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Analysis of Cementum Layers in Archaeological Material

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ABSTRACT The aim of this study was to assess the utility of cementum layers for estimating age at death of remains from an archaeological site. Variability in cementum layer counts due to interobserver error and variation among dental regions were analyzed. Interobserver error was later incorporated into age ranges based on counts of cementum layers and compared with age estimates derived from the skeleton. The layers were counted, using 9 teeth from 3 individuals, and the eruption age of the tooth was summed with the average layer count to achieve an estimated age. The research indicates that the assessment of archaeological dental cementum layers has a relatively high interobserver error. The cementum layer aging method resulted in large age ranges and did not correspond with age ranges from skeletal techniques. Chemical diagenetic processes can affect the observation and count of cementum layers by obscuring bands and/or creating additional bands. The variables that affected observability of cementum layers were: high interobserver error, discrepancy of readability of root regions, and large age ranges using the cementum layer technique that exceeded age ranges derived from other, skeletal methods *Dental Anthropology* 2010;23(3):67-73.

Dental cementum is calcified tissue that covers the dentine and helps support the teeth within the periodontium. Cementoblasts are cementum-forming cells that are interposed between bundles of the periodontal ligament fibers, while cementocytes are cementoblasts that have been incorporated into the matrix (Lieberman, 1994). The cementum-dentine junction (CDJ) defines where the dental cementum incremental layers begin (Jones, 1981). Cementum is composed of incremental layers that follow the circumference of the roots and thickens with age. There have been correlations between the number of cement layers in humans cement and the number of years that have elapsed since root formation, indicating these layers are supposed to be deposited annually (Hillson, 1986). Generally, cementum layers can be viewed using transmitted light microscopy, scanning electron microscope (SEM), or polarized light microscopy (Hillson, 1986, 1996). The section thickness to view cementum layers properly is debated, and suggestions range from 10 to 100 µm (Naylor *et al*., 1985; Maat *et al*,. 2006; Stamfelj *et al*., 2008).

There is a large body of research pertaining to the assessment of age-at-death estimates in humans based on the number of dental cementum layers (Charles *et al*., 1986; Condon *et al*., 1986; Kvaal and Solheim, 1995; Hillson, 1986; Wittwer-Backofen *et al*., 2004; Renz and Radlanksi 2006). The majority of these studies were developed using modern human teeth (Bosshardt and Schroeder, 1991; Maat *et al*., 2006; Wedel, 2007; Stamfelj *et al*., 2008). Cementum layers were first examined in marine and hibernating land mammals, migratory ungulates and their dependent carnivores (Morris, 1978; Perrin and Myrick, 1980; Hillson, 1986), and the method is useful for determining chronological age. Stott *et al*. (1982) evaluated the accuracy of age estimation using cementum layers in humans, and found a good correlation between the number of layers and the age-at-death in years.

Fewer studies have applied or tested this method on archaeological material (Beasley *et al*., 1992; Lieberman, 1994; Klevezal and Shishlina, 2001; Jankauskas *et al*., 2001; Stutz, 2002; Hillson and Antoine, 2003; Maat *et al*., 2006; Roksandic *et al*., 2009). Recording such structures in archaeological teeth presents additional challenges not found in modern specimens. For instance, the integrity of dental tissue can be compromised through various diagenetic processes (Lieberman, 1994; Stutz, 2002) and, when the chronological age at death is unknown, establishing the accuracy of such methods is difficult. Despite these issues, the method has often been applied to archaeological specimens (Stutz, 2002; Maat *et al*., 2006; Roksandic *et al*., 2009). Evaluating the recordability and accuracy of cementum layers as an ageing method in

Editor's note: Ms. Huffman's paper was awarded "First Prize" for 2010 in the Albert A. Dahlberg student research competition sponsored by the *Dental Anthropology Association*.

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archaeological material should be carefully considered.

