permanent teeth occurring during the first five postnatal months as seen in panoramic tomograms, and
- radiographic appearance of the fusion of the mandibular symphysis during the first five postnatal months.

Material and Methods

The material consisted of panoramic tomograms taken at the Department of Forensic Medicine, University of Helsinki, in medicolegal autopsies of 30 infants aged from 0.00 months to 4.80 months at death. The manner and cause of death had been determined by responsible forensic pathologists. The pathologists did not indicate any connection between the cause of death and the gestational age or birth weight. In 30 cases, for 20 (67%), the criteria of sudden infant death (SID) were fulfilled. Other causes were suffocation (two cases), cardiac disorder (two cases), hepatic fibrosis (one case), and extensive bleeding (one case). In four cases the cause of death remained unknown. The radiographs had been taken from 1990 to 2001 as a part of the routine procedure for SID. One infant was excluded from the present study because of cleft palate. The remaining sample consisted of panoramic tomograms of 29 ethnic Finns, 19 boys and 10 girls, who had been considered healthy before death. Furthermore, the material included some occlusal radiographs and lateral and frontal skull radiographs of the same children (Table 1).

TABLE 1—*Distribution of radiographs by age and gender.*

Age in Months			Boys ($N = 19$) Type of Radiograph					Girls ($N = 10$) Type of Radiograph				
Group*	Mean	SD	Tomo†	U occ‡	L occ§	Lat‖	Front¶	Tomo	U occ	L occ	Lat	Front
0	0.39	0.45	1					3				
1	1.40	0.27	10	3	2	1	2	1				
2	2.45	0.19	4	1	2	1	2	3				
3	3.50	0.68	2	1	1	1	1					
4	4.45	0.32	2			1		3	1	1	1	1
Total			19	5	5	4	5	10	1	1	1	1

*Age in attained months, e.g., age group two months includes infants from 2.00 to 2.99 months. †Panoramic tomogram. ‡Maxillary occlusal radiograph. §Mandibular occlusal radiograph. ‖Lateral skull radiograph. ¶Frontal skull radiograph.

The panoramic tomograms were taken with OP 6® (Palomex, Helsinki, Finland) operating at 45 kV. This apparatus was equipped with a head adapter, and the corpse was positioned horizontally. Trimax® (3M, St. Paul, MN) cassettes with intensifying screens were used and an aluminum filter added (18). Several tomograms were taken of each infant, and the best were chosen for the present study.

The criteria of stages of tooth formation used were those designed by Gleiser and Hunt (9) in the version applied by Moorrees et al. (5), with one small modification (7). Instead of the grade "cusp outline complete" we used the grade "crown ¼ complete." This describes better the view of developing primary teeth, in which the approximal enamel already has distinct extensions when the occlusal enamel is very thin. The degree of fusion between the mandibular halves was graded in three stages: separate, partly fused, totally fused.

The tomograms were viewed by both authors, and the criteria for rating the formation stages of the teeth and the fusion of the mandibular halves were discussed and confirmed. The final evaluation was conducted by one author (MN). Results were based on evaluations of panoramic tomograms. Radiographs taken with other techniques, if available, served as auxillaries. The statistical methods used were percentiles, median, mean, and standard deviation (SD).

Intra-Rater Variability

The first author re-evaluated developmental stages of the teeth in 27 panoramic tomograms two months after the first rating. Thus, 574 teeth, 486 primary and 88 permanent, were re-evaluated. The ratings of 524 teeth (91.3%) concurred, and in the remaining 50 teeth (8.7%) the ratings differed by one stage. The second rating was for 25 teeth advanced and for 25 delayed. The first and second ratings of the stage of the fusion of the mandibular halves (separate, partly united, united) differed in three cases of 28 by one stage (10.7%).

