Sex- and Age-related Differences in Primary and Secondary Dentin Formation

U. Zilberman, P. Smith

Laboratory of Bioanthropology and aDNA, Faculty of Dental Medicine, The Hebrew University-Hadassah, School of Dental Medicine, POB 12272, Jerusalem 91120, Israel; pat@cc.huji.ac.il

Adv Dent Res 15:42-45, August, 2001

Abstract — Clinical studies carried out on dentin thickness in adults, as well as experimental studies carried out on ovariectomized animals, indicate that odontoblast activity, like that of osteoblastic cells, differs in the two sexes. To examine the evidence for differences in odontoblast activity before puberty, we have measured dentin thickness and other crown dimensions from bitewing radiographs of the lower first molars in 240 children aged 4-16 years. The radiographs were obtained from pedodontic clinics throughout Israel. Only teeth without caries or fillings were used, and the study population had minimal attrition. The results showed that dentin thickness, measured on the roof of the pulp chamber, was significantly greater in boys than in girls at all ages, and that the differences increased during puberty. The differences remained highly significant even when standardized for crown size. They demonstrate that dimorphism in dentin thickness is present even in the earliest stages of odontogenesis and increase with puberty.

Introduction

Three types of dentin have been identified in human teeth: primary dentin, which forms rapidly, in association with enamel or cementum apposition, during tooth formation; secondary dentin, which results from the continued but relatively slow apposition of dentin in later life and may be associated with a reduction in the number of functioning odontoblasts (Franquin *et al.*, 1998); and tertiary, irregular, dentin, laid down as a localized response to trauma (Ten Cate, 1998). Sex differences have been reported in the volume of the dentin-pulp complex and enamel (Stroud *et al.*, 1994; Zilberman and Smith, 1994; Alvesalo, 1997: Harris and Hicks, 1998; Zilberman *et al.*, 2000), and sex hormones appear to affect odontoblast function in later life. Estrogen receptor antigens have been identified in the pre-dentinal-odontoblast layer and pulpal blood vessels of extracted human wisdom teeth of both sexes (Hietala *et al.*, 1998), while ovariectomized rats show enhanced dentin formation as well as enhanced periosteal bone formation (Hietala and Larmas, 1992; Svanberg *et al.*, 1994).

This study examines the hypothesis that dimorphism in odontoblast activity occurs even before puberty, and is expressed in differences in dentin thickness. The study was carried out on bitewing radiographs of lower first permanent molars. In this tooth, crown formation is completed at age 3-4 years, and root formation is completed at age 8-9 years (Moorrees *et al.*, 1963). The sample was divided into three age groups designed to provide information on primary dentin thickness, the combined thickness of primary and secondary dentin laid down before puberty, and the amount of dentin laid down in adolescence.

Materials & Methods

Bitewing radiographs of caries-free teeth without restorations from 247 girls and 271 boys, aged 4 to 16 years and treated at different pedodontic clinics in Israel, were examined. The radiographs were taken as part of treatment protocol and were submitted to the authors with no identification other than age and sex some years after treatment had been completed. Under these conditions, the Helsinki committee decided to waive the requirement for informed consent. Exact age was known for 160 of the boys and 153 girls. Only radiographs with good superimposition of cusp tips and no overlapping of mesial and distal borders of adjacent teeth were measured. In such radiographs, rotation and distortion of the image seen on the radiograph have been previously shown to be less than 5 degrees (Zilberman *et al.*, 1992). Age and sex of the children were obtained from their dental charts. Enamel height (EH), dentin height (DH), and pulp height (PH) were measured as shown in the Fig. All measurements were expressed as a ratio of mesio-distal crown width (CW), to minimize the effects of external tooth size and possible errors due to magnification. To ensure unbiased measurements, we coded all radiographs so that age and sex were unknown at the time of measurement. The same examiner performed all measurements using a digital caliper on a light table. The differences found between measurements of the same tooth after 10 days ranged from 2-5% and averaged 3.2%. CW showed the least variation and EH the most.

Two-tailed Student's t test was carried out for the total sample. Individuals of known age were then divided into three age groups (4-7, 8-11, and 12-16 years) and analyzed by two-tailed Student's t test and analysis of variance. In all groups, enamel formation and thus enamel apposition and crown formation were complete. Dentin thickness in the three groups, however, represents the total dentin formed under different conditions. In the first group, all dentin present is primary dentin, since the roots are not yet fully formed. In the second group, there is some secondary dentin, while in the third group, dentin thickness represents the total amount of dentin formed both in childhood and during puberty.