Previous studies have found cementum counts to be a useful method for estimating biological age in archaeological material (Beasley *et al*., 1992; Lieberman, 1994; Jankauskas *et al*., 2001; Klevezal and Shishlina, 2001; Maat *et al*., 2006). Many of these studies conclude that cementum layers in archaeological material should give the same results as cementum layers in modern dentitions, as long as diagenetic processes do not affect the cementum and certain preparation methods are followed (section technique, type of microscopy). The results of Roksandic *et al*. (2009) and Stutz (2002) suggest that cementum in archaeological teeth is affected by diagenetic processes that can—particularly when observed in transmitted light microscopy –obscure layers or create optical artifacts in the form of extra cementum layers. These processes can result in observability and counting issues. This is particularly true of transmitted light microscopy, where the observation plane requires light to pass through several tens or hundreds of microns of tissue, offering ample opportunity for the light reflecting from each cementum layer to be affected by the optical properties of the tissue (Roksandic *et al*., 2009).

The present study focuses on human dental cementum in archaeological material, specifically with issues of observability, area of root with highest quality of cementum, and comparison to other aging methods. Particular emphasis is placed on interobserver error, region of root correlating most closely with chronological age, and comparisons between this cementum-layer aging method and other aging techniques. Understanding the variables that affect observability of archaeological cementum layers should aid establishing a best practice when using these layers to estimate biological age of individuals.

MATERIALS AND METHODS

The specimens used were from the Farringdon Street excavation, London (1730-1849), currently housed at The Museum of London. Three individuals of unknown age were chosen from the collection, and were aged using the Lovejoy *et al*. (1985) eight-phase auricular surface technique and the Suchey-Brooks (1990) six-phase pubic symphysis method. This aging method was chosen because it has been shown to give good estimates of age at death (Scheuer and Black, 2000; Bass, 2005).

TABLE 1. Tooth types of the 9 specimens analyzed

Specimen number	Tooth type
FA090 1408	
	maxillary right canine (URC)
	maxillary right third premolar (URP3)
	mandibular right second molar (LRM2)
FA090 1519	
	mandibular left central incisor (LLCI)
	maxillary right canine (URC)
	maxillary right third premolar (URP3)
FA090 1116	
	maxillary right canine (URC)
	maxillary left fourth premolar (ULP4
	mandibular right first molar (LRM1)

Three teeth were taken from each individual for a total of 9 teeth. A tooth was only used if an antimere was present so as to preserve the integrity of the Museum of London collection. Each specimen and tooth type was chosen on the basis of preservation, the presence of its antimere, and prior use in other published studies (Table 1). Typically, incisors, canines, premolars, and molars are used to count cementum layers (Solheim, 1990; Jankauskas *et al*., 2001), although some studies have indicated that premolars are a more reliable age indicator (Condon *et al*., 1986; Charles *et al*., 1986; Renz *et al*., 1997).

Specimens were embedded in the methylmethacrylate (MM). The two-week slow curing of this resin allows it to be fully absorbed into the tooth, strengthening the cementum and allowing the integrity of the tissue to be preserved during sectioning and polishing (Hillson, 1986). Sectioning was performed as follows (adapted from Antoine 2001):

1. A Buehler Isomet Low Speed Saw with a diamond abrasive-edge blade was used for the sectioning with 1:1 distilled water: industrial methylated spirit (IMS) as the lubricant.
2. Two cuts were made. The first was taken approximately 50 µm from the central plane of the tooth. After the first cut, half of this block section was kept for scanning electron microscopy (SEM).
3. The other half of the block was sectioned a second time to create a “thin” section. The cut was taken 900 µm (500 µm + the thickness of the blade) away from the first section plane towards the attached side of the tooth. This second cut was used for transmitted light microscopy.

Each tooth was sectioned from the tip of the cusp to the apex of the root. The incisors, canines, and premolars were sectioned longitudinally through the radial plane, orientated either buccolingal/palatal or labiolingual/palatal (Antoine *et al*., 2009). The molars were sectioned longitudinally via a tangential plane oriented through the tips of both the buccal/labial and lingual/palatal cusps (Antoine *et al*., 2009).

