Volume 20, Number 1, 2007 ISSN 1096-9411

Dental Anthropology

A Publication of the Dental Anthropology Association

Dental Anthropology

Volume 20, Number 1, 2007

Dental Anthropology is the Official Publication of the Dental Anthropology Association.

Address for Manuscripts

Dr. Edward F. Harris
College of Dentistry, University of Tennessee
870 Union Avenue, Memphis, TN 38163 U.S.A.
E-mail address: eharris@utmem.edu

Address for Book Reviews

Dr. Greg C. Nelson
Department of Anthropology, University of Oregon
Condon Hall, Eugene, Oregon 97403 U.S.A.
E-mail address: gcnelson@oregon.uoregon.edu

Published at

Craniofacial Biology Laboratory, Department of Orthodontics
College of Dentistry, The Health Science Center
University of Tennessee, Memphis, TN 38163 U.S.A.

Comparison of Permanent Mandibular Molar Crown Dimensions between Mongolians and Caucasians

Yuh Hasegawa[1,2*], James R. Rogers[2], Ikuo Kageyama[1], Sen Nakahara[3], Grant C. Townsend[2]

[1]*School of Life Dentistry at Niigata, The Nippon Dental University, Niigata, Japan*
[2]*School of Dentistry, The University of Adelaide, Adelaide, South Australia, Australia*
[3]*School of Life Dentistry at Tokyo, The Nippon Dental University, Tokyo, Japan*

ABSTRACT The aims of this study were to compare crown dimensions of mandibular first molars (M1) and second molars (M2) between Mongolians (belonging to the Khalkha-Mogol grouping) and Caucasians (Northern European ancestry) and to attempt to explain any observed differences in phylogenetic and ontogenetic terms. Materials in this study comprised dental casts of 48 Mongolian female subjects with a mean age of 20.5 years and 50 Caucasian female subjects with a mean age of 21.5 years. For M1, the buccolingual diameters of both mesial and distal crown components in Mongolians were significantly larger than in Caucasians. For M2, the mesiodistal and buccolingual diameters of the distal crown components in the Mongolian sample were significantly larger and the mesiodistal and buccolingual diameters of mesial components were significantly smaller compared with those of Caucasians. Common environmental effects, possibly related to the prenatal environment, as well as genetic influences, may be contributing to the differences in buccolingual dimensions of M1 between Mongolians and Caucasians. Given that the M2 develops later and over a longer period of time than the M1, it is reasonable to assume that this tooth may be subject to greater environmental pressures than applied to the M1. *Dental Anthropology* 2007;20:1-6.

Mongolia is a sparsely populated, landlocked country between Russia and the People's Republic of China. The capital city is Ulaanbaatar and the population is around 2.4 million. The Mongol confederation was established by Ghengis Khan in 1206 but after the fall of the Great Mongolian Empire, during the Qing Dynasty of China, tribal alignments became more rigid as they were incorporated into a more centralized administrative system imposed by the Chinese. Ethnohistorically, the Mongolian population can be divided into four clusters comprising Khalkha-Mongols, Western or Oirat Mongols, Turkic speakers, and a Northeastern cluster. The Khalkha-Mongols make up the majority of modern Mongolians and they are dispersed throughout the country (Chimge and Batsuuri, 1999).

It is well established that there are two patterns of dental variation in Mongoloid populations. One is the Sundadont pattern, typical of South-East Asia, and the other is the Sinodont pattern, typical of North-East Asia. Sundadonts whose teeth are relatively simple are thought to have retained dental features similar to those evident in late Pleistocene populations. Sinodonts were first recognized in a large skeletal series originating in Northern China and are hypothesized to have evolved from the Sundadont condition, developing a relatively more specialized and complex dental pattern. Turner (1990) observed this dental pattern in populations of Northern China, Mongolia, and Southern Siberia. Even though frequencies of occurrence and degrees of expression of nonmetric morphological crown features have been described in many Asian populations, including Mongolians (Scott and Turner, 1998; Turner, 1990; Manabe *et al*., 2003), there have been only a few studies describing mesiodistal and buccolingual crown diameters in Mongolians (Matsumura, 1995; Matsumura and Hudson, 2005; Hanihara, 2005). Recently, more emphasis has been placed on describing how the various components of the dental crown contribute to overall crown size, with studies focussing on intracoronal components rather than traditional mesiodistal and buccolingual crown diameters. However, as far as we are aware, no such study has been carried out in Mongolians.

Therefore, the aim of this study was to compare not only overall crown size but also the sizes of various crown components (*i.e.*, talonid and trigonid) of mandibular

---

*Correspondence to: Yuh Hasegawa, School of Life Dentistry at Niigata, The Nippon Dental University, 1-8, Hamaura-chou, Chuuou-ku, Niigata-city, Niigata, Japan 951-8580
E-mail: haseyu@ngt.ndu.ac.jp

first and second molars between a sample of modern young female adult Mongolians and a sample of female Caucasians of similar ages, and to attempt to explain any observed differences in phylogenetic and ontogenetic terms. The study forms part of a larger investigation of the Mongolian dentition being undertaken by researchers from the Health Science University of Mongolia, Mongolia, and the Nippon Dental University School of Life Dentistry, Japan.

MATERIALS AND METHODS

Materials in this study comprised dental casts of 48 Mongolian female subjects and 50 Caucasian female subjects. The Mongolian dental casts were produced from impressions collected by a survey team from the Nippon Dental University School of Life Dentistry, Japan. This material is stored at the School of Dentistry, Health Science University of Mongolia, Ulaanbaatar, Mongolia. The ages of the Mongolian subjects ranged between 18.4 and 25.0 years, with a mean age of 20.5 years. Mongolian dental casts were collected from students attending colleges and universities in Ulaanbaatar, who were born in Ulaanbaatar or its suburbs and who belonged to the Khalkha-Mogol grouping. The Caucasian dental casts are stored in the School of Dentistry, The University of Adelaide, and were obtained from dental students between 20.8 and 24.5 years, with a mean age of 21.5 years. For the Caucasian group, only those students with Northern European ancestry were chosen.

Dental casts were used only if mandibular first and second molars (M1 and M2) had no caries, no dental treatment, no anomaly of crown morphology, and only if the cusp tips, central pits and occlusal grooves were not noticeably affected by tooth wear. According to ethical standards, it was necessary for Mongolian students to be told the purpose of the study and agreements were obtained from them before impressions for dental casts were taken. Casts of the dentitions of the Adelaide students were obtained as part of their dental course requirements and were selected from a larger collection. M1 and M2 were measured using a pair of sliding digital calipers to an accuracy of 0.05 mm. The selected dimensions of the tooth crowns that were measured are shown in Figure 1.

The methods adopted to measure mesiodistal and buccolingual crown diameters were as described by Fujita (1949). Mesiodistal crown diameters of the trigonid and talonid were recorded as described by Yamada (1992), and buccolingual crown diameters of the trigonid and talonid followed the definitions given by Kondo *et al*. (1998). A suggestion made by Yamada (1992) was adopted to make it possible to define the border between the trigonid and talonid by defining the midpoint between the mesial central fossa and the intersection of the buccal groove.

Comparisons of mean values for mandibular molar crown dimensions between the Mongolian and Caucasian samples were made using Student's t-test. F-tests were used to compare variances. Statistical significance was set at alpha = 0.05. Descriptive statistics including distribution parameters were calculated with StatView (SAS institute, version 5.0 for Macintosh).

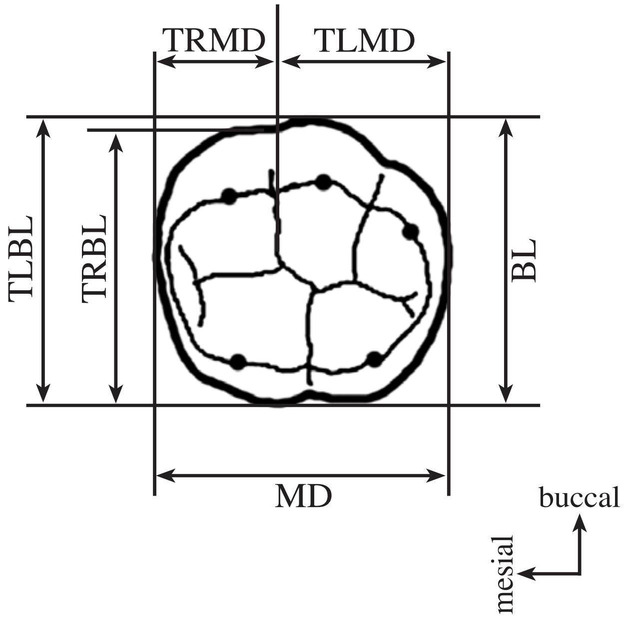


Fig. 1. Tooth crown dimensions selected for measurements. Abbreviations: BL, buccolingual diameter; MD, mesiodistal diameter; TRBL, buccolingual diameter of trigonid; TRMD, mesiodistal diameter of trigonid; TLBL, buccolingual diameter of talonid; TLMD, mesiodistal diameter of talonid.

Measurement errors were analyzed by a procedure of double determination measurements using paired t-tests (statistical significance set at alpha = 0.05) for systematic errors and the method described by Dahlberg (1940) for random errors.

RESULTS

With reference to systematic errors, there were significant differences between first and second measurements for the following dimensions: in the Mongolian sample: TLMD for the right M1, TRMD for the left M1, and TLMD and TRMD for the left M2 in the Mongolian sample; MD, BL and TLBL for the right M1, MD, and TLBL for the right M2 in the Caucasian sample. However, the magnitudes of mean differences between first and second determinations were relatively small, ranging from 0.01 to 0.21 mm. Random measurement errors ranged from 0.09 to 0.22 mm and these values were very small in magnitude compared with the mean values. Therefore, it was confirmed that errors of the method were relatively small and unlikely to bias results.

TABLE 1. Descriptive statistics of crown diameters in the mandibular first molar (mm)

	Mongolian (female)					Caucasian (female)			
	n	mean	sd	CV (%)	Significance	n	mean	sd	CV (%)
					Right side				
MD	48	10.93	0.50	4.6	ns	50	10.69	0.63	5.9
TLMD	48	6.23	0.55	8.8	ns	50	5.99	0.59	9.8
TRMD	48	4.69	0.29	6.3	ns	50	4.70	0.35	7.6
BL	48	10.51	0.39	4.3	**	50	10.25	0.46	4.5
TLBL	48	10.43	0.45	4.4	*	50	10.16	0.48	4.7
TRBL	48	10.31	0.45	7.5	**	50	10.05	0.52	5.2
					Left side				
MD	48	10.96	0.51	4.6	ns	50	10.73	0.61	5.7
TLMD	48	6.27	0.51	8.2	ns	50	6.12	0.61	10.0
TRMD	48	4.69	0.38	8.0	ns	50	4.61	0.38	8.3
BL	48	10.52	0.39	3.9	**	50	10.28	0.49	4.8
TLBL	48	10.40	0.40	3.5	*	50	10.21	0.51	5.0
TRBL	48	10.36	0.36	6.9	**	50	10.11	0.48	4.7

ns: not significant
*0.05 > P > 0.01; **P < 0.01
CV = (sd / mean) 100

TABLE 2. Descriptive statistics of crown diameters in the mandibular second molar (mm)

	Mongolian (female)					Caucasian (female)			
	n	mean	SD	CV (%)	Significance	n	mean	SD	CV (%)
					Right side				
MD	48	10.12	0.75	7.4	ns	50	10.15	0.61	6.1
TLMD	48	5.18	0.62	12.0	**	50	4.81	0.48	10.0
TRMD	48	4.94	0.38	7.7	**	50	5.34	0.48	9.0
BL	48	10.07	0.47	4.7	*	50	9.82	0.62	6.3
TLBL	48	9.93	0.53	5.4	**	50	9.44	0.60	6.4
TRBL	48	9.89	0.54	5.4	ns	50	9.73	0.69	7.1
					Left side				
MD	48	10.05	0.69	6.9	ns	50	10.11	0.62	6.2
TLMD	48	5.12	0.59	11.6	*	50	4.89	0.55	11.3
TRMD	48	4.93	0.37	7.5	**	50	5.22	0.43	8.3
BL	48	10.08	0.43	4.3	ns	50	9.94	0.62	6.3
TLBL	48	9.92	0.46	4.6	**	50	9.51	0.69	7.3
TRBL	48	9.95	0.49	4.9	ns	50	9.89	0.64	6.5

ns: not significant
*0.05 > P > 0.01; **P < 0.01
CV = (sd / mean) 100

TABLE 3. Descriptive statistics of reduction indices (%) for the mandibular second molar

	Mongolian (female)					Caucasian (female)			
	n	mean	SD	CV (%)	Significance	n	mean	SD	CV (%)
					Right side				
MD	48	92.61	4.91	5.3	**	50	94.99	3.36	5.9
TLMD	48	83.31	8.95	10.7	ns	50	80.62	7.62	9.8
TRMD	48	105.58	9.04	8.6	**	50	113.86	9.32	7.6
BL	48	95.77	3.15	3.3	ns	50	95.87	3.93	4.5
TLBL	48	95.29	3.50	3.7	**	50	92.91	4.27	4.7
TRBL	48	95.96	4.00	4.2	ns	50	96.79	4.52	5.2
					Left side				
MD	48	91.74	4.68	5.1	**	50	94.20	3.94	4.2
TLMD	48	81.71	7.04	8.6	ns	50	80.21	8.62	10.8
TRMD	48	105.56	8.00	7.6	**	50	113.59	10.33	9.1
BL	48	95.85	2.76	2.9	ns	50	96.72	3.48	3.6
TLBL	48	95.37	2.88	3.0	**	50	93.09	4.34	4.7
TRBL	48	96.02	3.30	3.4	**	50	97.76	3.43	3.5

ns: not significant
*0.05 > P > 0.01; **P < 0.01
CV = (sd / mean) 100

Comparisons between right and left side measurements of M1 and M2 were made using paired t-tests (statistical significance set at alpha = 0.05). In the Mongolian sample, there was no significant difference between sides but, in the Caucasian sample, there were significant differences between right and left sides, namely for TLMD and TRMD of M1, and TRMD, BL and TRBL of M2. The magnitude of differences ranged from 0.03 to 0.12 mm.

Table 1 shows basic descriptive statistics of crown diameters in the Mongolian and Caucasian samples for M1. When consideration was given to mesiodistal crown diameters, there was no significant difference between Mongolian and Caucasian samples on either right or left sides. However, all the buccolingual crown diameters of the Mongolian sample were significantly larger than those of Caucasians; that is, BL, TLBL and TRBL were all larger. Coefficients of variation showed that TLMD, TRMD and TRBL displayed the greatest variation in the Mongolian sample, and TLMD and TRMD also displayed high relative variability in the Caucasian sample.

Table 2 shows basic descriptive statistics of crown diameters in Mongolian and Caucasian samples for M2. Two dimensions displayed statistically significant differences between the samples: TLMD was significantly larger in Mongolians than in Caucasians, whereas TRMD was significantly smaller in Mongolians than in Caucasians. However, there was no significant difference between Mongolian and Caucasian samples in MD dimensions. With reference to the buccolingual crown diameters, there was a significant difference only for BL on the right side between the Mongolian and Caucasian samples. TLBL in Mongolians was significantly larger than those of the Caucasians but there was no statistically significant difference between the samples for TRBL. Coefficients of variation showed that MD, TLMD and TRMD displayed high relative variation in Mongolians and TLMD, TRMD also displayed high coefficients of variation in Caucasians.