Results

Contralateral Teeth

As presented in Table 2, in the analysis of the data, right and left sides were combined. Genders were combined due to the small numbers of individuals in the one-month age groups. Developmental stages of contralateral teeth could be compared in 253 primary tooth pairs. In 14 tooth pairs (5.5%) the ratings differed by one stage. In nine cases, the tooth on the left side was advanced and in five, delayed. Differences in ratings between the sides concerned all types of primary teeth and occurred equally often in both jaws. In permanent first molars (M1) of 30 tooth pairs, differences between contralateral teeth were encountered in three (10.0%): the left side was once advanced and twice delayed.

Primary Teeth

The panoramic view showed no or only slight overlapping of the developing primary incisor and canine crowns during the first five postnatal months. At birth, the incisal edges of primary central (di1) and lateral (di2) incisors, and the primary canine (dc) cusps in the same jaw were at the same level (Fig. 1). From the age of one month onwards, the incisal edges of mandibular di1 were closer to the oral cavity than were di2 and dc in the same jaw. At the age of four months, maxillary incisors, di1 or di2, which were more advanced in root development, reached closer to the oral cavity (Fig. 2).

Medians (Table 2) and distributions (Fig. 3) of radiologic formation stages of primary teeth are given in five one-month age groups. In this cross-sectional sample, the median formation stage developed on average two stages between the ages of zero and four months. Figure 3 also suits for visual estimations of age in cases where the developmental stage of one or several primary teeth is known. Ages corresponding to developmental stages were calculated only for stage Cr½ in primary first molars (dm1), because it was the only grade that fell completely within the age limits of the study, e.g., it was not represented in the youngest or the oldest age group. In the maxilla the mean age was 2.53 months ($SD = 0.62$, $N = 13$) and in the mandible 2.69 months ($SD = 0.71$, $N = 11$).

Permanent Teeth

Tomograms showed all mandibular first molars at the crypt stage at birth and at the age of one month. Initial mineralization of mandibular M1 was seen in 82% of the teeth at two months and in all teeth at three months, whereas it was already at one month visible in skull radiographs. Neither tomograms nor frontal or lateral skull radiographs showed mineralization of maxillary M1 during the first three months. At four months, coalescence of cusps was visible in all these teeth. Crypt formation or mineralization of permanent central (I1) and lateral (I2) incisors and canines was not seen during the first five months in tomograms and skull radiographs, but, in occlusal radiographs, the crypts of maxillary I1 were visible at the age of two months and initial mineralization of maxillary I1 and of mandibular I1 and I2 at four months.

TABLE 2—*Mineralization stage* medians of teeth during the first five postnatal months in panoramic tomograms. Genders combined.*

		Mandible			Maxilla		
Teeth	Age, months	*N*, Infants	*N*, Teeth	Median Stage	*N*, Infants	*N*, Teeth	Median Stage
Primary central incisor	0	4	8	Cr½; Cr¾	4	8	Cr¾
	1	11	22	Cr¾	10	20	Cr¾
	2	6	10	Cr¾	7	13	Cr¾
	3	2	4	Crc	2	4	Crc; Ri
	4	5	9	Ri	5	10	Crc
Primary lateral incisor	0	4	8	Cr¼	4	8	Cr½
	2	6	10	Cr½	7	13	Cr¾
	3	2	4	Cr¾	2	4	Cr¾; Ri
	4	4	8	Crc	5	10	Ri
Primary canine	0	4	8	Cco	4	8	Crco
	1	11	22	Cco	10	20	Crco
	2	6	11	Cr¼	6	11	Cr¼
	3	2	4	Cr¼	2	4	Cr¼
	4	5	9	Cr½	5	9	Cr½
Primary first molar	0	4	8	Cr¼	4	8	Cr¼
	1	11	22	Cr¼	9	18	Cr¼
	2	7	13	Cr½	6	11	Cr½
	3	2	4	Cr½	2	3	Cr½
	4	5	10	Crc	5	10	Cr¾
Primary second molar	0	4	8	Cco	3	5	Cco
	1	11	22	Cco	9	16	Cco
	2	7	13	Cr¼	6	11	Cco
	3	2	4	Cr¼; Cco	2	4	Cr¼
	4	5	10	Cr½	4	7	Cr¼
Permanent first molar	0	4	8	O		Not visible	
	1	11	21	O		Not visible	
	2	7	11	Ci		Not visible	
	3	2	4	Ci		Not visible	
	4	5	10	Ci; Cco	4	7	Cco