Preparation of the SEM Blocks

Once the sectioning was accomplished, the halves kept for SEM analysis were polished using an Engis LTd Kent MK2a polishing machine. The tooth was held onto a 3 µm and then a 1 µm hard plastic mat fixed to a rotating metal plate covered in 3 µm or 1 µm diamond polishing compound (Metadi II) and sprayed with dilap fluid as a lubricant (adapted from Hillson, 1986).

Preparation of Thin Sections

The thin sections were created to view the cementum layers under transmitted and polarized light microscopy. Each thin section was polished using a Lapping Machine Logitech Ltd. PM2 (after Antoine, 2001, 2009).

1. Thin sections were temporarily fixed to glass slides with a thin layer of melted removable sticky wax (Detrey Model Cementum Dental Sticky Wax), vacuum-held to a jig (Logitech PP5GT), and lapped down (approximately 50 µm to remove scratches or marks from the sectioning process); a 3 µm aluminium oxide abrasive solution was used as a lubricant-abrasive.
2. The polished portion of the tooth was desiccated in silica gel for 30 minutes, permanently mounted to another glass slide using photopolymeric cyanoacrylate resin (Logitech UV resin 358), and exposed to UV light for 30 minutes.

Polishing Thin Sections

Once one side of a thin section had been mounted to a glass slide, the other surface of the specimens could be polished.

1. Each specimen was polished on abrasive paper with finer grades of 600 and 1200, using deionized water as a lubricant. A glass plate with 3 µm aluminium oxide abrasive solution as the lubricant was used for the final polish to remove scratch marks.
2. Each specimen was polished down progressively to 400, 300, 200, and 100 µm, and the appearance of the cementum layers was recorded at each thickness to determine the impact this may have on their observability.

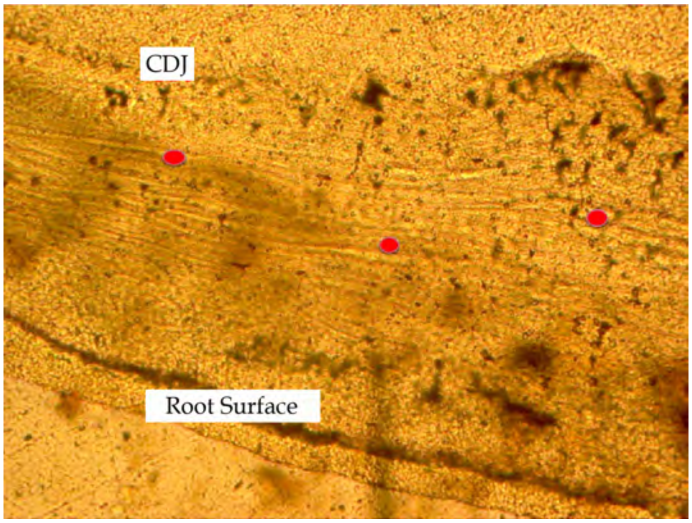

Fig. 1: This is an illustration of cementum layers. The cementum-dentine junction (CDJ) is to the top; the root surface is to the bottom. Each red dot identifies one clearly identifiable cementum layer.

Procedure for Counting the Incremental Layers

1. Two pictures from each progressive thickness were taken from each tooth. Using digital images, the Granular Layer of Tomes (GLT) was located, a feature that is normally found near the end of the dentine and close to the CDJ.
2. The CDJ initiates where the cementum layers begin. Cementum layer counts were recorded from the CDJ to the root surface or the last preserved cementum layer (Fig. 1).
3. The root was scanned and the clearest areas of dental cementum were selected for analysis (cervical, middle, or apical). One layer was defined from the border of two parallel darker lines. If the layers were difficult to find, the one layer was followed to another region where the increments were clear. If layers were not definable, pictures were taken to indicate no layering. In addition, if only a few layers were visible within the cementum thickness and large areas depicted no clear increments, the specimen was labeled as not having recordable layers.
4. Each of the images for the individuals was counted on three separate occasions, to create an estimated age. Age was calculated by adding the age of eruption of the tooth to the average count of cementum layers, using the Schour and Massler (1941) dental chart. The images and protocol for recording the layers were given to a colleague to count in order to assess interobserver error.