Table 3 shows basic descriptive statistics of reduction indices of crown measurements for M2 compared with M1 in the Mongolian and Caucasian samples. For reduction indices of mesiodistal crown dimensions, there were two significant differences between Mongolian and Caucasian samples, namely MD and TRMD. Both were significantly smaller in Mongolians compared with Caucasians but the reduction index of MD was less than 100 whereas that for TRMD was over 100—indicating a reduction for MD but an enlargement for TRMD of M2 relative to M1. The values of reduction indices for TLMD were the lowest of all variables, indicating that the largest reduction in size from M1 to M2 occurred in TLMD in both Mongolian and Caucasian samples. For buccolingual crown dimensions, there was no significant difference in the mean value of reduction indices for BL between Mongolian and Caucasian samples. However, there was a significant difference in the mean reduction index of TLBL between samples, with the mean value being lower in Caucasians. There was also a significant difference for reduction indices of TRBL on the left side only between Mongolian and Caucasian samples.

DISCUSSION

The lower first molar begins to form around 30 weeks *in utero* and crowns have completed their formation at approximately three years after birth. In contrast, lower second molars commence to form around three years after birth and their crowns are fully-formed by approximately seven years (Christensen and Kraus, 1965; Oka and Kraus, 1969). Most permanent lower molars have five cusps: mesiobuccal, mesiolingual, distobuccal, distolingual, and distal. During formation the mesiobuccal cusp is always the first to start development, followed by mesiolingual, distobuccal, and then the distolingual. The last component of the crown to form is the distal cusp (Christensen and Kraus, 1965; Hillson, 1996). The trigonid consists of the mesiobuccal and mesiolingual cusps, while the talonid consists of the distobuccal, distolingual and distal cusps. In four-cusped molars, the distal cusp is missing.

Our study has shown that BL, TLBL and TRBL dimensions in M1 of the Mongolian sample were significantly larger than those of the Caucasian sample. In contrast, there was no significant difference in the MD, TLMD and TRMD dimensions. Thus, there was a significant size difference in buccolingual dimensions but not in mesiodistal dimensions between the two samples.

Tooth size variability appears to have a strong genetic component, but environmental factors are also of importance (Dempsey and Townsend, 2001). Indeed, there is evidence that common environmental contributions to tooth size variability are greater for buccolingual dimensions than mesiodistal ones (Townsend and Brown, 1978). The buccolingual diameters of both the talonid (distal part of the crown) and trigonid (mesial part of the crown) of M1 in Mongolians were significantly larger than in Caucasians. This suggests that common environmental effects, possibly related to the prenatal environment, as well as genetic influences, may be contributing to the differences in buccolingual dimensions between Mongolians and Caucasians.

For M2, there were significant differences between Mongolians and Caucasians for TLMD, TRMD, right BL and TLBL. The mean values for TLMD, TRMD and TLBL differed by around 5% whereas the difference in the means for BL (right side only) between Mongolians and Caucasians was around only 2%. The diameters of the talonid (TLMD and TLBL) of Mongolians were significantly larger than those of Caucasians. On the other hand, TRMD in Mongolians was significantly smaller than in Caucasians. Furthermore, there was no significant difference in TRBL. Thus, the mesiodistal and buccolingual diameters of the distal part of tooth crown in the Mongolian sample were significantly larger and the mesiodistal and buccolingual diameters of mesial part were significantly smaller compared with those of Caucasians. It is difficult to explain why this differential effect exists. It may be due to an interaction between these two crown components during development, with larger earlier-forming components being associated with smaller later-developing components. Alternatively, the finding could be due to chance variation associated with a small sample size.

The last tooth to develop in each class tends to be the most variable in size and shape (Dahlberg, 1945). This variability is thought to be due to greater environmental influence during development linked to a decrease in intrinsic genetic control over tooth size from the early to the late developing teeth within each class (Sofaer *et al.*, 1971). Given that the M2 develops later and over a longer period of time than the M1, it is reasonable to assume that this tooth may be subject to greater environmental pressures than would be applied to the M1. Indeed, the dimensions of M2 tended to display more variation, as evidenced by the values of CVs, than those of M1. The M2 develops later than the M1, therefore, environmental influences acting an each population may have contributed more to size variation than genetic factors for M2 compared with M1.

The reduction indices of MD and TRMD were significantly smaller in the Mongolian sample compared with Caucasians. This indicates that overall mesiodistal crown size of M2 in Mongolians, and also the mesiodistal size of the trigonid, are more reduced compared to M1. In contrast, the reduction indices for TRMD did not differ significantly between the samples. The reduction index for TLBL was larger in Mongolians, confirming that this dimension did not reduce as much in M2 compared with M1 as it did in Caucasians. Our results are consistent with the findings of Kondo *et al.* (2005) and show a tendency for increasing size in the mesial component of molar crowns and decreasing size in the distal component when comparing M2 to M1. They are also consistent with the findings of Yamada (1992) who noted that the distal part of molars was most affected by morphological variations, including tooth size reduction.

In the maxillary molars, the mesiobuccal cusp generally increases in size from M1 to M2 and reduces from M2 to M3. The mesiolingual cusp follows a pattern similar to that of the mesiobuccal, whereas the distobuccal cusp shows a marked reduction in size from M1 to M3 (Macho and Moggi-Cecchi, 1992). It would seem that there are also interactions between the mesial and distal crown components of maxillary molars as well as mandibular ones. The mesial crown component may tend to become larger to maintain the occlusal surface area of M2 as the distal component is reduced. A broader occlusal surface is likely to be advantageous for masticatory activity (*e.g.*, crushing and/or grinding food), and the enlargement of mesial crown component makes the occlusal surface broader as overall tooth size is reduced. Overall molar crown size and intra-coronal components showed differential patterns of reduction in the two study samples, as has been shown between other living human populations (Kanazawa *et al*., 1985; Kondo *et al*., 2005).

This study has investigated the size relationships between the talonid and trigonid of M1 and M2 in Mongolian and Caucasian samples. Sexual dimorphism was not explored in this study but it is planned to collect data from male Mongolians in the future. Once we have gained greater knowledge of tooth size variation in Mongolians, it will be of interest to compare tooth size in Mongolians with Japanese, bearing in mind that both groups share a Sinodont dental pattern.

ACKNOWLEDGEMENTS

We are grateful for the assistance of Associate Professor Shintaro Kondo who made valuable suggestions regarding study methods. We are also indebted to the staff of the Schools of Dentistry of both the Health Science University of Mongolia and the University of Adelaide. The dental casts of Mongolians used in this study were collected during a dental anthropological survey in 2006. The dental casts of Caucasians used in this study were collected from the students of the School of Dentistry, the University of Adelaide, from 1982 to 1991.

LITERATURE CITED

Chimge N, Batsuuri J. 1999. Interethnic genetic differentiation: HLA Class I antigens in the population of Mongolia. Am J Hum Biol 11:603-618.

Christensen GJ, Kraus BS. 1965. Initial calcification of the human permanent first molar. J Dent Res 44:1338-1342.

Dahlberg AA. 1945. The changing dentition of man. J Am Dent Assoc 32:676-690.

Dahlberg G. 1940. Statistical methods for medical and biological students. London: George Allen and Unwin Ltd.

Dempsey PJ, Townsend GC. 2001. Genetic and environmental contributions to variation in human tooth size. Heredity 86:685-693.

Fujita T. 1949. On the standard of the measurement of teeth. J Anthropol Soc Nippon 61:27-32 (In Japanese with German summary).

Goyal HD. 1999. A development perspective on Mongolia. Asian Survey 39:633-655.

Hanihara T, Ishida H. 2005. Metric dental variation of major human populations. Am J Phys Anthropol 128:287-298.

Hillson S. 1996. Dental anthropology. Cambridge, England: Cambridge University Press.

Kanazawa E, Sekikawa M, Akai J, Ozaki T. 1985. Allometric variation on cuspal areas of the lower first molar in three racial populations. J Anthropol Soc Nippon 93:425-438.

Kondo S, Funatsu T, Amino S, Sasa R, Wakatsuki E. 1998. An odontometrical analysis of the mandibular molariform teeth in the Japanese males. Pediatr Dent J 8:73-77

Kondo S, Townsend GC, Nakajima K, Yamada H, Wakatsuki E. 1999. Size of crown components of the mandibular deciduous and permanent molars in Australian Aborigines. In: Mayhall JT, Heikkinen T, editors. Dental morphology 1998. Oulu, Finland: Oulu University Press. p 150-156.

Kondo S, Townsend GC, Kanazawa E. 2005. Size relationships among permanent mandibular molars in Aboriginal Australians and Papua New Guinea Highlanders. Am J Hum Biol 17:622-633.

Macho GA, Moggi-Cecchi J. 1992. Reduction of maxillary molars in *Homo sapiens sapiens*: a different pespective. Am J Phys Anthropol 87:151-159.

Manabe Y, Oyamada J, Kitagawa Y, Rokutanda A, Kato K, Matsushita T. 2003. Dental morphology of the Dawenkou Neolithic population in North China: implications for the origin and distribution of Sinodonty. J Hum Evol 45:369-380.

Matsumura H. 1995. Dental characteristics affinities of the prehistoric to the modern Japanese with the East Asians, American Natives and Australo-Melanesians. Anthropol Sci 103:235-261.

Matsumura H, Hudson MJ. 2005. Dental perspectives on the population history of Southeast Asia. Am J Phys Anthropol 127:182-209.

Oka SW, Kraus BS. 1969. The circumnatal status of molar crown maturation among the Hominoidea. Arch Oral Biol 14:639-659.

Scott GR, Turner CG II. 1988. Dental anthropology. Ann Rev Anthropol 17:99-126.

Sofaer JA, Bailit HL, MacLean CJ. 1971. A developmental basis for differential tooth reduction during hominid evolution. Evolution 25:509-517.

Sofaer JA. 1973. A model relating developmental interaction and differential evolutionary reduction of tooth size. Evolution 27:427-434.

Townsend GC, Brown T. 1978. Heritability of permanent tooth size. Am J Phys Anthropol 49:497-504.

Turner CG II. 1990. Major features of Sundadonty and Sinodonty, including suggestions about east Asian microevolution, population history, and late Pleistocene relationships with Australian Aboriginals. Am J Phys Anthropol 82:295-317.

Van Valen L. 1962. Growth field in the dentition of Peromyscos. Evolution 16:272-277.

Yamada H. 1992. On the “talonid” in Japanese lower molars. Jpn J Oral Biol 34:15-24 (In Japanese with English summary).

A Longitudinal Study of Continued Tooth Eruption During Adulthood

Edward F. Harris* and Yoav Shiloah

College of Dentistry, University of Tennessee, Memphis, Tennessee

ABSTRACT Teeth retain their capacity to continue to erupt throughout life. What is less-well appreciated is that occlusal migration—with corresponding alveolar proliferation—continues as a normal process during adulthood. Historically, this continuous eruption has been viewed as accommodative for the loss of crown height due to serious occlusal abrasion. Nowadays, with only trivial wear, the result of continuous eruption is to increase lower face height during adulthood. This study reports on changes in the mandibular first and second molars in 73 Americans whites (63 females) examined at 17 and again at about 31 years of age. A computer-assisted method was used to measure alveolar and dental changes using the inferior alveolar canal as a fiducial benchmark. Each molar's image was scaled to the mesiodistal molar crown dimension measured from that subject's dental cast. Major findings were: Both lower molars erupted during adulthood to statistically significant extents, more so in men. Alveolar bone proliferated apace with the coronal tooth migration, so the CEJ-to-crestal bone distance did not change in these healthy, young, dentate adults. First and second molar roots increased in length, apparently by the progressive deposition of cementum. Prior studies have documented continuous eruption in peoples with severe occlusal wear; this study shows that comparable increases occur without any macroscopic loss of tooth substance. These normative changes that—assumedly occur in both jaws—have discernible, cumulative effects on lower face height and facial proportions in adulthood. *Dental Anthropology* 2007;20:7-15.

In spite of extensive work on the subject, the forces that cause a tooth to erupt—to move coronally into occlusion—are poorly understood (Marks and Cahill, 1984; Steedle and Proffit, 1985; Gorski and Marks, 1992; Wise *et al*., 2002). Indeed, research now suggests that much of the information gleaned from studying rodents (with rootless, continuously erupting incisors) may not apply to humans. Moreover, the forces responsible for a tooth's movement in its pre-emergent phase may be different from those that carry the erupted tooth into occlusion (Lee and Proffit, 1995; Trentini *et al*., 1995).

Tooth eruption conventionally refers to the rather rapid movement of a tooth from its formative position in its bony tooth crypt coronally into functional occlusion (Sato and Parsons, 1990). This is active tooth eruption and, for the permanent teeth, the eruptive phase (ignoring the third molars) starts around 6 years of age and is completed around 12 years of age (Hurme, 1949). Less well studied is the second, slow and protracted, albeit cumulative phase of tooth eruption termed continuous eruption. This consists of coronal movements of the permanent teeth that occur well after the active phase and that increases in crown height increase lower face height and change facial proportions with age (Iseri and Solow, 1996).

Early studies (Manson, 1963; Bhaskar, 1962) suggested that teeth moved coronally during adulthood such that the CEJ-to-crestal bone distance increases. The argument was that teeth erupted more than bony remodeling could keep pace, thereby exposing more root coronal to the bone. These findings were readily criticized because inflammatory periodontitis—which has been prevalent (Carranza and Newman, 1996)—produces the same increase in CEJ-to-crestal bone distance over time.

Subsequent work shows that the "mobile" feature actually is both the tooth and the gingival and crestal bone (Murphy, 1959;Levers and Darling, 1983; Whittaker *et al*., 1990; Dannenberg *et al*., 1991). This difference in perspective was documented definitively by Iseri and Solow (1996) who studied cephalographs taken by Arne Björk of people in whom metallic implants had been placed (Björk, 1968). In contrast to conventional bony landmarks that remodel with age (*e.g*., Nasion, Menton), metallic implants remain immobile, sequestered in the bone proper (Enlow, 1977). These metallic implants serve as immobile fiducial landmarks against which skeletodental growth can be quantified without distortion (Björk and Skieller, 1972, 1977). Iseri and Solow studied subjects in their later teens and twenties, which is several years after the last teeth had erupted into occlusion (ignoring M3s). Findings were (A) that

---

*Correspondence to: Edward F. Harris, College
of Dentistry, University of Tennessee, Memphis,
Tennessee 38163
E-mail: eharris@utmem.edu

continuous eruption was a normative consequence of ageing, (B) that that continuous eruption occurred in all teeth, and (C) that there was greater coronal eruption of the distal teeth than the anterior teeth, so the occlusal plane flattened with age. While quite informative, this study was restricted to the study of females (one supposes that changes in males would be greater; Behrents, 1985; Bishara *et al*., 1994) and, again, most subjects were followed just to their early 20s. One considerable value of this study was its longitudinal design—the same individuals were examined serially—so *individual* changes with time could be quantified.