*Stages: Stage O = crypt, no mineralization; Ci = initial mineralization; Cco = coalescence of cusps; Cr¼ = crown ¼ complete; Cr½ = crown ½ complete; Cr¾ = crown ¾ complete; Crc = crown complete; Ri = initial root formation; R¼ = root ¼ complete; R½ = root ½ complete.

FIG. 1—*Panoramic tomogram of jaws of a girl at birth. Mandibular halves are separated. Incisal edges and occlusal surfaces of all primary teeth and crypts of permanent mandibular first molars are visible.*

FIG. 2—*Panoramic tomogram of jaws of a boy aged four months. Mandibular halves are fused. Crown formation of all primary incisors and first molars is completed. Crowns of primary canines are more developed than second molars. Separate cusps of permanent mandibular first molars are visible.*

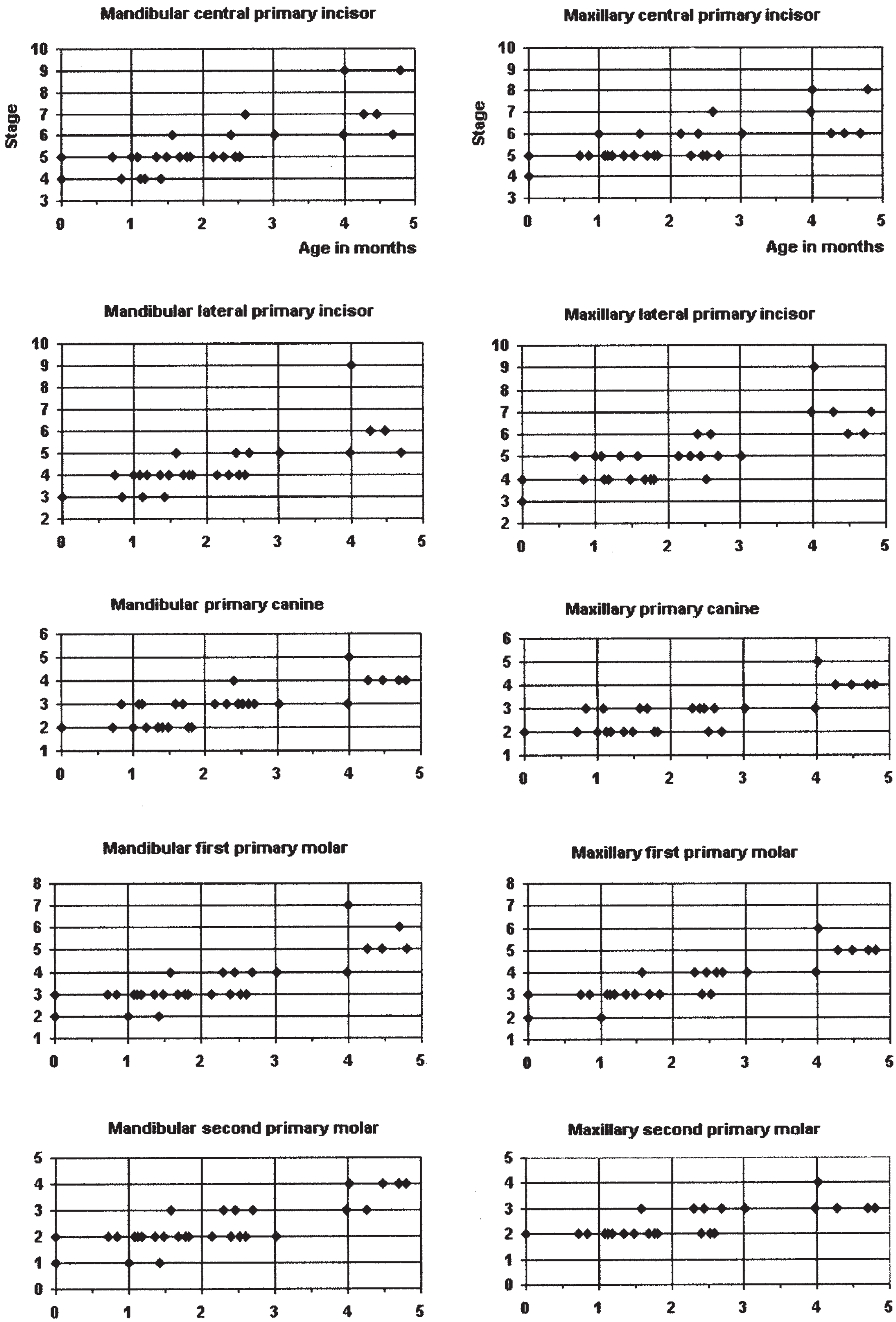

FIG. 3—*Distribution of children by mineralization stages* of primary teeth† as seen in panoramic tomograms during the first five postnatal months. Genders combined.*

**Stages: 1 = Ci (initial mineralization); 2 = Cco (coalescence of cusps); 3 = Cr¼ (crown ¼ complete); 4 = Cr½ (crown ½ complete); 5 = Cr¾ (crown ¾ complete); 6 = Crc (crown complete); 7 = Ri (initial root formation); 8 = R¼ (root length ¼); 9 = R½ (root length ½).*

†*Teeth on the left side. If not available, contralateral teeth were used.*

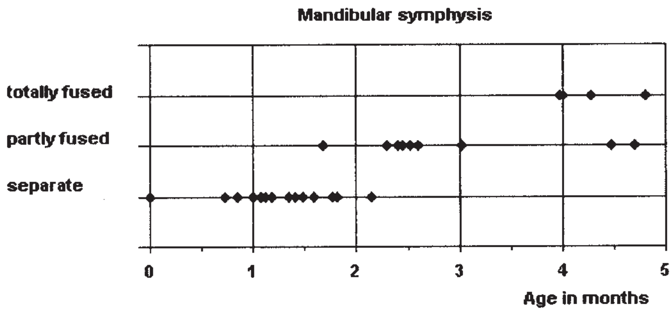

FIG. 4—*Distribution of children by radiographic appearance of fusion between the mandibular halves during the first five postnatal months. Genders combined.*

Bony Union Between the Two Halves of the Mandible