Variability in layer counts

Using the digitized images from transmitted light microscopy and from the SEM, cementum layers were counted, age of eruption was then combined with the layer count to calculate chronological age. Age ranges for each of the three individuals were then compared with the age ranges from the pubic symphysis (Brooks and Suchey 1990) and auricular surface (Lovejoy *et al*. 1985).

The interobserver error was tested on a subset of 9 randomly chosen images. The layers were counted twice

Table 2. Interobserver error for cementum layer counts

Specimen	Layer count, colleague	Layer count, author
1408 LRM2 400µm	63	24
1408 URC 400µm	29	31
1408 URP3 300µm	16	20
1116 ULP4 300µm	17	14
1519 URP3 200µm	42	20
1519 URP3 200µm	23	20
1116 URC 200µm	53	32
1116 ULP4 100µm	0	0
1116 LRM1 100µm	15	19

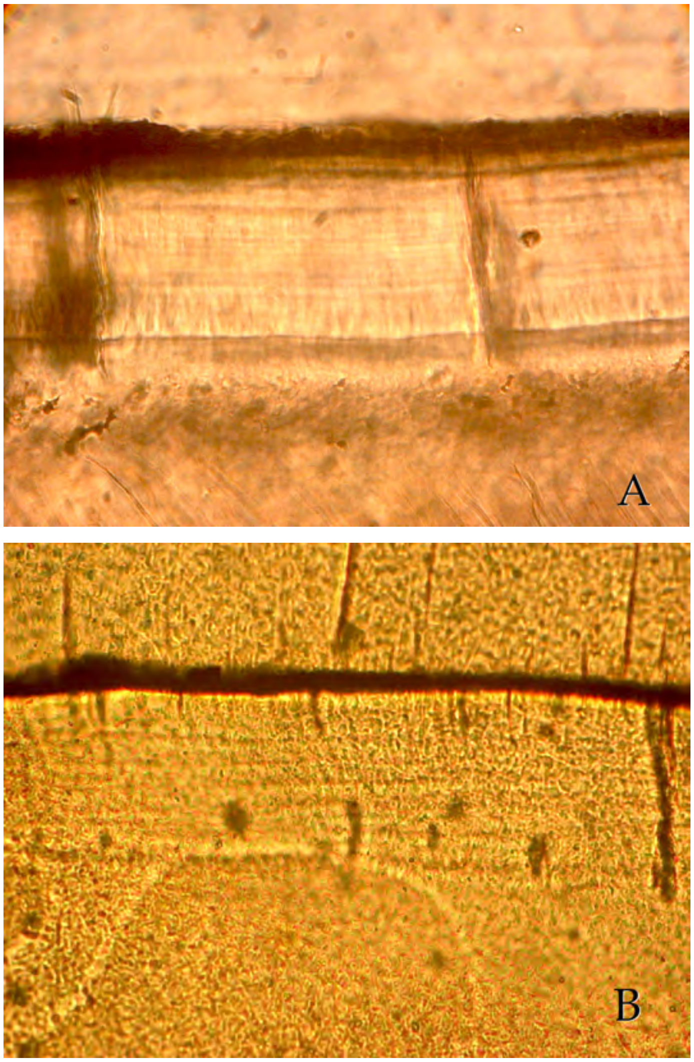

Fig. 2. Interobserver error of cement layer observations between author and colleague. (***A***) This is a transmitted light microscopy image of cementum layers on an upper right canine at 400 µm thickness. The author observed 31 layers, while a colleague observed 29 layers. (***B***) A transmitted light microscopy image of cementum layers on a lower right first molar at a 100 µm thickness. The author observed 19 layers, while a colleague observed 15 layers.