Cross-sectional data are, however, far more available. A key study in this area was by Varrela and coworkers (1995). Varrela examined archeologically derived material from a European archeological site and grouped the mandibles into age intervals based on age at death. Results showed that even accounting for the insensitive cross-sectional nature of the design, continuous eruption—measured as increasing distance from the cementoenamel junction (CEJ) to the inferior alveolar canal—was evident.

As in the study by Varrela, most peoples (historically and prehistorically) have exhibited appreciable occlusal wear, which reduces crown height. It commonly has been speculated that continuous eruption is an adaptive, accommodative response to the need to extend a tooth's functional longevity. Continuous eruption provides greater tooth mass before, as was common, occlusal attrition wears the tooth to the gum line. Begg, speaking of the prehistoric Australian condition, contended that, "Tooth eruption does not stop at the neck of the teeth, but proceeds apically to the ultimate shedding of the teeth if we live long enough. Continued tooth eruption rendered continual tooth attrition harmless" (Begg and Kesling, 1971:26). Nowadays, with virtually no grit in the diet, occlusal attrition is trivial, even in advanced age, so this accommodative increase in crown height provides no selective advantage. Instead, continuous eruption without occlusal attrition simply increases lower face height.

Purpose of the present study was to test whether continuous eruption is discernible in a sample of contemporary Americans who were followed radiographically from their mid-teens to about 30 years of age. The sample consists of people who had received comprehensive orthodontic treatment starting at the conventional age of around 13 years of age, with completion around 16 years of age. The cases were reexamined at a long-term follow-up at an average of 30.7 years of age. This study reports on continuous eruption of the mandibular molars between these two examinations (ca. 17 and 31 years of age).

MATERIALS AND METHODS

Data for this study were collected from an on-going project involving the long-term recall of patients who, at adolescence, had received comprehensive orthodontic treatment. The end of treatment averaged 16.7 years (sd = 1.8 years), and the average age at the recall examination was 30.7 years (sd = 6.8 years), so the mean duration was 14.0 years. Statistically, there was no difference in any age parameter between males and females. All of the subjects in this study (n = 73) are American whites, and there is a preponderance of females (n = 63) because several women had their recall examination when they brought their own child to the orthodontist for treatment.

A computer-assisted photogrammetric method was used to obtain the measurements. The panoramic film was digitized at high resolution on a flat-bed scanner, and the image was imported into SigmaScan Pro 5.0 (SPSS Inc., Chicago, IL), where the image was enlarged several-fold (which facilitates landmark location but does not affect actual dimensions), landmarks were located, and the program generated the desired variables.

Reliance on panoramic radiographs introduces variability because the source-to-film distance and the object-to-film distance are only approximately standardized. When taking a given film, the operator chooses from among a few pre-set trough paths based on the patient's size and facial form. The "trough" is the two-dimensional pathway that the source (cathode) tracks around the person's head. Ideally, the trough scribed by the machine parallels the shape of the person's dental arches.

Landmark studies regarding continuous eruption (Thompson and Kendrick, 1964; Levers and Darling 1983) used data collected from panoramic radiographs, though their data were cross-sectional. When studying skeletal specimens, radiation exposure is irrelevant, and bone-holding devices can be rigged to provide stationary periapical (or equivalent) X-rays with known radiographic magnification (Whittaker *et al*., 1990). In the future, the increasingly prevalent use of three-dimensional cone-beam computed tomography will provide measurements that are fully corrected for magnification (*e.g*., Cevidanes *et al*., 2006, 2007). Such long-term longitudinal data are not, however, available now, so we felt warranted in using the panoramic data to test—using longitudinal data—whether changes in tooth length are discernible. In our opinion, long-term longitudinal radiographic data on the living are scarce enough that analysis is warranted—given appropriate caveats—even though the X-rays cannot be exactly standardized.

Measurements were made using a common technique (Whittaker *et al*., 1985; Varrela *et al*., 1995). The inferior alveolar canal was used as the fiducial landmark. The invariance of this neural structure has been confirmed by the metallic implant studies of Björk (1956, 1963). The longitudinal midline of a molar was defined by visual best fit (Fig. 1). Four landmarks were located along this line: (1) the cementoenamel junction (CEJ); (2) height of the crestal bone along the molar's midline; (3) the apical plane defined by the line through the tooth's mesial and distal root apices; and (4) superior aspect of the cortical bones of the inferior alveolar canal. In addition, we measured the height of the crestal bone separately at the mesial and distal aspect of the molar down to the IAC measured parallel with the molar's long axis.

There is no absolute scale on a panoramic radiograph, so we scaled each image to millimeters by using the specific molar's mesiodistal crown diameter measured from the dental cast taken at the same appointment. Tooth dimensions were obtained in a standardized manner (Moorrees, 1957) using sliding calipers. In other words, each individual molar's mesiodistal crown size was recorded from its panoramic image and from the associated dental cast, and the computer measurements were scaled to millimeters for each tooth. A panoramic radiographic image exhibits variable magnification because the X-ray head is not everywhere equidistant from the dental structures (Graber, 1967), but the pathway is least curvilinear in the buccal segment where the molars are situated. As described below, the complex of skeletodental changes found here cannot be explained by differences in magnification.

The inferior alveolar canal in the mandible is visible radiographically starting at the lingula and descending downward-and-forward to the premolar region where, in our experience, it seldom can be followed any farther. Consequently, we only measured the first and second molars. So far as possible, all four molars in the lower two quadrants were measured, but teeth with poor images were omitted. These young adults were in reasonably good oral health, and each molar was in contact with the tooth mesial to it, so there was no apparent instance of tipping. Also, all molars had an antagonist.

Measurement error is an issue because the changes are fairly subtle. Repeatability error was assessed using the conventional Dahlberg statistic (Dahlberg, 1940; Bland and Altman, 1996) and the intraclass correlation coefficient (from nested analysis of variance), which is the proportion of the total variation due to differences between measurements of the same individuals (i.e., repeatability error). There was no substantive difference among the types of variables, and, overall, Dahlberg's d was 0.31 mm. That is, the average error due to discrepancies in measurement was one-third of a millimeter, which is appreciably less than any of the statistically significant differences found here. The intraclass correlation was 0.987, meaning that just 1.3% of the observed variation was attributable to discrepancies in measuring the same dimensions repeatedly.

Statistically, repeated-measures analysis of variance was used to exploit the longitudinal nature of the data as well as the paired M1-M2 comparisons within individuals (Winer *et al*., 1991; Sokal and Rohlf, 1995). Statistics were calculated using JMP 5.0.2 (SAS Institute Inc., Cary, NC).

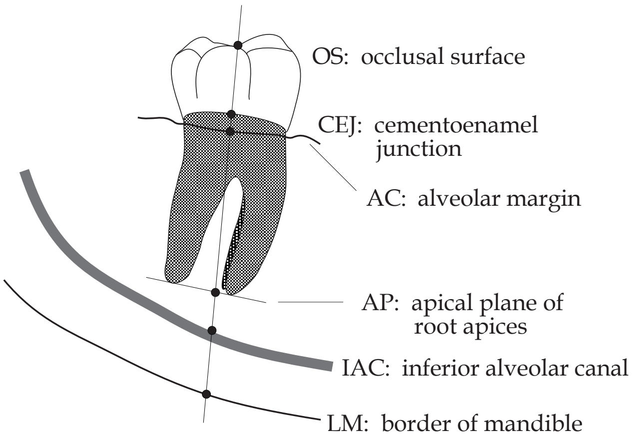


Fig. 1. Diagram showing the landmarks that were digitized for each mandibular molar. The vertical line through the tooth defines its long axis, and measurements were made along this best-fit line. The landmarks, from top to bottom, depict the crown's occlusal surface (OS), the CEJ, the alveolar crest (at its intersection with the tooth's long axis), the root apex (where a line defined by the mesial and distal roots crosses the long axis), the inferior alveolar canal, and the inferior border of the mandibular corpus.

RESULTS

Descriptive statistics are presented separately by sex because, as is characteristic (Behrents, 1985; Bishara *et al*., 1994), males exhibit more facial growth during their teens and early twenties. Also, changes in the first and second molar are described separately because, while the changes are comparable, the second molar is smaller, closer to the inferior alveolar canal (IAC), and migrates occlusally somewhat less than M1 (Table 1).

First Molar

At T1 (mean = 16.7 years) the root apices were about 5 mm above the IAC, and, as shown in Table 2, this distance increased to about 6 mm at T2 (mean = 30.7 years). This increase—adjusted to one decade of change across all subjects (Table 3)—was about 1 mm/decade in males and half this (which is significantly less) in females, with both changes being highly significant statistically. If, instead, one measures the distance from the IAC up to the CEJ, these increases are appreciably larger. The change in the IAC-CEJ distance was 1.7 mm/decade in males and 1.0 mm/decade in females. Again, both of these increases are highly significant (Table 3), and the change in men significantly exceeds that in women (Table 4).

The difference between these two distances (IAC to AP and IAC to CEJ) is informative in that it shows that, while M1 is erupting occlusally, there is evidence

TABLE 1. Results of two-way analysis of variance testing for size differences between molars and by sex[1]

	Molar[2]		Sex		Molar-x-Sex	
Variable	F Ratio	P value	F Ratio	P value	F Ratio	P value
IAC to AP, T1	34.43	< 0.0001	0.13	0.7169	1.97	0.2807
IAC to AP, T2	54.28	< 0.0001	0.00	0.9837	0.10	0.7538
IAC to CEJ, T1	245.71	< 0.0001	0.00	0.9411	0.02	0.8920
IAC to CEJ, T2	310.50	< 0.0001	1.62	0.2111	2.78	0.1037
Root Length, T1	70.69	< 0.0001	0.46	0.4997	2.06	0.1592
Root Length, T2	67.41	< 0.0001	5.30	0.0267	3.35	0.0749
CEJ to Crestal Bone, T1	3.55	0.0747	0.53	0.4698	1.16	0.2886
CEJ to Crestal Bone, T2	0.55	0.4643	3.02	0.0901	0.11	0.7379
IAC to Crestal Bone, Mesial T1	93.47	< 0.0001	0.02	0.9007	0.03	0.8686
IAC to Crestal Bone, Mesial T2	153.86	< 0.0001	0.98	0.3275	3.43	0.0716
IAC to Crestal Bone, Distal T1	169.55	< 0.0001	0.00	0.9910	0.69	0.4115
IAC to Crestal Bone, Distal T2	253.98	< 0.0001	0.18	0.6736	1.15	0.2891

[1] Numerator df is 1 and denominator df is 40 for each test.

[2] Both M1 and M2 could be measured for most subjects, so "Molar" was treated as a repeated measure, which provides greater statistical power (but limits the sample sizes to cases where both molars were measurable). The ANOVA is, then, a mixed model.

TABLE 2. Descriptive statistics, by sex

		Males			Females	
Variable	n	Mean	sd	n	Mean	sd
		Mandibular First Molar				
IAC to AP, T1	15	5.00	2.18	84	5.49	2.01
IAC to AP, T2	15	6.24	2.45	84	6.03	2.02
IAC to CEJ, T1	15	18.89	1.96	84	19.06	2.59
IAC to CEJ, T2	15	21.08	3.00	84	20.15	2.61
Root Length, T1	15	13.88	1.16	84	13.57	1.66
Root Length, T2	15	14.84	2.03	84	14.11	1.57
CEJ to Crestal Bone, T1	15	1.82	0.35	84	1.98	0.55
CEJ to Crestal Bone, T2	15	2.11	0.56	84	1.98	0.57
IAC to Crestal Bone, Mesial T1	15	17.94	2.13	84	18.27	2.09
IAC to Crestal Bone, Mesial T2	15	19.77	2.83	84	19.07	2.12
IAC to Crestal Bone, Distal T1	15	15.81	2.51	84	16.45	2.20
IAC to Crestal Bone, Distal T2	15	17.58	2.99	84	17.48	2.17
		Mandibular Second Molar				
IAC to AP, T1	10	4.48	2.02	50	4.30	2.56
IAC to AP, T2	10	5.16	2.30	50	4.88	2.65
IAC to CEJ, T1	10	16.72	2.27	50	16.40	2.63
IAC to CEJ, T2	10	18.75	3.39	50	17.36	2.88
Root Length, T1	10	12.24	0.95	50	12.09	1.76
Root Length, T2	10	13.58	2.07	50	12.48	1.77
CEJ to Crestal Bone, T1	10	1.83	0.37	50	1.85	0.50
CEJ to Crestal Bone, T2	10	2.32	0.42	50	2.03	0.59
IAC to Crestal Bone, Mesial T1	10	16.38	2.78	50	16.18	2.35
IAC to Crestal Bone, Mesial T2	10	17.58	3.33	50	16.91	2.52
IAC to Crestal Bone, Distal T1	10	13.70	2.84	50	13.50	2.17
IAC to Crestal Bone, Distal T2	10	14.57	3.24	50	14.41	2.46

TABLE 3. Changes standardized to 1 decade, sex-specific one-sample t-tests of whether the changes are significant statistically, and tests of whether the amounts of change differ between males and females

	Males					Females					Test for Sex Dimorphism	
Variable	n	mean	sd	t-test	P value	n	mean	sd	t-test	P value	F ratio	P value
Mandibular First Molar												
Δ IAC to AP	15	0.989	0.612	6.25	< 0.0001	84	0.505	0.696	6.65	< 0.0001	6.36	0.0133
Δ IAC to CEJ	15	1.727	1.011	6.61	< 0.0001	84	1.021	1.027	9.11	< 0.0001	6.06	0.0156
Δ Root Length	15	0.739	0.918	3.11	0.0076	84	0.516	0.820	5.77	< 0.0001	0.91	0.3430
Δ CEJ-Crestal Bone	15	0.155	0.518	1.16	0.2657	84	-0.043	0.472	0.83	0.4075	2.17	0.1436
Δ Crestal Bone-IAC Mesial	15	1.423	0.996	5.54	< 0.0001	84	0.786	1.066	6.75	< 0.0001	4.63	0.0338
Δ Crestal Bone-IAC Distal	15	1.404	0.668	8.14	< 0.0001	84	1.052	1.228	7.85	< 0.0001	1.16	0.2832
Mandibular Second Molar												
Δ IAC to AP	10	0.420	0.459	2.90	0.0177	50	0.475	0.585	5.74	< 0.0001	0.08	0.7799
Δ IAC to CEJ	10	1.341	1.146	3.70	0.0049	50	0.837	0.897	6.60	< 0.0001	2.39	0.1272
Δ Root Length	10	0.921	1.057	2.76	0.0222	50	0.362	0.910	2.81	0.0070	2.99	0.0893
Δ CEJ-Crestal Bone	10	0.341	0.497	2.17	0.0579	50	0.158	0.538	2.08	0.0428	0.99	0.3242
Δ Crestal Bone-IAC Mesial	10	0.811	0.611	4.20	0.0023	50	0.725	1.162	4.41	< 0.0001	0.05	0.8218
Δ Crestal Bone-IAC Distal	10	0.522	0.752	2.19	0.0560	50	0.852	1.082	5.57	< 0.0001	0.84	0.3615

of root remodeling (probably cementum deposition) that lengthens the roots and diminishes the apparent movement of the teeth away from the IAC. In other words, the roots lengthened from T1 to T2, and the increase was about 0.6 mm/decade in both sexes (Fig. 2).