Results

Table 1 shows the mean values for tooth components in boys and girls. For the entire sample, DH, PW, and CW were significantly larger in boys than in girls.. However, when tooth components were calculated as a ratio of CW, only DH/CW showed statistically significant differences (Table 1). EH/CW and EW/CW were significantly larger in girls. For the 160 boys and 153 girls for whom the exact age was known, mean age was similar: 9 years for boys compared with 9.1 years for girls. In all age groups, DH was

Key Words

Dentin, teeth, dimorphism, odontogenesis, odontoblasts.

Presented at the International Meeting on Signaling Mechanisms in Dentin Development, Regeneration, and Repair: from Bench to Clinic, held at Thessaloniki, Greece, November 10-11, 2000

TABLE 1 — Mean Values for Tooth Components in Mandibular First Permanent Molars (in mm)

		Total		4-< 8 yrs		8-< 11 yrs		11-< 16 yrs	
		Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
EH	Mean	1.74	1.75	1.76	1.65	1.68	1.72	1.71	1.99**
	No.	247	271	54	41	80	82	26	30
	SD	0.33	0.32	0.38	0.31	0.3	0.4	0.5	0.3
DH	Mean	3.58	3.21**	3.46	3.13**	3.6	3.21**	4.0	3.4**
	No.	247	271	54	41	80	82	26	30
	SD	0.51	0.45	0.53	0.41	0.48	0.47	0.37	0.47
PH	Mean	1.85	1.86	2.05	2.3*	1.87	1.92	1.47	1.47
	No.	240	268	51	40	77	81	26	30
	SD	0.57	0.57	0.56	0.51	0.57	0.49	0.47	0.4
EW	Mean	1.42	1.44	1.48	1.46	1.46	1.47	1.46	1.66**
	No.	246	271	54	41	80	82	26	30
	SD	0.22	0.21	0.23	0.18	0.2	0.21	0.28	0.23
PW	Mean	4.61	4.48**	4.76	4.53*	4.63	4.63	4.39	4.51
	No.	245	271	52	41	80	82	26	30
	SD	0.49	0.45	0.57	0.54	0.45	0.42	0.46	0.48
CW	Mean	11.78	11.43*	11.78	11.28**	11.78	11.39**	11.63	11.61
	No.	247	271	54	41	80	82	26	30
	SD	0.57	0.6	0.54	0.57	0.57	0.59	0.73	0.71
EH/CW	Mean	0.147	0.153*	0.15	0.15	0.14	0.15	0.15	0.17**
	No.	247	271	54	41	80	82	26	30
	SD	0.03	0.03	0.03	0.03	0.02	0.03	0.04	0.02
DH/CW	Mean	0.3	0.28**	0.29	0.28	0.31	0.28**	0.35	0.29**
	No.	247	271	54	41	80	82	26	30
	SD	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.04
PH/CW	Mean	0.157	0.163	0.17	0.2**	0.16	0.17	0.13	0.13
	No.	240	268	51	40	77	81	26	30
	SD	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.04
EW/CW	Mean	0.12	0.13**	0.13	0.13	0.12	0.13	0.126	0.143**
	No.	246	271	54	41	80	82	26	30
	SD	0.02	0.02	0.01	0.02	0.02	0.02	0.02	0.02
PW/CW	Mean	0.39	0.39	0.4	0.4	0.39	0.39	0.38	0.39
	No.	245	271	52	41	80	82	26	30
	SD	0.03	0.03	0.04	0.04	0.03	0.03	0.02	0.03
Age	Mean	9.01	9.11	6.56	6.67	9.24	9.04	13.35	12.62
	No.	161	153	54	41	80	82	26	30
	SD	2.5	2.2	1.03	0.78	0.94	0.83	1.5	1.3

Note: EH = Enamel Height; EW = Enamel Width; DH = Dentin Height; PW = Pulp Width; PH = Pulp Height; CW = Crown Width.
* P value < 0.05.
** P value < 0.01.

significantly greater in boys. PH was significantly greater in girls in the youngest age group, and EH and EW were significantly larger in girls than in boys in the two oldest age groups. With tooth components standardized for differences in crown width (Table 1), the ratio DH/CW was significantly greater in boys than in girls of similar age and increased more rapidly with age in boys than in girls. PH/CW ratios, however, were similar in both sexes, while EH/CW and EW/CW ratios tended to be greater in girls.

One-way analysis of variance, carried out with age and sex as dependent variables and CW as co-variant, showed that sex was the main factor contributing to differences in dentin thickness (36.9%), followed by age (27%), with CW contributing only 5% to total variance (Table 2). The combined effect of age and sex was only 47%, since the pattern of increase in dentin thickness differed in boys and girls

Discussion

Dimorphism in the dentin-pulp complex of the mandibular first permanent molar studied here is then expressed in relatively thinner enamel relative to crown size and faster apposition of dentin. The quantity of primary and secondary dentin formed in boys, at least on the roof of the pulp chamber, is greater than in girls, even before adolescence. These differences are statistically significant at age 7. Given the young age and lack of attrition in the sample examined, it is highly unlikely that functional differences influenced dentin thickness. Moreover, as shown in Table 2, crown size contributed only some 5% to the variance in dentin thickness, while sex contributed 39% and age 26%. The fact that this was a cross-sectional study carried out on individuals with different growth trajectories may account for some of the unexplained variance in DH.