TABLE 3. Visible layers present by region of root

Region of root	No. of images not available	n	Images of visible layers	% of visible layers
Cervical	7	29	6	0.21
Middle	7	29	5	0.17
Apical	7	29	15	0.52

TABLE 4. Visible layers by section thickness and region of root

Section thickness	Cervical region	Middle region	Apical region
100 µm	0.00	0.25	0.63
200 µm	0.14	0.29	0.57
300 µm	0.50	0.00	0.50
400 µm	0.25	0.13	0.38

per image via a high definition computer screen at high magnification, and then compared with the author's previous counts.

RESULTS

Aging using Standard Skeletal Methods

The 3 individuals were aged in the traditional methods of skeletal aging using the pubic symphysis and auricular surface. Individual 1519 was the youngest of the three skeletons, determined to be 20-24 years of age. The second individual, 1116, was estimated to be between 35-39 years. Specimen 1408 was the oldest of the three and was assessed to be 50-60 years (Lovejoy *et al*., 1985).

The interoberver error indicated that the layer counts were similar although there were differences for some specimens (Table 2). The minimum difference between cementum counts was 0 and the maximum difference was 39. These results indicate that the process of counting cementum layers, even with a specific definition outlining the features constituting an increment, has a level of subjectivity (Fig. 2).

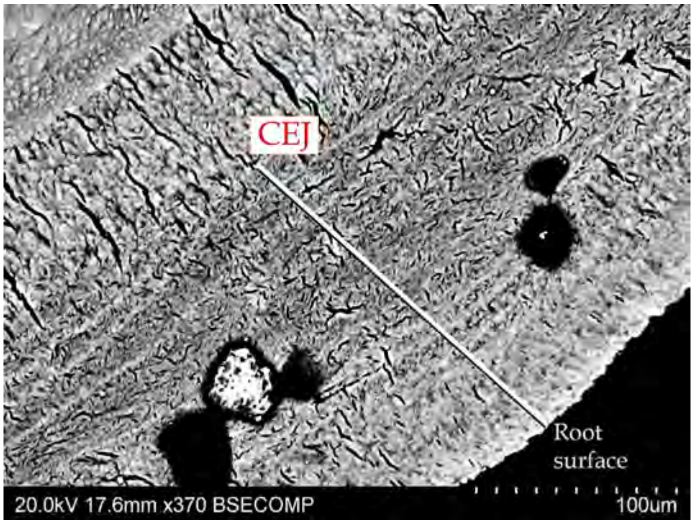

Fig. 3. Scanning electron microscopy (SEM) image depicting poorly defined cementum layering. The white line indicates the length of the cement layers. Most SEM blocks showed very few layers due to cracks affecting the imaging.

TABLE 5. Average counts of cementum layering for each specimen with eruption age compared with skeletal age estimate using the auricular surface[†]

Specimen	Cementum layer age range	Skeletal age range
1116	27-37	35-39
1519	24-43	20-24
1408	33-35	50-60+

[†]Eruption age of each tooth specimen was totaled with averaged cementum layer count to compile age ranges.

All regions of the root (cervical, middle, apical) were viewed in order to assess and count all cementum layers. The apical region of the root indicated the clearest area for observing and counting cementum layers (Tables 3-4).

When using SEM imaging, cementum layers were not visible in the majority of the specimens (Fig. 3). Transmitted light microscopy was found to be optimal for observing the cementum layers. Section thicknesses of 200 µm to 300 µm viewed under transmitted light microscopy showed the clearest cementum layers. The apical region of the root showed the clearest images of visible cementum layering in the majority of specimens. In general, the upper right third premolar consistently exhibited cementum layering.

This study found cementum layers tend to overestimate age in the younger individual, concurring with other studies (Miller *et al*., 1988; Kvaal and Solheim, 1995; Meinl *et al*., 2008). The present study found cementum layers to underestimate the older individuals in accord with other research (Miller *et al*., 1988; Kvaal and Solheim, 1995; Meinl *et al*., 2008). Overall, many ranges of cementum layer counts were found for each individual. For example, layer counts for individual 1116 specimen LRM1 at 400 µm ranged from 20-30, and at 300 µm 12-16 layers were identified. When the eruption age was added to these increments variable age ranges were found per each individual (Table 5).