The other measurements (Tables 1-2) define the molar's relationship to the crestal bone. The vertical distance from the CEJ to the crestal bone (measured at the middle of the crown; Fig. 1) did not change with time in these healthy subjects. The distance is just under 2 mm at both examinations. On the other hand, measuring height of the CEJ vis-à-vis the IAC makes it evident that the alveolar bone is appositional with age, such that its height increases an average of 1.4 mm/decade in men and a bit less in women (Table 3). So, while M1 is slowly erupting to the occlusal, alveolar bone being is deposited to keep pace. Table 2 shows that the crestal bone height is roughly 2 mm greater on the mesial than the distal aspect of M1, but this merely reflects the upward curvature of the IAC as it courses distally toward the lingula.

Second Molars

As shown by the ANOVA tests in Table 1, almost all of the dimensions taken at the second molar are substantially different than for M1. This primarily has to do with the upward curve of the IAC as it passes beneath this distal molar that provide different distances to the bone and tooth structures compared to M1. While the dimensions differ between teeth, the changes for M1 and M2 are comparable. At T1, apices of the M2 roots were about 4.5 mm superior to the IAC, and this distance increased to about 5.0 mm at T2. Adjusted to change-per-decade, the IAC-AP distances increased about one-half millimeter per decade in both sexes. Again, this distance was attenuated by remodeling of the root apices because the increase in the distance from the IAC up to the CEJ is twice as great (Table 3), averaging 1.3 mm/decade in men and 0.8 mm/decade in women.

At T2, there is suggestive evidence of some crestal bone loss with age, averaging 0.2 to 0.3 mm/decade, which is only marginally significant statistically ($P = 0.06$ in men; $P = 0.04$ in women). Of note, the net remodeling of bone around M is appositional, because there are increases of around 0.8 mm/decade when bone height is measured relative to the invariant IAC rather than the upwardly-migrating tooth.

DISCUSSION

Alveolar Bone

Enlow and Harris (1964) showed that the corpus is everywhere appositional throughout the active phase of growth, so width and height (and mechanical resilience) of the corpus increase with age. Israel (1979) documented that these trends continue well into adulthood. In the present study, dealing with dentate

TABLE 4. Results of two-way analysis of variance testing for differences in changes (standardized to 1 decade) from T1 to T2 between molars and by sex[1]

	Molar		Sex		Molar-x-Sex	
Variable	F Ratio	P value	F Ratio	P value	F Ratio	P value
IAC to AP	1.27	0.2669	0.06	0.8123	0.32	0.5766
IAC to CEJ	1.83	0.1834	3.89	0.0457	1.38	0.2470
Root Length	0.01	0.9202	5.49	0.0243	0.28	0.6006
CEJ-Crestal Bone	0.97	0.3298	5.63	0.0226	1.35	0.2514
IAC to Crestal Bone, Mesial	3.66	0.0631	0.67	0.4187	2.66	0.1111
IAC to Crestal Bone, Distal	6.38	0.0157	0.03	0.8715	2.33	0.1349

[1] These are mixed-model ANOVA tests, with repeated measures on Molar while Sex is a fixed effect; degrees of freedom are 1 and 39 for each test.

young adults, alveolar bone continued to be deposited along the surface such that corpus height provided by the alveolar crestal bone (above the IAC) increased about 1.5 mm/decade in men and just under 1 mm/decade in women. This bony apposition increases lower face height. The rate is significantly slower in women, though still significant statistically.

Continuous tooth eruption keeps pace with the proliferation of alveolar bone. Indeed, in these healthy young adults, the distance from the CEJ down to the crestal bone did not change with age even though the molars moved coronally about 1 mm in women and an average of 2 mm in men (Table 2).

The question of whether the CEJ has a constant relationship with crestal bone (CB) with advancing age has been contentious, primarily because an increase in this distance can more parsimoniously be attributed to chronic inflammatory periodontal disease than to continued tooth eruption. Danenberg *et al*. (1991) documented significant increases in the CEJ-CB distance with advancing age in Australian Aborigines. These authors found no bony evidence of periodontal disease and contended that the increases were evidence of continued tooth eruption during adulthood. Other

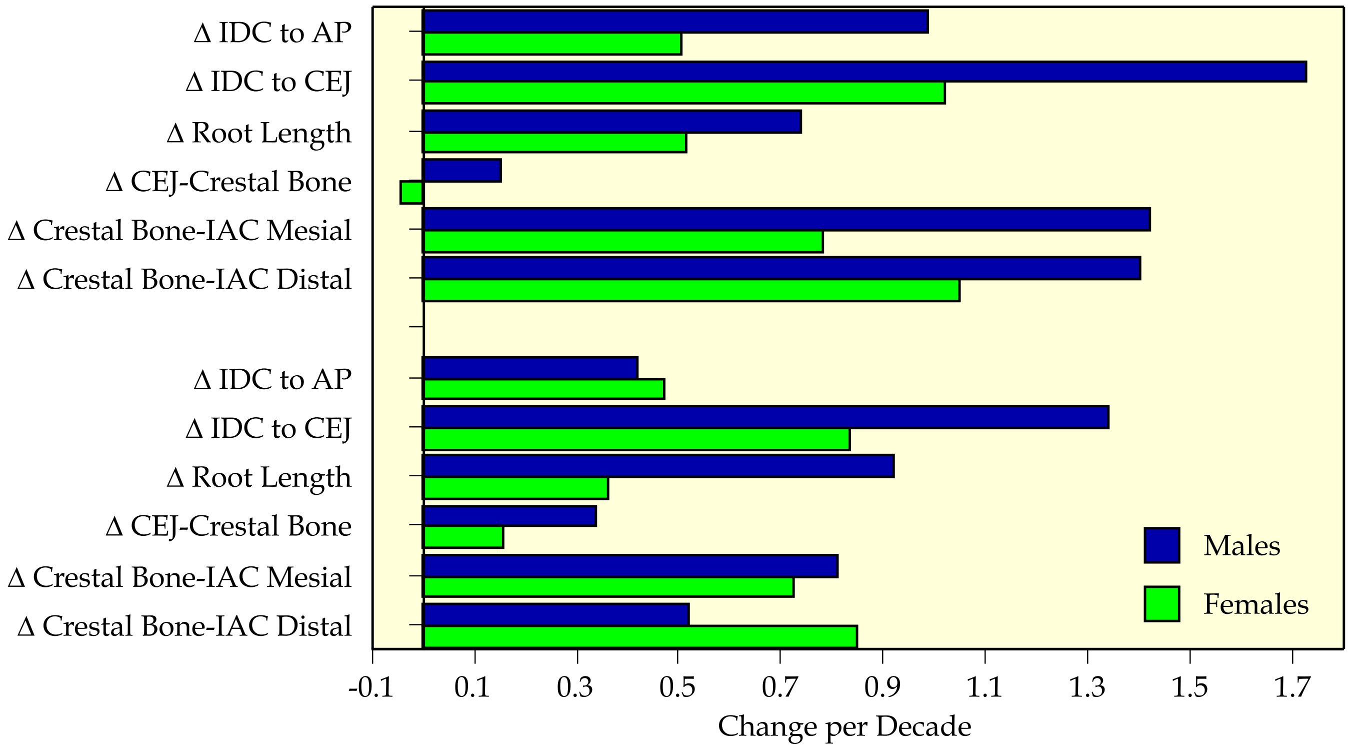


Fig. 2. Dimensional changes in lower molars, by sex and molar. The T1 to T2 changes have been standardized to one decade (10 years) on an individual basis.

researchers (Whittaker *et al*., 1990; Varrela *et al*., 1995) found only small, statistically nonsignificant increases in the CEJ-CB distance with advancing age. There was no change in this distance in the present study, though these adults may be too young and the interval may be too short to disclose such changes. During the observed age interval, the molars erupted significantly, especially in men, but alveolar bony proliferation was fully as aggressive.

Continuous Eruption

Continuous eruption refers to a tooth's life-long potential to further erupt. This capacity is readily observed in people who have lost an antagonist, where the unimpeded tooth supererupts (*e.g*., Compagnon and Woda, 1991; Yonezu and Machida, 1997). Similarly, orthodontists have experience "helping" a tooth erupt with the use of traction forces (*e.g*., Stevens and Levine, 1998; Durham *et al*. 2004) virtually regardless of the patient's age. The antithesis of this phenomenon is the ankylosed tooth (and osseointegrated implant) that becomes progressively submerged as adjacent teeth and surrounding alveolar bone continue to migrate occlusally (Ödman *et al*., 1991; Roberts, 1994). Of more general relevance, is whether continuously eruption is a dentition-wide phenomenon that characteristically occurs in all adults? Prior studies (Newman and Levers, 1979; Whittaker *et al*., 1982, 1985, 1990; Varrela *et al*., 1995) have shown that continous eruption does occur during adulthood, but (A) these studies have been cross-sectional, based on skeletal remains of subjects who died at different ages, (B) most studies have combined males and females, and (C) studies have used peoples who experienced moderate-to-severe occlusal wear because they lived on coarse, abrasive diets. It might be argued (Levers and Darling, 1983) that substantial occlusal wear increases freeway space, thereby "making room" for additional, compensatory tooth eruption. What happens in the absence of attrition? The modern American diet is so highly refined and grit-free that young adults present without any wear facets and most people never experience dentin exposure due to dietary abrasion. Consequently, there is only inconsequential loss of vertical dental height.

The theme of some studies has been that continous eruption occurs *because* of substantial attrition. For example, Begg (1954) contended that the severe occlusal wear that occurred in prehistoric Australian Aboriginals "made room" for the teeth to erupt farther. Murphy (1959), Levers and Darling (1983), and several others likewise have assumed that continuous eruption is the *respondent* and occurred when the opportunity was created by occlusal abrasion. As seen in the present study, eruption is occurring continuously and seemingly at equivalent rates even in the absence of any macroscopic abrasion. Whittaker *et al*. (1990) reported comparable findings from a 19th century British series where abrasion was slight. It seems that eruption is an ongoing physiological process that is indifferent to whether the crowns are worn down. It may well be that tooth eruption proceeds during adulthood simply because the forces causing eruption are never disabled.

The present study shows that lower face height is enhanced because the tooth itself migrates occlusally (presumably in both arcades; Iseri and Solow, 1996) but also because bone is proliferating apace with the teeth. The present study also documents the significantly greater rate of growth in men than women, notably in the vertical dimension. This is consistent with cephalometric studies of changes during adulthood (*e.g*., Forsberg, 1979; Behrents, 1986; Bishara *et al*., 1994) where growth is notably greater in men. The same has been reported from earlier, cross-sectional craniometric studies of dentate adults (Lasker, 1953; Thompson and Kendrick, 1964). This also was documented by West and McNamara (1999) who suggested that the increase in lower face height "probably is compensatory, resulting from either continued dental eruption, continued alveolar growth, or both, to balance the occlusions with the skeletal growth that is occurring." Opinions may differ as to what skeletodental changes are "balancing" and compensatory and which are passive respondents, but the net effect is slow but cumulative increase in adult facial dimensions, and the present study confirms that *both* tooth eruption *and* alveolar growth are contributory.

Root Length

At first impression, it probably is surprising to find that root length increased with age in this study, both for M1 and M2 and in both sexes. Indeed, the more common issue in the orthodontic literature deals with how treatment causes apical root resorption (Samehsima and Sinclair 2001a,b; Harris 2000), though there seems to be no posttreatment progression of the problem (Remington *et al*., 1989). Review of the literature suggests that there are very few longitudinal studies of root dimensions in adults. Cross-sectional studies, such as by Woods and coworkers (1990), typically encounter too much inter-individual variability to find any trend with age. The study by Bishara *et al*. (1999) is the most informative here. Bishara and coworkers had periapical films of the same 26 individuals at an average age of about 25 years and again at 45 years of age. Six of their comparisons of 32 root lengths (of 28 teeth) exhibited statistically significant increases in root length over time. However, when the Bonferroni correction for multiple comparisons was applied (which may be too conservative—see Holm, 1979; Rice, 1989), none of the changes remained significant. This led the authors to conclude "that there were no significant changes in root lengths between 25 and 45 years of age in either males or females."

This conclusion is perhaps overly cautious since other studies—albeit cross-sectional—have found that root lengths increase discernibly with age. Researchers have consistently attributed these increases to the accumulation of cementum, which is known to accumulate at a fairly regular pace (Wittwer-Backofen *et al*. 2004). Levers and Darling (1983) reported "continuous lengthening" of the roots with age, "presumably by cementum deposition." Whittaker *et a*l. (1990) found that root apices migrated away from the IAC significantly less than the CEJ, which they attributed to cementum apposition that lengthened the roots. Similarly, Varrela *et al*. (1990) reported that the CEJ-AP distances increased across age grades, with the most notable increases on M2.

SUMMARY

This longitudinal study spans late adolescence and early adulthood (*ca*. 17 to 30 years of age). Continued occlusal eruption is documented for the mandibular molars, with significantly greater changes in men than women. Importantly, the alveolar bone proliferated at the same rate, so crestal bone height remains the same distance from the molar's CEJ. Continuous eruption—in the effective absence of attrition—contributes to increasing lower face height.

LITERATURE CITED

Begg RP. 1954. Stone age man's dentition: with reference to anatomically correct occlusion, the etiology of malocclusion, and a technique for its treatment. Am J Orthod 40:298-312, 373-383, 462-475, 517-531.

Begg RP, Kesling PC. 1971. Begg orthodontic theory and technique, 2nd ed. Philadelphia: WB Saunders.

Behrents RG. 1985. Growth in the aging craniofacial skeleton. Monograph 17, Craniofacial Growth Series. Ann Arbor: Center for Human Growth and Development, University of Michigan.

Bhaskar SN. 1962. Synopsis of oral histology. St Louis: CV Mosby Company.

Bishara SE, Treder JE, Jakobsen JR. 1994. Facial and dental changes in adulthood. Am J Orthod Dentofac Orthop 106:175-186.

Bishara SE, Vonwald L, Jakobsen JR. 1999. Changes in root length from early to mid-adulthood: resorption or apposition? Am J Orthod Dentofacial Orthop 115:563-568.

Björk A. 1956. Facial growth in man, studied with the aid of metallic implants. Acta Odont Scand 13:9-34.

Björk A. 1963. Variations in the growth pattern of the human mandible: longitudinal radiographic study of the implant method. J Dent Res 42:400-411.

Björk A. 1968. The use of metallic implants in the study of facial growth in children: method and application. Am J Phys Anthropol 29:243-254.

Björk A, Skieller V. 1972. Facial development and tooth eruption. Am J Orthod 62:339-383.

Björk A, Skieller V. 1977. Growth of the maxilla in three dimensions as revealed radiographically by the implant method. Br J Orthod 4:53-64.

Bland JM, Altman DG. 1996. Measurement error. BMJ 313:744.

Carranza FA, Newman MG. 1996. Glickman's clinical periodontology, 7th ed. Philadelphia: WB Saunders.

Cevidanes LH, Bailey LJ, Tucker SF, Styner MA, Mol A, Phillips CL, Proffit WR, Turvey T. 2007. Three-dimensional cone-beam computed tomography for assessment of mandibular changes after orthognathic surgery. Am J Orthod Dentofacial Orthop 131:44-50.

Cevidanes LH, Styner MA, Proffit WR. 2006. Image analysis and superimposition of 3-dimensional cone-beam computed tomography models. Am J Orthod Dentofacial Orthop 129:611-618.