Studies carried out on the teeth of individuals of unknown sex have shown that more dentin is deposited on the floor of the pulp chamber of multi-rooted teeth than on the roof or walls (Philippas, 1961; Mjör, 1986). Philippas (1961) interpreted this as due to the reduced growth potential of coronal odontoblasts. Our study did not directly measure the thickness of dentin deposited on the floor of the pulp chamber. However, while in boys all of the reduction in pulp height

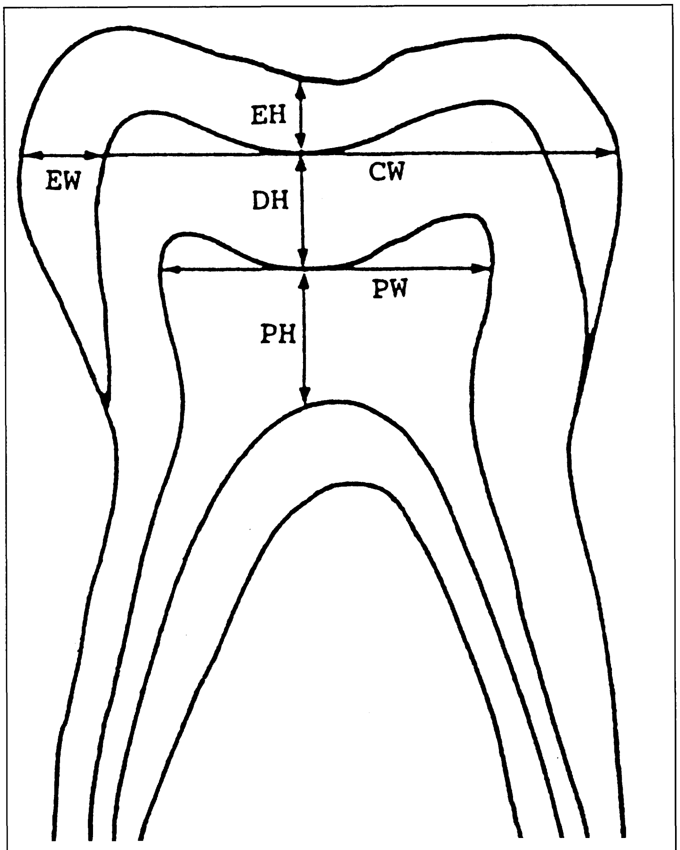

Fig. — Cross-section of molar showing measurements taken. Measurements were taken as follows: Enamel height (EH), dentin height (DH), and pulp height (PH) were measured parallel to the long axis of the tooth, one millimeter mesial to the central fossa on the same line. Pulp width (PW) was measured perpendicular to the long axis of the tooth on the widest part of the tooth. Enamel width (EW) and maximal crown width (CW) were measured on the widest mesio-distal length of the tooth on a line perpendicular to the long axis of the tooth.

observed can be attributed to the increased dentin thickness on the roof of the chamber, this does not apply to the girls. The mean difference in pulp height between boys in the youngest and oldest age groups was 0.58 mm, and this can be explained by increased dentin thickness in the oldest group. The mean difference in pulp height between the youngest and oldest girls was 0.83 mm. The reduction in pulp chamber height in the girls was much greater than can be accounted for by the increased dentin height. In girls, therefore, there may have been additional dentin deposited on the floor of the pulp chamber. This raises the issue of possible sex differences in the location as well as the quantity of secondary dentin formed. This dimorphism may be related to the different developmental pathway of coronal and radicular odontoblasts. The former differentiate earlier, show a more rapid rate of primary dentin formation, and follow a sinusoidal path. The radicular odontoblasts differentiate later, in a different milieu (Hertwig's epithelial sheath and cementoblasts), and follow a straighter, more parallel path (Ten Cate, 1998).