DISCUSSION

Skeletal The appreciable between-observer differences reflect how difficult recording cementum structures can be. When the interobserver results were combined, the cementum age estimates were very large (Table 6). The cementum layer estimates did not compare well with the pelvis age ranges. Overall, he observation and recording of cementum layers has proven to be difficult.

Table 6. Age range for each individual

Specimen	Cementum Layer Age Range	Cementum and Combined Interobserver Age Range	Skeletal Age Range
1519	24-43	24-52	20-24
1116	27-37	21-64	35-39
1408	33-35	26-75	50-60+

The apical region of the root proved to be the best area to observe and count cementum layers. Cementum layers in the cervical and middle regions of the root were markedly unclear and nearly incalculable in the majority of sections. Perhaps diagenetic processes or the sectioning technique rendered these regions of cementum unusable.

Counting cementum layers as an estimate of the age-of-death resulted in a broad range of age estimates. Unfortunately, the accuracy of cementum layering for aging individuals in the present study cannot be compared to other studies, in part because the skeletal specimens were of unknown age.

Many of the research studies have used modern teeth (Zander and Hurzeler, 1958; Charles *et al*., 1986; Kvaal *et al*., 1996; Renz and Radlanski, 2006); only a few have actually used archaeological specimens (Lieberman, 1994; Jankauskas *et al*., 2001; Wittwer-Backofen *et al*., 2008; Roksandic *et al*., 2009). As previously observed by Lieberman, using archaeological specimens to observe incremental layers can be problematic: unidentified diagenetic processes may affect the optical properties of the cementum with the dissolution of collagen reducing the number of visible layers and microbial action removing outer layers (Lieberman, 1994). Indeed, chemical diagenic processes such as collagen leaching (removal of collagen through water or other liquids) and apatite recrystallization (development of banded features that mimic cementum layers) can both dissolve layers or create extra bands, affecting the technique's accuracy (Stutz, 2002). The integrity of the dental cementum can also be compromised in archaeological specimens. The present study found that the more rapidly growing cellular cementum found at the apex of the root showed the clearest layers, whereas the slower and thinner acellular cementum layers found in the middle and cervical regions were difficult to observe. In their study of the applicability of cementum layers aging in archaeological specimens Roksandic *et al*. (2009) reported similar problems. Approximately 80% of the teeth were discarded because the cementum layers appeared to be compromised by diagenic processes causing wavy lines that were interspersed with pits, impurities bifurcating lines, and partially obscured lines (Roksandic *et al*., 2009). They also found that the cervical and middle regions of the cementum were the most difficult to record and most likely affected by diagenic processes.

The present study found that, in archaeological material, the observation of cementum layers can be difficult, and there is variability in the readability of various regions of the root, possibly caused by diagenic processes. Evaluating and understanding the variables that may affect the observability of archaeological cementum layers should be a prerequisite to assessing how useful cementum layers are in estimating biological age. Unfortunately for archaeologists, the growth structures in the cementum of ancient teeth often are difficult to observe. When they are observed, the number of visible layers can be affected by diagenetic processes, compromising their use as an aging technique.

CONCLUSION

The present study studied incisors, canines, premolars, and molars, cut and polished at progressively thin sections from archaeological specimens of unknown ages. Interobserver error indicated that viewing and counting cementum layers can prove to be a difficult process that can lead to large age ranges per individual. The readable and unreadable segments of the various root regions are disconcerting and can lead to a high level of subjectivity that increases intra- and interobserver error. Chemical diagenetic processes affect the integrity of archaeological dental tissue, often obscuring and/or creating additional layers within the cementum. The current study has found that there are incremental layers within dental cementum that correlate positively with age, although there is little understanding of the significance of these layers. Evaluating archaeological dental material and the variables, such as subjectivity in counts and diagenetic processes, that affect the observability of cementum layers is important. Therefore, to successfully evaluate the aging technique of cementum layers using archaeological material, researchers must understand the problems of observability. Research should focus on understanding the biological process of cementum formation, as well as an examination of how diagenetic processes affect archaeological dental tissue.