Compagnon D, Woda A. 1991. Supraeruption of the unopposed maxillary first molar. J Prosthet Dent 66:29-34.

Dahlberg G. 1940. Statistical methods for medical and biological students. London: George Allen and Unwin, Ltd.

Dannenberg PJ, Hirsch RS, Clarke NG, Leppard PI, Richards LC. 1991. Continuous tooth eruption in Australian aboriginal skulls. Am J Phys Anthropol 85:305-312.

Durham TM, Goddard T, Morrison S. 2004. Rapid forced eruption: a case report and review of forced eruption techniques. Gen Dent 52:167-175.

Enlow DH. 1977. The remodeling of bone. Yrbk Phys Anthropol 20:19-34.

Enlow DH, Harris DB. 1964. A study of the postnatal growth of the human mandible. Am J Orthod 50:25-50.

Forsberg CM. 1979. Facial morphology and ageing: a longitudinal cephalometric investigation of young adults. Eur J Orthod 15-23.

Gorski JP, Marks SC Jr. 1992. Current concepts of the biology of tooth eruption. Crit Rev Oral Biol Med 3:185-206.

Graber TM. 1967. Panoramic radiography in orthodontic diagnosis. Am J Orthod 53:799-821.

Harris EF. 2000. External apical root resorption resulting from orthodontic tooth movement. Semin Orthod 6:183-194.

Holm S. 1979. A simple sequentially rejective multiple test procedure. Scand J Statist 6:65-70.

Hurme VO. 1949. Ranges of normalcy in the eruption of permanent teeth. ASDC J Dent Child 16:11-15.

Iseri H, Solow B. 1996. Continued eruption of maxillary incisors and first molars in girls from 9 to 25 years, studies by the implant method. Eur J Orthod 18:245-256.

Israel H. 1979. Evidence for continued apposition of adult mandibular bone from skeletalized materials. J Prosthet Dent 41:101-104.

Lasker GW. 1953. The age factor in bodily measurements of adult male and female Mexicans. Hum Biol 25:50-63.

Lee CF, Proffit WR. 1995. The daily rhythm of tooth eruption. Am J Orthod Dentofac Orthop 107:38-47.

Levers BGH, Darling AI. 1983. Continuous eruption of some adult human teeth of ancient populations. Arch Oral Biol 28:401-408.

Manson JD. 1963. Passive eruption. Dent Practit 14:2-9.

Marks SC, Cahill DR. 1984. Experimental study in the dog of the nonactive role of the tooth in the eruptive process. Arch Oral Biol 29:311-322.

Moorrees CFA. 1957. The Aleut dentition: a correlative study of dental characteristics in an Eskimoid people. Cambridge: Harvard University Press.

Murphy T. 1959. Compensatory mechanisms in facial height adjustment to functional tooth attrition. Aust Dent J 4:312-23.

Newman HN, Levers BG. 1972. Tooth eruption and function in an early Anglo-Saxon population. J R Soc Med 72:341-350.

Ödman J, Gröndahl K, Lekhom U, Thilander B. 1991. The effect of osseointegrated implants on the dento-alveolar development: a clinical and radiographic study in growing pigs. Eur J Orthod 13:279-286.

Remington DN, Joondeph DR, Artun J, Riedel RA, Chapko MK. 1989. Long-term evaluation of root resorption occurring during orthodontic treatment. Am J Orthod Dentofacial Orthop 96:43-46.

Rice WR. 1989. Analyzing tables of statistical tests. Evolution 43:223-225.

Roberts WE. 1994. The use of dental implants in orthodontic therapy. In Davidovitch A, ed. The biological mechanisms of tooth eruption, resorption and replacement by implants. Boston: Harvard Society for the Advancement of Orthodontics, p 631-642.

Sameshima GT, Sinclair PM. 2001. Predicting and preventing root resorption: Part I. diagnostic factors. Am J Orthod Dentofacial Orthop 119:505-510.

Sameshima GT, Sinclair PM. 2001. Predicting and preventing root resorption: Part II. treatment factors. Am J Orthod Dentofacial Orthop 119:511-515.

Sato S, Parsons P. 1990. Eruption of permanent teeth: a color atlas. St Louis: Ishiyaku EuroAmerica, Inc.

Sokal RR, Rohlf FJ. 1995. Biometry: the principles and practice of statistics in biological research, 3rd ed. San Francisco: WH Freeman and Company.

Steedle JR, Proffit WR. 1985. The pattern and control of eruptive tooth movements. Am J Orthod 87:56-66.

Stevens BH, Levine RA. 1998. Forced eruption: a multidisciplinary approach for form, function, and biologic predictability. Compend Contin Educ Dent 19:994-998, 1000, 1002-1004.

Thompson JL, Kendrick GS. 1964. Changes in the vertical dimensions of the human male skull during the third and fourth decades of life. Anat Rec 150:209-214.

Trentini CJ, Brown WH, Paterson RL, Proffit WR. 1995. The application of Moire magnification to high-resolution studies of human premolar eruption. Arch Oral Biol 40:623-629.

Varrela TM, Paunio K, Wouters FR, Tiekso J, Soder PO. 1995. The relation between tooth eruption and alveolar crest height in a human skeletal sample. Arch Oral Biol 40:175-180.

West KS, McNamara JA Jr. 1999. Changes in the craniofacial complex from adolescence to midadulthood: a cephalometric study. Am J Orthod Dentofacial Orthop 115:521-532.

Whittaker DK. 1985. The effect of continuing eruption on bone growth at the alveolar margin. Prog Clin Biol Res 187:259-267.

Whittaker DK, Griffiths S, Robson A, Roger-Davies P, Thomas G, Molleson T. 1990. Continuing tooth eruption and alveolar crest height in an eighteenth-century population from Spitalfields, east London. Arch Oral Biol 35:81-85.

Whittaker DK, Parker JH, Jenkins C. 1982. Tooth attrition and continuing eruption in a Romano-British population. Arch Oral Biol 27:405-409.

Winer BJ, Brown DR, Michels KM. 1991. Statistical principles in experimental design, 3rd ed. New York: McGraw-Hill Book Company.

Wise GE, Frazier-Bowers S, D'Souza RN. 2002. Cellular, molecular, and genetic determinants of tooth eruption. Crit Rev Oral Biol Med 13:323-334.

Wittwer-Backofen U, Gampe J, Vaupel JW. 2004. Tooth cementum annulation for age estimation: results from a large known-age validation study. Am J Phys Anthropol 123:119-129.

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.

Yonezu T, Machida Y. 1997. Occlusal migration of the maxillary first primary molars subsequent to the loss of antagonists. Bull Tokyo Dent Coll 38:201-206.

Unilateral Fusion of Two Primary Mandibular Teeth: Report of a Portuguese Archeological Case

Ana Maria Silva* and Ana Leonor Silva

Centro de Investigação em Antropologia, Department of Anthropology, University of Coimbra, 3000 – 056 Coimbra – Portugal

ABSTRACT: This paper describes a unilateral fusion of two mandibular teeth in an infant skeleton recovered from the late Roman cemetery of Miroiço (Sintra, Portugal). Morphological and radiographic data were used for the analysis and interpretation of this dental anomaly. A brief review of the literature of present day primary dental fusion is presented. This report shows that primary dental fusion was present in Portuguese past populations, representing a contribution to the history of dental anomalies. *Dental Anthropology* 2007;20:16-18.

Double teeth, that is, two conjoined teeth, are considered a clinical manifestation of two developmental anomalies taking place during the bud stage of tooth formation: gemination and fusion. Gemination is the attempt of division of a single tooth germ whereas fusion, the joining together of two dental germs (Alpoz *et al*., 2003; Gurri and Balam, 2006; Tomizawa *et a*l., 2002). There is a general agreement that it is sometimes difficult to separate these two events, due to the possibility of synchronous anomalies (Neves *et al*., 2002). Thus, some authors argue that these two developmental events should not be separated while others propose that some diagnostic criteria be used, such as counting the teeth in the affected arch (Gurri and Balam, 2006) and radiological analysis (Neves *et al*., 2002; Santos *et al*., 2003; Schuurs and van Loveren, 2002). Fusion, for instant, will diminish the number of teeth, whereas gemination will not (Gurri and Balam, 2006; Neves *et al*., 2002; Tomizawa *et al*., 2002).

According to the clinical literature, the most commonly involved double teeth are central and lateral incisors, followed by lateral incisors and canines (Gurri and Galam, 2006; Neves *et al*., 2002; Santos *et al*., 2003; Schuurs and van Loveren, 2000; Tomizawa *et al*., 2002). Double teeth are more common in the primary dentition, ranging from 0.4% to 0.9% in the mandible and are predominantly unilateral (Schuurs and van Loveren, 2002). The majority of reports conclude that there is no sex preference for this anomaly (Santos *et al*., 2003; Schuurs and van Loveren, 2000). A family tendency has been suggested (Santos *et al*. 2003). Rarely, fusion in three elements is reported (Erdem *et al*., 2001; Mochizuki *et al*., 1999).

This paper reports an archeological case of double teeth, probably due to a unilateral fusion of two lower deciduous teeth, a lateral incisor and a canine.

MATERIALS AND METHODS

During osteological analysis of the human remains (minimal number of 64 individuals) recovered from the late Roman cemetery of Miroiço (Sintra, Portugal) (Macedo, 2002; Silva, 2003), a case of double primary mandibular teeth was recognized in the infant skeleton labelled 30.2. Although not firmly dated, it appears that the necropolis may have been in use during the 2nd – 4th centuries AD (Cardoso, 2001).

Age at death of this infant skeleton was estimated with the dental remains. The formation of each tooth crown was assessed using the standards of Smith (1991). Maturation of the recovered teeth is consistent with an age of death of 3 to 4 years old. There is consistency of this age at death assessed throughout the recovered dentition.

CASE REPORT

From the lower primary dentition of infant skeleton labelled 30.2 (Fig. 1A), only the two central incisors and the crowns of the left first molar were missing. In the position of teeth 72 and 73 (Fig. 1B), a double teeth was observed. Since no anomaly was observed in the right mandibular quadrant, this represents a unilateral event. From the maxilla, only the right arch was recovered with teeth 51 to 55 and the crowns of teeth 11, 12, 13, 14 and 15, visible through a postmortem broken area of the bone. Teeth 65 and crown of teeth 26 were recovered as loose teeth.

---

*Correspondence to: Ana Maria Silva, Centro de Investigação em Antropologia, Department of Anthropology, University of Coimbra, 3000 – 056 Coimbra – Portugal
E-mail: amgsilva@antrop.uc.pt

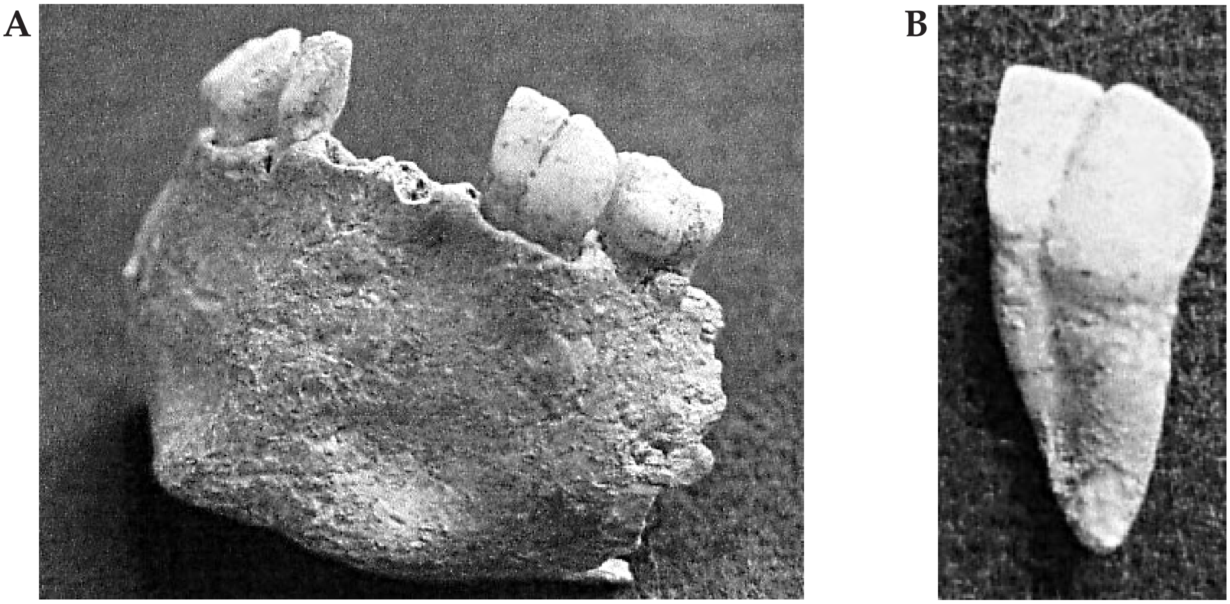


Fig. 1. Dental remains recovered from infant skeleton 30.2 from the late Roman cemetery of Miroiço (Portugal). (***A***) view of the anterior portion of the mandible; (***B***) detail of the double teeth from the mandibular left quadrant.

The double teeth displays a bifid crown with a well defined buccal groove that extends from the incisal edge to the apex of the root (Fig. 1B). In lingual view, the groove is readily visible between the incisal edge to initial cervical two-third of the crown, being very tenuous along the rest of the tooth.

Radiographic examination revealed that the double tooth has two separate pulp chambers and root canals (Figs. 2 and 3). No other bony or dental anomaly, such as supernumerary teeth, was detected in the skeletal remains from this infant.

DISCUSSION

This paper describes a case of double teeth detected in the primary dentition of a late Roman infant skeleton that seems to result from the fusion of teeth 72 and 73. This diagnosis is based on the tooth count and on radiological examination. Although clinical cases are described in the literature (Aguiló *et al*., 1999; Alpoz *et al*, 2003; Gurri and Balam, 2006; Neves *et al*., 2002; Schuurs and van Loveren, 2000; Tomizawa *et al*. 2002), this anomaly seems to be rare in past populations. To our knowledge, this is the first report of an archeological case, although another unpublished case was recovered from Peru, involving lower first and second deciduous incisors (oral communication from Prof. Simon Hillson).

The fusion is incomplete and took place late in odontogenesis resulting in a readily discernible fused crown and two roots. Radiographical examination (Figs. 2 and 3) revealed two separate pulp chambers and root canals. Although many clinical reports found association of fusion of primary teeth with succedaneous ones (*e.g.*, Reddy and Munshi, 1999), no other abnormality was detected in the present case.

Clinical problems related to double teeth include caries along the grooves dividing each crown, esthetics, and malocclusion (Neves *et al*., 2002; Santos *et al*., 2003). In the present archeological case, only the former issue could be analyzed. No cariogenic lesion was detected in the double teeth or any other tooth recovered from the dentition of this late Roman child.

Regarding the etiology of this dental anomaly, Neves *et al*. (2002) proposed genetic inheritance or physical pressure leading to the union of teeth. In a recent review, Gurri and Balam (2006) concluded that fusion is probably associated with a mandibular extension of tooth reduction and that it is under different genetic control of gemination. Gemination, in contrast, could be link to a maxillary extension of tooth enlargement and increment in number. Unfortunately, no inferences are possible in the present archeological case because in the human remains unearthed from this Necropolis no other dental anomalies were detected.