At birth, mandibular halves were separated (Figs. 1, 4). Partial fusion was seen in five of the six infants aged two months (Fig. 4). At four months, radiographs showed complete fusion (Fig. 2) between mandibular halves in three infants. In the remaining two infants, incomplete fusion was seen as a thin dark vertical line either at the lower border or in the middle of the mandibular symphysis.

Discussion

The present sample is, to our knowledge, the largest radiographical material concerning the development of the whole dentition in early infancy. Furthermore, it also suits for observations of the radiographic appearance of the mandibular symphysis, which has not previously gained attention during the first postnatal months. The infants had been considered healthy before their death, and in most cases the criteria of SID were fulfilled. In SID, skeletal growth is reported to be normal (19), and, although no studies concern tooth development in SID, there is no reason to assume that it would deviate from normal.

Panoramic tomograms have the advantage of showing the whole dentition in one radiograph, which makes it possible to give a total description of dental development. It should, however, be noted that in small children the shape of the dental arches may not conform well to the average sharply depicted plane of the tomographic unit. Especially in the incisor area, the tomographic cut is not always optimal. Accordingly, several radiograms per infant had been taken at autopsies. In dentitions of average shape and size, marked overlap of teeth frequently occurs in the maxillary premolar area of panoramic tomograms (20). This phenomenon is accentuated around birth, because the tooth-bearing part of the maxilla has smaller transverse dimensions than does the mandible (21). For this reason, and because of ghost images, maxillary permanent first molars were visible at the earliest at four months of age.