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The 15th International Symposium on Dental Morphology will be held from 24-27 August, 2011 at Northumbria University in Newcastle upon Tyne, United Kingdom, sponsored by the Newcastle University School of Dental Sciences. This symposium will bring together scholars from around the world to present research in all aspects of dental morphology. The range of presentations will be broad and include topics such as dental anthropology, dental evolution, dental function, growth and development, dental tissues, and the genetics and clinical aspects of dental morphology. For more information or to be added to our mailing list, please contact Dr Wendy Dirks (Wendy.Dirks@ncl.ac.uk).

The Dental Traits of Indonesian Javanese

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Dental Traits of Indonesian Javanese

ABSTRACT This study describes the dental crown morphology of 91 Javanese of known sex and age, in Surabaya, East Java. The purpose was to explore the dental morphology in the area of East Java, especially in Surabaya. I scored a battery of three dozen dental traits on the permanent dentition (sexes pooled). Comparisons of the trait frequencies show that this Javanese sample does not exhibit a classic combination either of the Sinodont or Sundadont dental patterns. Instead, it represents some features of each, and this probably is due to the millennia of human migrations through this region. *Dental Anthropology* 2010(23):74-78.

The dental morphology of Southeast Asia is poorly known. Studies in dental anthropology have never been conducted on Indonesians even though the area has a rich variety of peoples and cultures. Data on the variety of populations in this area may be useful regarding human evolution (Hillson, 2002), migration patterns (Scott and Turner, 2000), and for evaluating forensic cases (Brown, 1992). Previous studies have assessed menarcheal age (Artaria and Henneberg, 2000), mesiodistal diameters of the primary dentition (Kuswandari and Nishino, 2004), and adolescents' growth and development (Artaria, 2009), but little has been found on the characteristics of the dentition in Javanese people, so it is useful to initiate studies of this kind.

Previous study on the Javanese dentition (Artaria, 2007) found that shovel shape, winging, tuberculum dentale, interruption groove, canine distal accessory ridge, premolar accessory ridges, premolar multiple lingual cusps, cusp 5, cusp 6, Y5 pattern, cusp 7, protostylid, deflecting wrinkle, anterior fovea, and Carabelli's cusp occurred in the sample. However, that preliminary sample size was small, and no scoring was done for each variable.

The literature suggest that dental variation is heritable, the traits appear to be controlled by multiple genes, and they are little influenced by environmental factors (Rodríguez-Flórez *et al*., 2006), so phenotypic differences among samples can be interpreted as differences in genotypic composition (Varela and Cocilovo, 2000). Phenotypic similarity is suggested to approximate genetic similarity.

Research on the primary dentition of Javanese children (Kuswandari and Nishino, 2004) found that the mesiodistal tooth diameters fell between those of Australian Aboriginals and Hong Kong Chinese. This makes sense because Jacob (1967) and others note that the islands of Indonesia historically were occupied by ancient Homo sapiens similar to those of the Australians. The teeth of the Javanese may reflect the admixture of two ancestral lines, namely Australomelanesid and Mongoloid.

The goal of the present research was to describe the frequencies of some common dental traits as they were represented in a contemporary sample of Javanese.

MATERIAL AND METHODS

The sample was 91 individuals from the Surabaya, East Java (Indonesia). The dental traits examined were shovel shape, double shovel, winging, tuberculum dentale, interruption groove, canine distal accessory ridges, Carabelli's cusp, odontomes, premolar accessory ridge, parastyle, multiple lingual cusps, Dryopithecus pattern, Cusp 5, Cusp 6, Cusp 7, deflecting wrinkle, anterior fovea, protostylid, and uncommon shape/place of lateral incisors. Dental traits were scored using the descriptions in Scott and Turner (2000), and the dental plaques provided by ASU. Percentages were counted using simple descriptive statistic analysis.