In sum, in recent years interdisciplinary studies in areas such as paleopathology, odontology and radiology (Chimenos-Küstner *et al*., 2006; Jordana *et al*., 2004), as in the present study, are contributing to the documention and interpretation of past (Silva, 2002) and present dental anomalies (Aguiló *et al*., 1999; Alpoz *et al*., 2003; Gurri and Balam, 2006; Neves *et al*., 2002; Schuurs and van Loveren, 2000; Tomizawa *et al*., 2002).

Fig. 2. Posterio-anterior radiograph of the mandible of infant skeleton 30.2 from Miroiço (Portugal). Note the double teeth in positions 72 and 73.

Fig. 3. Labiolingual radiograph of the double teeth from infant skeleton 30.2 from Miroiço (Portugal).

ACKNOWLEDGMENTS

We would like to thank Maria Teresa Ferreira and Eugénia Cunha (Departamento de Antropologia da Universidade de Coimbra); Ana Corte Real (Faculdade de Medicina Dentária, University of Coimbra); Simon Hillson (Institute of Archaeology, University College London), Miguel Costa (Dentist), and Câmara Municipal de Sintra.

LITERATURE CITED

Aguiló L, Gamdia JL, Cibrian R, Catala M. 1999. Primary double teeth. A retrospective clinical study of their morphological characteristics and associated anomalies. Int J Pediatric Dent 9:175-183.

Alpoz AR, Munanoglu D, Oncag O. 2003. Mandibular bilateral fusion in primary dentition: case report. J Dent Child 70:74-76.

Cardoso G. 2001. A Necrópole de Miroiço (Manique – Cascais). Unpublished field report.

Chimenos-Küstner E, Agustí-Farjas B, Probable keratocyst in a mandible from the late Roman era. Dentomaxillofacial Radiol 35:60-64.

Erdem G, Uzamis M, Ölmez S, Sargon M. Primary incisor triplication defect. ASDC J Dent Child 68:322-325.

Gurri F, Balam G. 2006. Inheritance of bilateral fusion of the lower central and lateral incisors: a pedigree of a Maya family from Yucatan, Mexico. Dental Anthropology 19:29-34.

Jordana X, García C, Palacios M, Chimenos E, Malgosa A. 2004. Bifid mandibular condyle: archaeological case report of a rare anomaly. Dentomaxillofacial Radiol 33:278-281.

Macedo M. 2002. Villa Romana de Miroiço… uma leitura. Estudo Paleobiológico de uma amostra de esqueletos de Manique – Cascais. Tese de licenciatura. Coimbra, Departamento de Antropologia da F.C.T.U.C.. Unpublished report.

Mochizuki K, Yonezu T, Yakushiji M, Machida Y. 1999. The fusion of three primary incisors: Report of case. ASDC J Dent Child 66:421-425

Neves AA, Neves MLA, Farinhas JA. 2002. Bilateral connation of permanent mandibular incisors: a case report. Int J Paediatric Dent 12:61-65.

Reddy NN, Munshi AK. 1999. Fusion of primary incisors–a report of six cases. J Indian Soc Pedod Prev Dent 17:55-60.

Santos LM, Forte FDS, Rocha MJC. 2003. Pulp therapy in a maxillary fused primary central incisor—report of a case. Int J Paediatric Dent 13:274-278.

Schuurs AHB, van Loveren C. Anomalies. 2000. Double teeth: review of the literature. ASDC J Dent Child 67:313-325.

Silva AM. 2002. Antropologia funerária e Paleobiologia de populações Portuguesas do Neolítico final/Calcolítico. Tese de Doutoramento em Antropologia Biológica, Coimbra, Departamento de Antropologia da F.C.U.T.U. Unpublished Ph.D. thesis.

Silva, AL. 2003. Registo de um quotidiano….na Villa Romana de Miroiço. Análise paleobiológica de uma amostra de esqueletos exumados da Necrópole de Miroiço. Tese de licenciatura. Coimbra, Departamento de Antropologia da F.C.T.U.C. Unpublished report.

Smith BH. 1991. Standards of human tooth formation and dental age assessment. In: Kelley M, Larsen CS, editors. Advances in Dental Anthropology. New-York: Wiley-Liss, 1991, p 143-168.

Tomizawa M, Shimizu A, Hayashi S, Noda T. 2002. Bilateral maxillary fused primary incisors accompanied by succedaneous supernumerary teeth: report of a case. Int J Paediatric Dent 12:223-227.

Bilateral Asymmetry of Upper Permanent Dentition in Six Archeological Pre-Conquest Samples from Colombia, South America

Carlos David Rodríguez-Flórez[1]* and Sonia E. Colantonio[2]

[1]Grupo de Investigaciones ARQUEODIVERSIDAD, Museo Arqueológico "Julio César Cubillos," Universidad del Valle - Colombia
[2]Cátedra de Antropología Biológica y Cultural, Facultad de Ciencias Exactas, Físicas y Naturales, Universidad Nacional de Córdoba - CONICET - Argentina

ABSTRACT Bilateral asymmetry is an important field of study in physical anthropology. The present study evaluated the frequencies of bilateral asymmetry of four traits (one for each tooth type in the maxillary arcade) in six pre-Conquest human archeological samples from Colombia, South America. Results show the importance of a preliminary analysis of bilateral asymmetry in archeological fragmented samples and its relevance in molding subsequent interpretations. *Dental Anthropology* 2007;20:19-23.

Bilateral symmetry is the antimeric repetition of the size and shape of a structure. In a morphological sense, symmetry can be defined as if the structure were divided into two or more parts exactly identical in size, shape, and position relative to the dividing point; in other words, the repetition is of exactly similar parts facing each other across the body's midline.

Van Valen (1962) grouped deviations from perfect symmetry in the structures of an organism into three types, namely (1) directional asymmetry (such as position of the mammalian heart); (2) antisymmetry (such as right- and left-handedness); and (3) fluctuating asymmetry (an asymmetry involving a paired structure that is usually distributed symmetrically). Fluctuating, mirror or flip symmetry may be either qualitative or quantitative. Bilateral asymmetry in tooth cusp occurrence (the presence or absence of a cusp on a tooth) is an example of qualitative fluctuating asymmetry (Staley and Green, 1971).

Theoretically, antimeric teeth should exhibit symmetrical mirror images of each other with respect both to size and surface detail (Scott, 1977). Some studies suggest that mirror imaging of asymmetry in twins likely results from chance effects of minor developmental disturbances between bilateral structures (Wetherell *et al*., 1994). Increased directional asymmetry has been reported in the occlusal morphology of first permanent molars from 45,X/46,XX mosaics, indicating that the different cell lines (each regulated by different genes) may be responsible for the more pronounced differences observed on left than right molars (Piriniemi *et al*., 1998).

Observations on the expressions of bilateral asymmetry in human dental morphological traits has been used in dental anthropology in a manner similar to a measure of population heritability (Garn *et al*., 1966a; Staley and Green, 1971; Baume and Crawford, 1979). Little metrical differences between antimeric teeth have been reported (Garn *et al*., 1966b; Garn and Bailey, 1977). Bailit *et al*. (1970) discuss their observations that metric fluctuating asymmetry values of tooth crown dimensions vary among human populations. In a study concerning the invariable bilateralism of Carabelli´s trait (*i.e*., the suggestion that this trait always occurs bilaterally when present), Meredith and Hixon (1954) reported that, in fact, nearly 13% of their sample exhibited expression of the trait on just one side of the dental arch. Small side differences in trait expressions were reported by Wood and Green (1969) who compared the bilateralism of seven morphological traits in premolars of twins. Similar deductions for Carabelli's trait were reached by Scott (1972, cited in Scott, 1977) and by Biggerstaff (1973).

Another factor that can be important in evaluating

---

*Correspondence to: Carlos David Rodríguez-Flórez, Grupo de Investigaciones ARQUEODIVERSIDAD, Museo Arqueológico "Julio César Cubillos," Universidad del Valle - Colombia
E-mail: david@syllabapress.com

the extent of bilateral asymmetry in a sample is sample size. Garn *et al*. (1979) showed how the effect of small samples (generally below 100 and in some cases as small as 15) increases the apparent intergroup differences in tooth crown asymmetry and, thus, how small sample sizes can influence biological interpretations.

Dental asymmetry in fragmented archeological samples

The use of morphological traits from the human dentition can create some problems of a methodological nature when studying fragmented archeological samples. One issue is the assumption of dental trait expression as individually immutable, in the sense of being morphologically symmetrical between homologous teeth.

In bioarcheology, estimating the frequency of a dental trait is influenced by the availability of samples and limited crown wear and the absence of caries (so the presence of the trait can be ascertained). Some authors recommend scoring the higher grade of expression for each dental trait (Turner and Scott, 1977) or counting both the left and right sides for each individual (Haeussler *et al*., 1988). In cases where the bioarcheologist only has fragmented remains (pieces from maxillas and mandibles) these counting methods are very practical. Either of these two recording methods maximizes the usable sample sizes without taking into account unilateral or bilateral trait expression. But, if we consider this affirmation in detail, an anthropological study on archeological samples could be carried out without a previous evaluation of bilateral asymmetry, thus underestimating possible environmental influences on trait expressions as much as over-estimating its taxonomic value and relevance in microevolutionary and historical inferences. At this point, researchers face a recording problem with only two possible alternatives: counting the trait as bilateral or discarding the individual, thus reducing the total sample size. There seem to be very few prior bioarcheological studies that deal with this issue of bilateral asymmetry as it relates to the development of biological distance calculations.

Taking into account that bilateral asymmetry could reflect environmental influences, and that bilateral trait asymmetries could affect a trait's usefulness in determining biological distances, we undertook a study of bilateral asymmetry on dental types.

Prior to using fragmented arches and traditional counting procedures for trait presence (Turner and Scott, 1977; Haeussler *et al*., 1988), bilateral analysis of available complete dental arches from the same sample can add elements that help develop useful comparative indicators in the crowns. The present study was carried out using six human pre-conquest samples from Colombia, with the aim of exploring the ranges of morphologic reliability of each dental type.

MATERIALS AND METHODS

This study consists of data from six pre-conquest human populations from Colombia dated between the VIII and XV centuries A.D. (Table 1). The sample sizes (n) correspond to the total number of individuals with complete arches that could be examined.

Permanent teeth of 58 individuals between 10 and 20 years of age with complete arches (maxilla) were selected (Fig. 1). The dental traits examined here are listed in Table 2. The ASU Dental Anthropology System was used to register the expression grade of incisor shovel shape, distal accessory ridge, and Carabelli's complex. The marginal ridges on the maxillary premolars were observed following the descriptions of Burnett (1996). A binary recording system was employed that consisted of grouping all trait expressions into either "present" (1) and "absent" (0) categories. Then, using these records, Molto´s Bilateral Index (BI) was calculated with this formula:

$$BI = (bp / bp + up) \times 100$$

where BI is the Bilateral Index, bp is the count of cases (individuals) where the trait is present bilaterally, and up is the count of cases where the trait is present just unilaterally. The Bilateral Index quantifies the tendency for a trait to occur symmetrically. An index above 50 suggests a positive bilateral tendency for the trait (Tocheri, 2002). The standard deviation and coefficient of variation also were calculated for the assessments of intra- and inter-sample variation of bilateral traits' presence.

TABLE 1. Materials used in this study

Sample	Centuries (A.D.)	Collection	Provenience	n
Obando	VIII - XIII	Museo Arqueológico, Univalle	Valle del Cauca	13
Guacanda	X - XV	Museo Arqueológico, Univalle	Valle del Cauca	9
La Escopeta	XIII - XV	Museo Arqueológico, Univalle	Valle del Cauca	6
El Morro - Tambo	XIII - XV	Museo de Historia Natural, Unicauca	Cauca	7
Marín	XIII - XV	Museo Nacional de Colombia	Cundinamarca	11
Soacha	X - XIII	Museo Nacional de Colombia	Cundinamarca	12
Total				58

RESULTS

Bilateral and unilateral presence of traits and bilateral index values are shown in Table 3. Bilateral expressions of shovel shape (maxillary central incisor), distal accessory ridge (maxillary canine), and marginal ridges (maxillary first premolar) all show clear tendencies to occur bilaterally—with values higher 50—and relatively low standard deviations (sd) and variation coefficients (CV). In contrast, Carabelli´s trait exhibits the highest sd and CV (Table 4). Comparing among the samples, exceptional values are found in La Escopeta, which has a CV higher than 50% (Table 5).

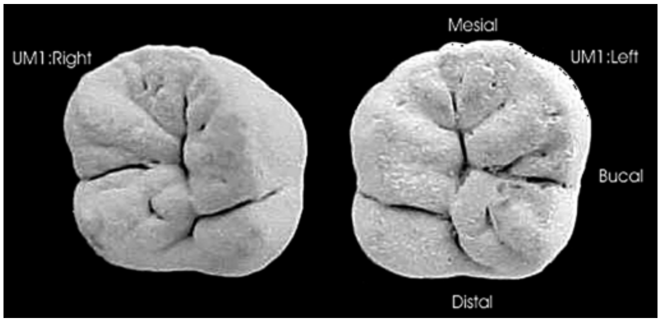


Fig. 1. UM1 of Indiviual 7 from La Escopeta.

DISCUSSION

With the assumed model of polygenetic inheritance, trait expression is due to interactions among a number of genes at different loci that interplay with environmental factors to produce the phenotypic expression of that trait. It is supposed that various genes have different contributions to phenotypic variation but they have an additive effect on the trait in question (Lauc *et al*., 2003). Dental asymmetry has generally been thought to be an indicator of developmental instability in humans and other animals. The occurrence of bilateral asymmetry can be interpreted as a reflection of instability in the normal development of a biological form (Palmer and Strobeck, 2003). Results of the present study suggest that the expression of Carabelli's complex (on UM1) is most easily influenced by environmental forces from among the several traits examined. BI values for Carabelli's trait were below 50 for Guacanda and for La Escopeta; both of these pre-conquest samples suggest that this trait would have low taxonomic value, at least in biological comparisons that involve these two samples. CV values for this trait (37.3%) and his variation in the La Escopeta sample (50.1%) support this conclusion. The comparatively high frequency of bilateral asymmetry for this dental trait could indicates its greater sensitivity to environmental stressors; comparably, these data may also imply changes in the gene pool of these prehistoric people. Other values greater but still close to a BI of 50 occurred in the samples from El Morro-Tambo (*i.e.*, shovel shape UI1 BI = 66), Soacha (*i.e.*, Carabelli UM1 BI = 60), and Guacanda (*i.e.*, marginal ridges UP1 BI = 57). The bilateral expression of these traits could also represent an environmental impact that could influence the phenetic component in the total sample. Of the traits studied, the distal accessory ridge displays the highest BI values, which promotes its reliability for use in phenetic inter-group comparisons.

An appreciation of the degree of bilateral expression of dental features such as Carabelli's trait, shovel shape incisors, and marginal ridges is valuable in order to assess the importance of previous bilateral asymmetry analysis in a prehistoric dental series. Estimating the bilateral index is useful for the observation of possible environmental influences that can affect the overall frequency of the trait expression sufficient to exclude Carabelli´s trait in biological distances that polled all populations considered here.