All primary teeth begin to mineralize prenatally (Fig. 1). Information on tooth development in healthy individuals before birth does not exist, and most developmental schedules of primary teeth described in reviews (1,22) derive from the findings of Kronfeld and Schour (8) in children, many of whom had died of severe diseases. At birth, mineralization of primary incisors and canines was in the present study slightly delayed and that of primary molars slightly advanced compared with data from that study. Studies with information of only one or some primary teeth at birth have also been published (4,23,24), and the present results conform to them. Median ages for the stage "crown completed" (Crc) were in the primary incisors of our radiological study about one month delayed compared with ages in the histological study of Kronfeld and Schour (8). In both studies, primary canines mineralized later than primary incisors and first molars. In mandibular primary canines and molars, the present mineralization schedules either concorded (25) or were somewhat later (6) than in two other radiographic studies.

In histological studies, the first permanent molar has been reported to begin to mineralize before or about the time of birth (3,26,27). Charts based on lateral "oblique" radiographs taken at three-month intervals showed initial mineralization of mandibular M1 soon after birth (5). In the present panoramic tomograms, mineralization of the mandibular M1 was observed later, at the age of two months in most instances. We did not find mineralization of permanent incisors in any panoramic tomogram taken during the first five postnatal months, whereas it was visible during the fifth month in the child with occlusal radiographs. A previous study with lateral and frontal skull radiographs reported the earliest evidence of the mandibular central incisor before six months of age (15), and, in histological studies, the age of initial mineralization of the central incisors in both jaws and for the mandibular lateral incisor has been reported to be from three to four months (3,28).

As to the timing of the fusion of the mandibular symphysis, textbooks and review articles state that the mandibular halves remain separated until shortly after birth (16), and bony union occurs at the end of the first year (29–31). In an archeological study, in which the age of infant skeletons was estimated on the basis of tooth formation and eruption, fusion was seen on average at seven to eight months of age (17), somewhat later than in our radiolographical study. The present results show that fusion of the mandibular symphysis is a process that proceeds rapidly during the first postnatal months. Thus, observation of the radiographic appearance of fusion between mandibular halves provides, together with the formation of primary teeth, valuable information for age estimation of infants.

Acknowledgments

The authors wish to thank Professor Antti Penttilä and Mr. Seppo Tyynelä at the Department of Forensic Medicine, University of Helsinki, for fruitful discussions and expert technical assistance.

References

1. Smith BH. Standards of human tooth formation and dental age assessment. In: Kelley MA, Larsen CS, editors. Advances in dental anthropology. New York: Wiley-Liss Inc., 1991;143–68.
2. Logan WHG, Kronfeld R. Development of the human jaws and surrounding structures from birth to the age of fifteen years. J Am Dent Assoc 1933;20:379–427.
3. Reid DJ, Beynon AD, Ramirez Rozzi FV. Histological reconstruction of dental development in four individuals from a medieval site in Picardie, France. J Hum Evol 1998;35:463–77.
4. Hess AF, Lewis JM, Roman B. A radiographic study of calcification of the teeth from birth to adolescence. Dent Cosmos 1932;74:1053–60.
5. Moorrees CFA, Fanning EA, Hunt EE Jr. Age variation of formation stages for ten permanent teeth. J Dent Res 1963a;42:1490–1502.
6. Moorrees CFA, Fanning EA, Hunt EE Jr. Formation and resorption of three deciduous teeth in children. Am J Phys Anthropol 1963b;21: 205–13.
7. Nyström M, Kilpinen E, Kleemola-Kujala E. A radiographic study of the formation of some teeth from 0.5 to 3.0 years of age. Proc Finn Dent Soc 1977;73:167–72.
8. Kronfeld R, Schour I. Neonatal dental hypoplasia. J Am Dent Assoc 1939;26:18–32.
9. Gleiser I, Hunt EE Jr. The permanent first molar: its calcification, eruption and decay. Amer J Phys Anthrop 1955;13:253–83.
10. Schour I, Massler M. Rate and gradient of growth in human deciduous teeth, with special reference to neonatal ring (abstract). J Dent Res 1937;16:349–50.