Most of the previous studies of age-related changes in the dentin thickness of human teeth have been carried out on older adults, with few if any juveniles included. Most used samples from individuals of unknown sex and focused on anterior teeth (Gustafson, 1950; Philippas, 1961; Philippas and Applebaum, 1966; Woods *et al.*, 1990; Solheim, 1992; Drusini *et al.*, 1997). In those studies in which samples of known sex were examined, significant dimorphic differences were found in the rate of dentin formation in adults (Woods *et al.*, 1990; Solheim, 1992). Another study carried out by Drusini *et al.* (1977) showed a similar pattern of dimorphic differences. However, they concluded that these differences were unimportant for age estimation. Woods *et al.* (1990) examined lower molars of known sex, age, and population group. They concluded that all factors influenced the amount of secondary dentin laid down, and that in females the rate of dentin formation appeared to increase suddenly in the fourth decade. However, they did not directly examine dentin thickness but measured changes in the dimensions of the pulp cavity. The results presented here show that the sex differences in dentin thickness present in adults are already present in infancy and accelerate during puberty. They support the hypothesis of dimorphism in odontoblast activity throughout life.

TABLE 2 — Analysis of Variance: Dentin Height by Age Groups and Sex with Crown Width (experimental sums of squares; covariates entered first)

	Sum of Squares	DF	Mean Square	F	Sig. of F
Covariates	8.847	1	8.847	43.314	0.000
Crown width	8.847	1	8.847	43.315	0.000
Main effects	13.067	3	4.356	21.325	0.000
Age groups	5.725	2	2.863	14.016	0.000
Sex	8.162	1	8.162	39.960	0.000
2-way interactions	1.503	2	0.751	3.679	0.026
Age groups and sex	1.503	2	0.751	3.679	0.026
Explained	23.416	6	3.903	19.109	0.000
Residual	62.499	306	0.204		
Total	85.915	312	0.275		

Note: Multiple Classification Analysis results for dentin height by age group and sex, with crown width, show that sex contributes 37%, age group 26%, and CW 5% to variance found.

Acknowledgments

The authors thank all those pedodontists who contributed radiographs for this study. This investigation was supported in part by the Israel Science Foundation.

References

Alvesalo L (1997). Sex chromosome and human growth. A dental approach. *Hum Genet* 101:1-5.

Drusini AG, Toso O, Ranzato C (1997). The coronal pulp cavity index: a biomarker for age determination in human adults. *Am J Phys Anthropol* 103:353-363.

Franquin JC, Remusat M, Abou Hashiech I, Dejou J (1998). Immunocytochemical detection of apoptosis in human odontoblasts. *Eur J Oral Sci* 106 (Suppl 1):384-387.

Gustafson G (1950). Age determinations on teeth. *J Am Dent Soc* 41:45-54.

Harris EF, Hicks JD (1998). A radiographic assessment of enamel thickness in human maxillary incisors. *Arch Oral Biol* 43:825-831.

Hietala EL, Larmas M (1992). The effect of ovariectomy on dentin formation and caries in adult rats. *Acta Odontol Scand* 50:337-343.

Hietala EL, Larmas M, Salo T (1998). Localization of estrogen–receptor-related antigen in human odontoblasts. *J Dent Res* 67:1384-1387.

Mjör IA (1986). Age changes in the teeth. In: Geriatric dentistry: a textbook of oral gerontology. Holm-Pedersen P, Löe H, editors. St. Louis: C.V. Mosby Co., pp. 94-101.

Moorrees CFA, Fanning EA, Hunt EE Jr (1963). Age variation of formation stages for ten permanent teeth. *J Dent Res* 42:1490-1502.

Philippas GG (1961). Influence of occlusal wear and age on formation of dentin and size of pulp chamber. *J Dent Res* 40:1186-1198.

Philippas GG, Applebaum E (1966). Age factor in secondary dentin formation. *J Dent Res* 45:778-789.

Solheim T (1992). Amount of secondary dentin as an indicator of age. *Scand J Dent Res* 100:193-199.

Stroud JL, Buschang PH, Goaz PW (1994). Sexual dimorphism in mesiodistal dentin and enamel thickness. *Dentomaxillofac Radiol* 23:169-171.

Svanberg M, Hietala EL, Knuuttila M (1994). The effect of dietary xylitol on dentin formation in ovariectomized rats. *Acta Odontol Scand* 52:82-85.

Ten Cate AR (1998). Oral histology: developmental structure and function. 5th rev. ed. St. Louis: The C.V. Mosby Co.

Woods MA, Robinson QC, Harris EF (1990). Age progressive changes in pulp widths and root lengths during adulthood: a study of American blacks and whites. *Gerodontology* 9:41-50.

Zilberman U, Smith P (1994). Sex discrimination using tooth components measured from bite-wing radiographs (abstract). *Am J Phys Anthropol* (Suppl 18):214.

Zilberman U, Skinner M, Smith P (1992). Tooth components of mandibular deciduous molars of *Homo sapiens sapiens* and *Homo sapiens neanderthalensis*. *Am J Phys Anthropol* 87:255-262.

Zilberman U, Smith P, Alvesalo L (2000). Crown components of mandibular molar teeth in 45,X females (Turner Syndrome). *Arch Oral Biol* 45:217-225.