Thanks to the present evaluation, analysis of the samples can be pursued more carefully in the validation of dental traits expressed for UM1 prior to phenetic analysis, in this case Carabelli's trait. To conclude, it is advisable to consider a bilateral analysis of fragmented archeological samples prior to the more complete investigation since it provides additional, insightful elements for among-sample interpretation.

LITERATURE CITED

Bailit HL, Workman PL, Niswander JD, McClean CJ. 1970. Dental asymmetry as an indicator of genetic and environmental conditions in human populations. Hum Biol 42:626-638.

TABLE 2. Dichotomization of trait expressions used in this study

Tooth type	Trait	Dichotomy	Presence	Absence
UI1	Shovel shape	0 vs 1 6	1 - 6	0
UC	Distal Accesory Ridge	0 vs 1-5	1 - 5	0
UP1	Marginal Ridges	0 vs 1	1	0
UM1	Carabelli's trait	0 vs 1-6	1 - 6	0

TABLE 3. Values observed in this study[1]

	Shovel Shape UI1						Distal Accessory Ridge UC						Marginal Ridges UP1						Carabelli UM1					
		BP		UP				BP		UP				BP		UP				BP		UP		
Sample	n	k	%	k	%	BI	n	k	%	k	%	BI	n	k	%	k	%	BI	n	k	%	k	%	BI
Obando	13	10	76.9	1	7.7	90.9	13	10	76.9	1	7.7	90.9	13	8	61.5	2	15.4	80.0	13	5	38.5	2	15.4	71.4
Guaranda	9	7	77.8	2	22.2	77.8	9	5	55.6	2	22.2	71.4	9	4	44.4	3	33.3	57.1	9	2	22.2	2	22.2	50.0
La Escopeta	6	6	100.0	0	0.0	100.0	6	5	83.3	1	16.7	83.3	6	6	100.0	0	0.0	100.0	6	1	16.7	4	66.7	20.0
El Morro–Tambo	7	4	57.1	2	28.6	66.7	7	5	71.4	1	14.3	83.3	7	4	57.1	1	14.3	80.0	7	3	42.9	1	14.3	75.0
Marín	11	8	80.0	2	20.0	80.0	10	9	90.0	1	10.0	90.0	10	6	60.0	2	20.0	75.0	10	4	40.0	1	10.0	80.0
Soacha	12	9	75.0	3	25.0	75.0	12	10	83.3	1	8.3	90.9	12	9	75.0	1	8.3	90.0	12	3	25.0	2	16.7	60.0
Summation	57	44		10			57	44		7			57	37		9			57	18		12		
Mean						81.7						85.0						80.4						59.4

[1] BP = bilateral presence; UP = unilateral presence; BI = Bilateral Index

TABLE 4. BI statistics for each dental trait

Sample	Shovel shape UI1	Distal Accesory Ridge UC	Marginal Ridges UP1	Carabelli UM1
Mean	81.73	84.99	80.36	59.4
sd	11.91	7.544	14.47	22.15
CV (%)	14.57	8.877	18.01	37.29

*sd = standard deviation. CV = coefficient of variation

TABLE 5. BI statistics calculated for each pre-conquest sample, all traits considered

Statistic	Obando	Guaranda	La Escopeta	Morro-Tambo	Marín	Soacha
Mean	83.31	64.09	75.83	76.25	81.25	78.98
sd	9.445	12.75	38.04	7.249	6.292	14.6
CV (%)	11.34	19.9	50.17	9.507	7.743	18.49

Baume RM, Crawford MH. 1979. Discrete dental trait asymmetry in Mexico and Belize. J Dent Res 58:1811.

Biggerstaff RH. 1973. Heritability of the Carabelli cusp in twins. J Dent Res 52:40-44.

Burnett SE. 1996. A new look at premolar trait variation: maxillary premolar accessory ridges. Dental Anthropology 10:17-18.

Garn SM, Bailey SM. 1977. The symmetrical nature of bilateral asymmetry of deciduous and permanent teeth. J Dent Res 56:1422.

Garn SM, Cole PE, Smith BH. 1979. The effect of sample size on crown size asymmetry. J Dent Res 58:2012.

Garn SM, Lewis AB, Kerewsky RS. 1966a. Bilateral asymmetry and concordance in cusp number and crown morphology of the mandibular first molar. J Dent Res 45:1820.

Garn SM, Lewis AB, Kerewsky RS. 1966b. The meaning of bilateral asymmetry in the permanent dentition. J Dent Res 36:55-62.

Haeussler AM, Turner CG II, Irish JD. 1998. Concordance of American and Soviet methods in dental anthropology. Am J Phys Anthropol 75:218.

Lauc T, Rudan P, Rudan I. Campbell H. 2003. Effect of Inbreeding and endogamy on occlusal traits in human isolates. Am J Orthod 30:301-308.

Meredith HV, Hixon EH. 1954. Frequency. size. and bilateralism of Carabelli´s tubercle. J Dent Res 33:435-440.

Palmer AR, Strobeck C. 2003. Fluctuating asymmetry analyses revisited. In: Polak M, editor. Development instability: causes and consequences. Oxford: Oxford University Press, p. 279-319.

Piriniemi P, Alvesalo L, Silven O, Heikkila J, Julku J, Karjalahti P. 1998. Asymmetry in the occlusal morphology of first permanent molars in 45.X/46. XX mosaics. Arch Oral Biol 43:25-32.

Scott GR. 1977. Classification, sex dimorphism, association. and population variation of the canine distal accesory ridge. Hum Biol 49:453-469.

Staley RN, Green LJ. 1966. Bilateral asymmetry in tooth cusp occurrence in human monozygotic twins. dizygotic twins. and nontwins. J Dent Res 50:83-89.

Tocheri MW. 2002. The effects of sexual dimorphism, asymmetry, and inter-trait association on the distribution of thirteen deciduous dental nonmetric traits in a sample of Pima Amerindians. Dental Anthropology 15:1-8.

Wetherell J, Winning T, Townsend GC. 1994. Localized asymmetry in human dental crown form – an interesting case. Dental Anthropology 17:18-23.

Wood BF, Green LJ. 1969. Second premolar morphologic trait similarities in twins. J Dent Res 48:74-78.

Turner CG II, Scott GR. 1977. The dentition of Easter Islanders. In: Dahlberg AA, Graber TM, editors. Orofacial growth and development. The Hague: Mouton. p. 229-249.

Van Valen L. 1962. A study of fluctuating asymmetry. Evolution 16:125-142.

TEETH, 2nd Edition. By Simon Hillson, 2005. Cambridge University Press, Cambridge. ISBN: 0-521-54549-8

As Hillson himself says, "one of the striking things about returning to the text almost 20 years later is how few of the fundamentals have in fact changed." The revised and updated edition of his 1986 classic Teeth, however, demonstrates that things can be improved upon. Teeth, in the Cambridge Manuals in Archaeology series, provides material on field techniques and methodology combined with current and relevant archaeological examples. Teeth are a very common aspect of the archaeological assemblage and can provide extraordinary information on the health and diet of paleocommunties, and Hillson brings all these aspects together in a comprehensive manual on the study of teeth. The improvements and updates to this classic are not dramatic, but slight shifts in emphasis and description of recent technological advances makes this second edition a valuable manual for any practitioner of anthropology, paleontology or zoology.

The book opens with a lengthy and comprehensive description of tooth form in mammals, intended as a reference manual for identification of teeth in an archaeological context. It is in this section that the bulk of the revisions are evident. While the first edition was wide-ranging, Hillson has more than doubled the genera of mammals described and illustrated from 150 to 325, representing the entire Holarctic region. One of the most striking changes is the introduction of computer graphics for all the illustrations, Teeth has now entered the digital age. This was a labor intensive process for Hillson, but the resulting illustrations are legible and highly informative. The level of detail is impressive, greatly aiding in field identification. To offset these additions, Hillson has deemphasized human dentition in this edition, setting the tone for what is truly a mammalian tooth book. These are excellent changes, widening the readership and the utility of the book as a field manual. However, with the exclusion of reptiles, amphibians and fish from the book, many of which have teeth, one could argue that the book should be titled Mammal Teeth. For those with interests primarily in the human tooth, Hillson's (1996) *Dental Anthropology* is a wonderful supplemental resource.

While the remaining chapters of the book are not as dramatically restructured as the first, Hillson has carefully reviewed his earlier work, updating and correcting as necessary. One such example is in the "Dental Tissues" section (previously "Dental Microstructure") which now includes a new section on the chemistry and physics of dental tissue analysis in archaeology. This includes a clear and informative description of the uses of isotopic analysis in dietary reconstruction that have been developed since the first edition came out in 1986 and the role of dentine in DNA preservation and analysis. The section has been further updated with a new discussion on methods of dental development reconstruction in hominids and advances in dental preparation techniques including proper use of new camera and scanner technology.

The section on "Teeth and Age" has been updated with more recent studies on dental microwear and its utility in comparing extant and extinct animal behaviors such as diet and life history. This section also includes a new discussion on the genetics, development and morphology of teeth. The first edition devoted significant space to a discussion of tooth size and human evolution. This topic has been dramatically edited and abbreviated in the second edition. In keeping with Hillson's current emphasis on mammals in general rather than humans specifically, discussion of tooth size in human evolution is limited to a few paragraphs on dental reduction through time.

Even in a field that has not changed significantly since its first printing, the previous edition of Teeth is out of date, and was in need of revision. Discussion of the origin and evolution of teeth would have been a nice topic to include. However, in a book intended as a practical manual for researchers in many disciplines, it is not a glaring omission. As we all discovered in our use of the first edition, Hillson's Teeth is an essential and comprehensive reference manual for all archeologists and paleontologists. This second edition is an excellent update of a reliable and invaluable resource.

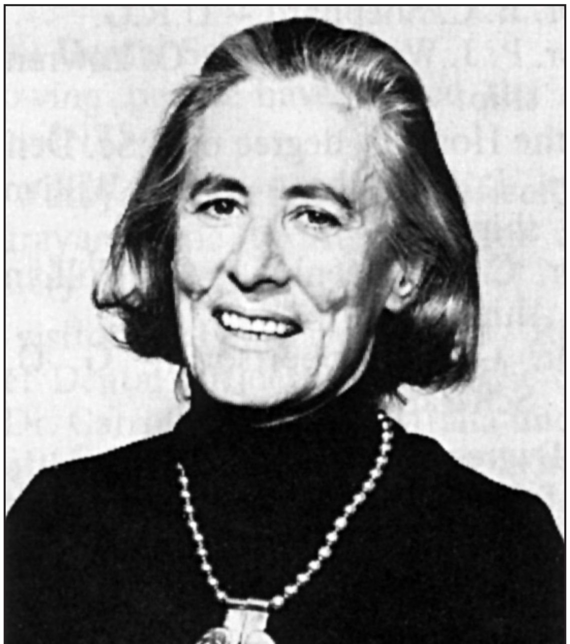
Emily H. Henderson [was Guthrie]
Department of Anthropology
University of Oregon

COMMENTS FROM READERS

I read with interest the paper by Vincent Stefan on rotated premolars and the associated commentary by Edward Harris in (*Dental Anthropology* 2006;19(3):70-78). In his comments, Edward refers to the pioneering work of Elizabeth (Betty) Fanning on dental development (Fanning, 1962: Effect of extraction of deciduous molars on the formation and eruption of their successors. *Angle Orthodontist* 32:44-53).

I thought readers might be interested to know that Betty Fanning (Born April 14, 1918, in Wellington, New Zealand) was a Reader in Preventive Dentistry in the Dental School at the University of Adelaide in South Australia for over 20 years, from the early 1960s until her retirement in the 1980s. Betty was a New Zealander who spent her postdoctoral years (1958-1963) working with Coenraad Moorrees and Ed Hunt at the Forsyth Dental Infirmary in Boston where she studied various aspects of dental development, including the timing and sequencing of tooth calcification. When she came to Adelaide she continued this work using the records collected by Murray Barrett and Tasman Brown of Australian Aborigines living at Yuendumu in Central Australia.

Betty Fanning was also a strong campaigner for improving children's oral health in Australia. She was instrumental in conducting the first fluoride toothpaste trials in Australia and she led the lobby for fluoridation of Adelaide's water supplies. After retiring from academia, she moved to Queensland and lived on Tambourine Mountain just inland from the Gold Coast. Betty volunteered her time during her retirement working in nursing homes. She passed away on May 2, 2007.



Elizabeth A. Fanning, 1918-2007

Fanning's findings on how extraction of primary molars can influence the eruption of the succeeding premolar teeth provide a research basis to the clinical technique of serial extraction, used since the 1930s, in which the primary first molar is extracted about six months prior to when it would normally be exfoliated to accelerate the emergence of the permanent first premolar underneath. This is part of a strategy in which primary lateral incisors, canines and first molars are extracted, followed by permanent first premolars, to enable the permanent anterior teeth to align themselves and then to create space posteriorly in children with severe dental crowding.

I agree with Edward Harris that a common cause of rotated premolars is premature loss of one or both deciduous molars, usually due to dental caries, with associated mesial migration of the permanent first molar, leading to a lack of space for the erupting premolars. As the second premolar is usually later to erupt than the first, it tends to be affected most by the space constraint. In this sense, I would usually view the problem of rotated premolars as a localised environmental disturbance, linked to dental disease, rather than a reflection of an underlying "premolar" morphogenetic field. However, not all cases of rotated premolars follow premature loss of primary molars and so we should not rule out the possibility of a field effect altogether. Studies that measure the amount of arch space available in cases of premolar rotations would help to clarify whether mesial migration of the permanent first molar is an issue. Also, longitudinal studies of related individuals and comparisons of the expression of rotations on right and left sides should provide insights into the relative contributions of genetic and environmental factors to observed variation in this very interesting feature.

Grant Townsend
Professor of Dental Science
School of Dentistry
The University of Adelaide University,
South Australia 5005

[A bibligraphy of Betty Fanning's publications is listed on the next page. *Editor*]

Bibliography of Elizabeth A. Fanning

Fanning EA. 1982. Sugar in breakfast cereals. Aust Dent J 27:134.

Fanning EA, Cellier KM, Somerville CM. 1980. South Australian kindergarten children: effects of fluoride tablets and fluoridated water on dental caries in primary teeth. Aust Dent J 25:259-263.

Gurling FG, Fanning EA, Leppard PI. 1980. Handicapped children: behavioural and co-ordination characteristics affecting the delivery of dental care. Aust Dent J 25:201-204.

Fanning EA. 1979. Nutrition in childhood: the role of the dentist. Aust Dent J 24:352-357.

Gurling FG, Fanning EA, Leppard PI. 1979. The dental care of handicapped children in South Australia. Aust Dent J 24:178-181.

Fanning EA. 1978. Nutrition in childhood: long-term effects on general and dental health. Australas Nurses J 8:19-20.

Gurling FG, Fanning EA, Leppard PI. 1977. The handicapped child population in South Australia in 1975. Aust Dent J 22:107-112.

Fanning EA, Leppard PI. 1975. Oral hygiene home care kits: effects on the dental behaviour of kindergarten children. Aust Dent J 20:39-42.

Fanning EA, Cellier KM, Leadbeater MM, Somerville CM. 1975. South Australian kindergarten children: fluoride tablet supplements and dental caries. Aust Dent J 20:7-9.

Fanning EA, Somerville CM. 1975. South Australian kindergarten children: dental health factors in urban and country families. Australas Nurses J 4:3, 19.