11. Gilster JE, Smith FH, Wallace GK. Calcification of mandibular second primary molars in relation to age. J Dent Child 1964;31:284–8.
12. Stack MV. Vertical growth rates of the deciduous teeth. J Dent Res 1967;46:879–82.
13. Liversidge HM, Molleson TI. Developing permanent tooth length as an estimate of age. J Forensic Sci 1999;44:917–20.
14. Beynon AD, Clayton CB, Ramirez Rozzi FVR, Reid DJ. Radiographic and histological methodologies in estimating the chronology of crown development in modern humans and great apes: a review, with some applications for studies on juvenile hominids. J Hum Evol 1998;35: 351–70.
15. Simpson SW, Kunos CA. A radiographic study of the development of the human mandibular dentition. J Hum Evol 1998;35:479–505.
16. Ten Cate AR. Embryology of the head, face, and oral cavity. In: Ten Cate AR, editor. Oral histology, development, structure, and function. 3rd ed. St Louis: C.V. Mosby Company, 1989;16–43.
17. Becker MJ. Mandibular symphysis (medial suture) closure in modern Homo sapiens: preliminary evidence from archaelogical populations. Am J Phys Anthrop 1986;69:499–501.
18. Ranta H, Nyström M. Sudden infant death: orthopantomographic findings. In: Jakob B, Bonte W, editors. Advances in forensic sciences (1), Forensic pathology. Berlin: Verlag Dr. Köster, 1995;163–5.
19. Byard RW, Fazzalari NL, Byers S, Moore A, Wilsdon C, Makrides M, et al. Studies of bone growth plate and cerebral lipid levels in SIDS. In: Rognum TO, editor. Sudden infant death syndrome. New trends in the nineties. Oslo: Scandinavian University Press, 1995;253–5.
20. Langland OE, Langlais RP, McDavid WD, DelBalso AM. Panoramic radiology. 2nd ed. Philadelphia: Lea & Febiger, 1989.
21. van der Linden FPGM, Duterloo HS. Development of the human dentition. An atlas. Hagerstown, Maryland: Harper & Roy, Publishers, Inc., 1976.
22. Lunt RC, Law DB. A review of the chronology of calcification of deciduous teeth. J Am Dent Assoc 1974;89:599–606.
23. Kraus BS, Jordan RE. The human dentition before birth. Philadelphia: Lea & Febiger, 1965.
24. Calonius PEB, Lunin M, Stout F. Histologic criteria for age estimation of the developing human dentition. Oral Surg 1970;29:869–76.
25. Pfau RO, Sciulli PW. A method for establishing the age of subadults. J Foresic Sci 1994;39:165–76.
26. Kronfeld R. First permanent molar: its condition at birth and its postnatal development. J Am Dent Assoc 1935a;22:1131–55.
27. Boller RJ. Fetal morphogenesis of the human dentition. J Dent Child 1964;31:67–81.
28. Kronfeld R. Postnatal development and calcification of the anterior permanent teeth. J Am Dent Assoc 1935b;22:1521–36.
29. Greenberg A. The life cycle of the human mandible. N.Y. St. Dent J 1965;51:98–105.
30. Josephsen K, Melsen B, Fejerskov O. The development of the face and oral cavity. In: Mjör IA, Fejerskov O, editors. Human oral embryology and histology. Copenhagen: Munksgaard, 1986;10–30.
31. Bhaskar SN. Maxilla and mandible (alveolar process). In: Bhaskar SN, editor. Orban's oral histology and embryology. 11th ed. St. Louis: Mosby Year Book, 1986;239–59.

Additional information and reprint requests:
Marjatta Nyström, Ph.D., D.D.S.
Department of Pedodontics and Orthodontics
Institute of Dentistry
P.O. Box 41
SF-00014 University of Helsinki
Finland
E-mail: marjatta.nystrom@helsinki.fi