Fanning EA, Somerville CM. 1974. South Australian kindergarten children: dental health factors in urban and country families. Aust Dent J 19:35-38.

Fanning EA. 1973. Dental problems in the young child. Australas Nurses J 2:2.

Fanning EA. 1973. The medical and chemical aspects of water fluoridation. Australas Nurses J 2:3.

Fanning EA, Leppard PI. 1973. A survey of university students in South Australia. Part 3. Attitudes to dental treatment. Aust Dent J 18:20-22.

Clarke NG, Fanning EA. 1973. Further consideration of the effects of calcium sucrose phosphate on dental plaque: a telemetric study. Aust Dent J 18:229-232.

Fanning EA. 1972. University of Adelaide Dental students: sociological aspects and oral health status. Med J Aust 2:615-616.

Fanning EA, Leppard PI. 1972. A dental survey of university students in South Australia. Aust Dent J 17:363-372.

Fanning EA. 1971. The needs of the community—dental health. Australas Nurses J 5:10-1 passim.

Fanning EA. 1971. An exercise in preventive dentistry. Aust Dent J 16:172-174.

Fanning EA, Brown T. 1971. Primary and permanent tooth development. Aust Dent J 16:41-43.

Fanning EA, Cellier KM, Gotjamanos T, Vowles NJ. 1971. The effect of fluoride dentifrices on the caries incidence of individual toothsurfaces. Aust Dent J 16:287-290.

Clarke NG, Fanning EA. 1971. Plaque pH and calcium sucrose phosphate: a telemetric study. Aust Dent J 16:13-16.

Clarke NG, Graf H, Fanning EA. 1971. Fluoride ion release from dentifrices and caries inhibition in a clinical trial. Aust Dent J 16:249-251.

Fanning EA, Moorrees CF. 1969. A comparison of permanent mandibular molar formation in Australian aborigines and Caucasoids. Arch Oral Biol 14:999-1006.

Fanning EA, Gotjamanos T, Vowles NJ. 1969. Dental caries in children related to availability of sweets at school canteens. Med J Aust 1:1131-1132.

Fanning EA, Gotjamanos T, Vowles NJ. 1969. Dental health and treatment requirements of South Australian secondary schoolchildren. Med J Aust 2:899-901.

Fanning EA, Gotjamanos T, Vowles NJ. 1968. The use of fluoride dentifrices in the control of dental caries: methodology and results of a clinical trial. Aust Dent J 13:201-206.

Fanning EA, Gotjamanos T, Vowles NH, van der Wielen I. 1968. The effects of fluoride dentifrices on the incidence and distribution of stained tooth surfaces in children. Arch Oral Biol 13:467-469.

Henning FR, Fanning EA. 1968. Instruction in oral hygiene. Aust Dent J 13:40-45.

Cellier KM, Fanning EA, Gotjamanos T, Vowles NJ. 1968. Some statistical aspects of a clinical study on dental caries in children. Arch Oral Biol 13:483-508.

Fanning EA, Gotjamanos T, Vowles NJ, Cellier KM, Simmons DW. 1967. The use of fluoride dentifrices in the control of dental caries: a preliminary report of a clinical trial. Med J Aust 1:383-385.

Fanning EA, Henning FR. 1967. Toothbrush design and its relation to oral health. Aust Dent J 12:464-467.

Henning FR, Fanning EA. 1967. Toothbrushing habits in a group of Australian dental patients. Aust Dent J 12:274-276.

Fanning EA, Barrett MJ. 1966. An acute dental health problem: a study at a maternity hospital. Med J Aust 2:643-644.

Barrett MJ, Brown T, Fanning EA. 1965. A long-term study of the dental and craniofacial characteristics of a tribe of Central Australian Aborigines. Aust Dent J 10:63-68.

Fanning EA. 1964. Some practical applications of research findings in tooth development. Aust Dent J 9:374-379.

Moorrees CF, Fanning EA, Hunt EE Jr. 1963. Formation and resorption of three deciduous teeth in children. Am J Phys Anthropol 21:205-213.

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

Fanning EA. 1962. Effect of extraction of deciduous molars on the formation and eruption of their successors. Angle Orthod 32:44-53.

Fanning EA. 1962. Third molar emergence in Bostonians. Am J Phys Anthropol 20:339-346.

Fanning EA. 1962. The relationship of dental caries and root resorption of deciduous molars. Arch Oral Biol 7:595-601.

Fanning EA. 1961. A longitudinal study of tooth formation and root resorption. NZ Dent J 57:202-217.

Fanning EA. 1960. A longitudinal study of tooth formation and root resorption. D.D.S. thesis, University of New Zealand.

DAA Subscription

The new secretary-treasurer of the **Dental Anthropology Association** is Dr. Loren R. Lease of Youngstown State University. Loren was elected at the 2007 Association meeting in Philadelphia, and she replaces Dr. Heather Edgar, who deserves a rest from keeping up with the membership and can now focus on other commitments.

Enclosed in this issue is a membership renewal insert and, as well, a facsmile of this form on page 28. Membership in the Association and, thus, your subscription to *Dental Anthropology* is on an annual basis coinciding with the calendar year.

To extend your membership, fill out the relevant portions of the enclosed form—remember to include appropriate payment—and mail it to the Secretary-Treasurer of the Association:

Dr. Loren R. Lease
Department of Sociology and Anthropology
Youngstown State University
One University Plaza
Youngstown, Ohio 44555 USA

Telephone: (330) 941-1686
E-mail: lrlease@ysu.edu

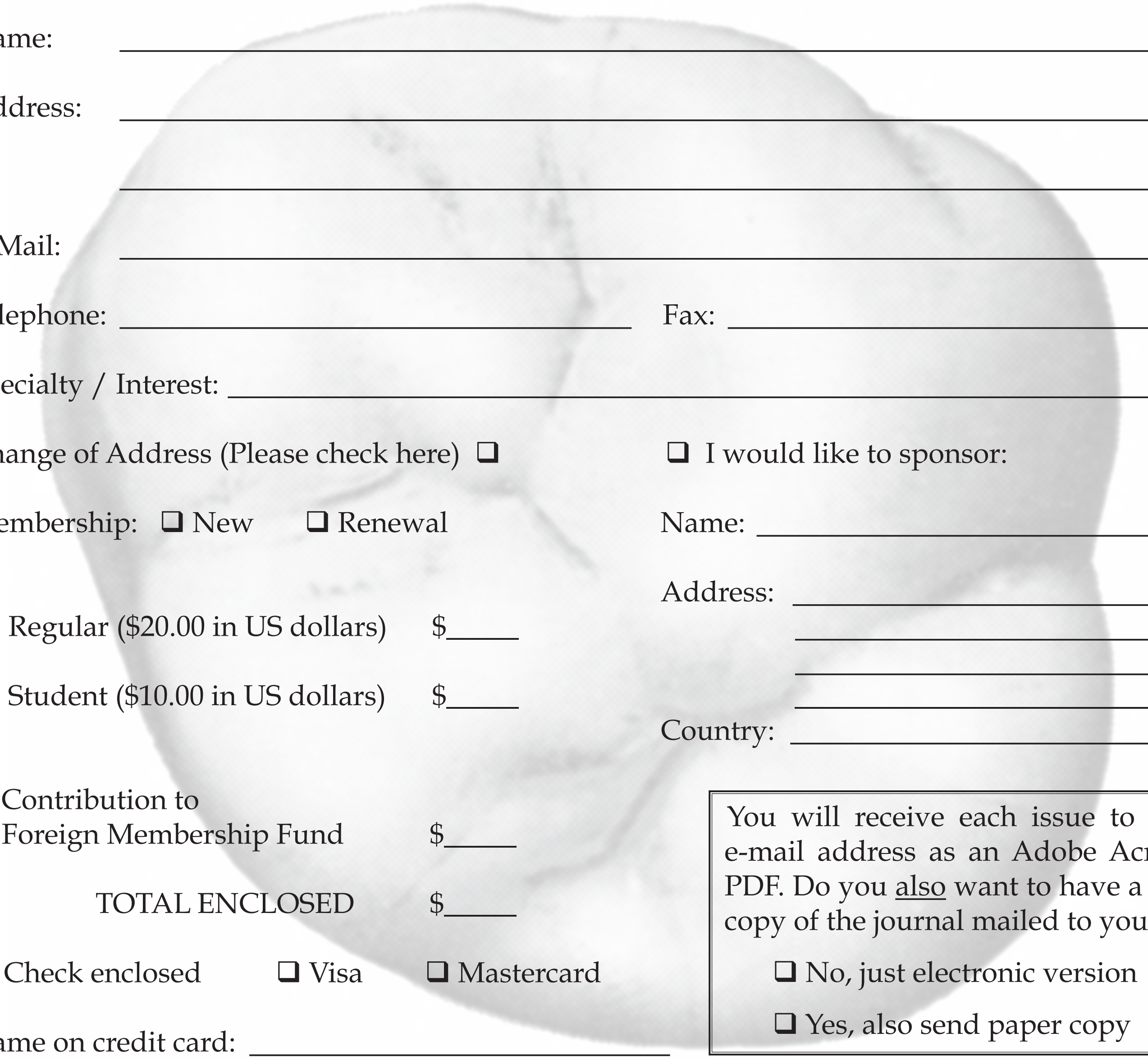
Dental Anthropology now is published electronically and e-mailed to all members as a PDF. If you **also** want to receive a hard copy, be sure to make this clear on the membership form.

Speed communication about your membership by contacting Loren directly (other officers may not have current membership lists).

DENTAL ANTHROPOLOGY ASSOCIATION

MEMBERSHIP APPLICATION / RENEWAL FORM

☐ Membership is for the calendar year and paid in US dollars. **Year: 2007**
Membership includes a one-year subscription to Dental Anthropology (three issues annually).
☐ Regular membership = US $20.00 ☐ Student Membership = US $10.00
☐ Members sponsored by the DAA should apply in writing for membership renewal.



Name: ______________________________

Address: ______________________________
____

E-Mail: ______________________________

Telephone: ____________________ Fax: ____________________

Specialty / Interest: ______________________________

Change of Address (Please check here) ☐

Membership: ☐ New ☐ Renewal

☐ Regular ($20.00 in US dollars) $_____

☐ Student ($10.00 in US dollars) $_____

☐ Contribution to
Foreign Membership Fund $_____

TOTAL ENCLOSED $_____

☐ Check enclosed ☐ Visa ☐ Mastercard

Name on credit card: ____________________

Visa/Mastercard # ____________________

☐ I would like to sponsor:

Name: ____________________

Address: ____________________
____
____
____

Country: ____________________

You will receive each issue to your e-mail address as an Adobe Acrobat PDF. Do you also want to have a hard copy of the journal mailed to you?

☐ No, just electronic version

☐ Yes, also send paper copy

Expiration date _____/_____ Signature: ______________________________

☐ Please make checks payable to DENTAL ANTHROPOLOGY ASSOCIATION.
☐ Mail to: Dr. Loren R. Lease / DAA Secretary-Treasurer / Department of Sociology and Anthropology / Youngstown State University / One University Plaza / Youngstown, OH 44555 USA.

☐ Or, send order by e-mail (*send form as attachment*) to: **lrlease@ysu.edu**

NOTICE TO CONTRIBUTORS

Dental Anthropology publishes research articles, book reviews, announcements and notes and comments relevant to the membership of the *Dental Anthropology Association*. Editorials, opinion articles, and research questions are invited for the purpose of stimulating discussion and the transfer of information. Address correspondence to the Editor, Dr. Edward F. Harris, Department of Orthodontics, University of Tennessee, Memphis, TN 38163 USA (E-mail: eharris@utmem.edu).

Research Articles. The manuscript should be in a uniform style (one font style, with the same 10- to 12-point font size throughout) and should consist of seven sections in this order:

Title page
Abstract
Text
Literature Cited
Tables
Figure Legends
Figures

The manuscript should be double-spaced on one side of 8.5 x 11″ paper (or the approximate local equivalent) with adequate margins. All pages should be numbered consecutively, beginning with the title page. Electronic submission is preferred. Submit two (2) copies—the original and one copy—to the Editor at the address above. Be certain to include the full address of the corresponding author, including an E-mail address. All research articles are peer reviewed; the author may be asked to revise the paper to the satisfaction of the reviewers and the Editor. All communications appear in English.

Title Page. This page contains (a) title of the paper, (b) authors' names as they are to appear in publication, (c) full institutional affiliation of each author, (d) number of manuscript pages (including text, references, tables, and figures), and (3) an abbreviated title for the header. Be certain to include a working E-mail address and/or telephone number.

Abstract. The abstract does not contain subheadings, but should include succinct comments relating to these five areas: introduction, materials, methods, principal results, and conclusion. The abstract should not exceed 200 words. Use full sentences. The abstract has to stand alone without reference to the paper; avoid citations to the literature in the abstract.

Figures. One set of the original figures must be provided with the manuscript in publication-ready format. Drawings and graphics should be of high quality in black-and-white with strong contrast. Graphics on heavy-bodied paper or mounted on cardboard are encouraged; label each on the back with the author's name, figure number, and orientation. Generally it is preferable to also send graphs and figures as computer files that can be printed at high resolution (300 dpi or higher). Most common file formats (Windows or Macintosh) are acceptable; check with the Editor if there is a question. The journal *does* support color illustrations. Print each table on a separate page. Each table consists of (a) a table legend (at top) explaining as briefly as possible the contents of the table, (b) the table proper, and (c) any footnotes (at the bottom) needed to clarify contents of the table. Whenever possible, provide the disk-version of each table as a tab-delimited document; do not use the "make table" feature available with most word-processing programs. Use as few horizontal lines as possible and do *not* use vertical lines in a table.

Literature Cited. *Dental Anthropology* adheres strictly to the current citation format of the *American Journal of Physical Anthropology*. Refer to a current issue of the *AJPA* or to that association's web-site since the "current" style is periodically updated. As of this writing, the most recent guidelines have been published in the January, 2002, issue of the *AJPA* (2002;117:97-101). *Dental Anthropology* adheres to the in-text citation style used by the *AJPA* consisting of the author's last name followed by the year of publication. References are enclosed in parentheses, separated by a semicolon, and there is a comma before the date. Examples are (Black, 2000; Black and White, 2001; White *et al*., 2002). The list of authors is truncated and the Latin abbreviation "*et al*." is substituted when there are three or more authors (Brown *et al*., 2000). However, *all* authors of a reference are listed in the Literature Cited section at the end of the manuscript.

Electronic Submission. Electronic submission *in place of* sending hard copies of articles is strongly encouraged. For articles that undergo peer review, the editor will request submission of the final revision of a manuscript in electronic format, not interim versions. Files can be submitted on a 3.5″ diskette, or a 100-megabyte Iomega Zip disk, or a compact disk (CD), either in Windows or Macintosh format. **Files can also be sent as E-mail attachments**. Microsoft Word documents are preferred, but most common formats are suitable. Submit text and each table and figure as a separate file. Illustrations should be sent in PDF or EPS format, or check with the Editor before submitting other file types. Be certain to label any disk with your name, file format, and file names.

Dental Anthropology

Volume 20, Number 1, 2007

Original Articles

Book Review

Comments from Readers

Association Membership

Published at
Craniofacial Biology Laboratory, Department of Orthodontics
College of Dentistry, The Health Science Center
University of Tennessee, Memphis, TN 38163 U.S.A.