RESULTS AND DISCUSSION

Scott and Turner (2000) have divided the world's populations into five groups based on their dentitions. The dental traits of Sahul-Pacific group—the same area occupied by the Australomelanesid according to Jacob (1967)—exhibit dental characteristics such as frequent expression of cusp 5, Carabelli's cusp, and cusp 6. In contrast, there are rare expressions of winging, shoveling, double shoveling, interruption grooves, and cusp 7. Further, they have intermediate position for several

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traits such as odontomes, 4 cusped LM1 and LM2, LM2 Y pattern, and deflecting wrinkle.

The Sino-Americas group, according to Scott and Turner (2000) has characteristics of dentition such as high frequency of winging, double shoveling, interruption grooves, odontomes, cusp 6, and deflecting wrinkle. The Sunda Pacific groups have no high frequency dental traits that set them apart; however, they have high frequencies of Carabelli's cusp and cusp 6, and low frequencies of cusp 7 and 4-cusped LM1.

Shovel shape had been widely studied by several authors (*e.g.*, Campusano *et al.*, 1972; Dahlberg, 1951; DeVoto *et al.*, 1968; Bollini *et al.*, 2006; Nelson, 1938; Rothhammer *et al.*, 1968). Most of these studies concluded that high frequency of strong shovel shaped incisors was found in Mongoloid populations, especially those descendants of Mongoloid people from the Asian continent. A study by Bollini *et al*. (2009) reported a high frequency of shovel shape (80%) but absence of Carabelli's complex in the Pre-Conquest sample "Calchaquí" from Argentina.

In the present sample, shovel shape was common, although the expressions were mostly grades 2 and 3 (Table 1) using the ASU shovel shape dental plaque. This is expected given the Asian ancestry of the group, especially the Sundadont. The most frequent degree of expression for upper first incisor and lateral incisors was 2. It was also noteworthy that the frequency of the sample that did not have shoveled-shape upper incisors was comparatively high—8% to 9% (Table 1). These frequencies for shoveling suggest similarities to the Sunda Pacific group.

Some subjects have slight double shovel (Table 1). The frequency of double shovel in recent Southeast Asia predicted by Scott and Turner (2000) is 5% to 18%. However, this higher frequency in these Javanese may reflect admixture of the Surabayan people in the coastal area of northeast Java with the Sinodont-people from Asia who migrated to the Indonesian areas during the first to second centuries. Double shovel was found in the upper central incisors in 73% of the sample, but only in a weak expression, scores 1 to 3, and 47% of the sample had double shovel of their lateral incisors. Double shoveling frequency is similar to that of the Sunda Pacific group.

TABLE 1. Percentages of shovel and double shovel shape†

Grade	Shovel UI1	Shovel UI2	Shovel lower I and C	Double shovel UI1	Double shovel UI2
0	8.8	7.7	62.3	26.2	53.3
1	8.8	24.2	27.9	57.4	38.3
2	40.7	30.8	8.2	14.8	7.4
3	24.2	17.6	1.6	1.6	0.0
4	9.9	13.2	0.0	0.0	0.0
5	7.7	3.3	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0
7	0.0	2.2	0.0	0.0	0.0
Missing	0.0	1.0	0.0	0.0	1.0
Total	100.0	100.0	100.0	100.0	100.0

†UI1: upper central incisor, UI2: upper lateral incisor, I: incisor, C: canine

TABLE 2. Percentage of tuberculum dentale (TD), interruption groove (IG), maxillary incisor winging, and uncommon shape/ place of lateral incisors (LI)

Grade	TD	IG	Winging	LI Shape
0	47.3	86.7	84.6	0.0
1	18.7	12.3	7.7	0.0
2	24.2	0.0	5.5	0.0
3	3.3	0.0	2.2	0.0
Absent	0.0	0.0	0.0	98.3
Present	0.0	0.0	0.0	1.7
Missing	0.0	1.0	0.0	0.0
Total	100.0	100.0	100.0	100.0

High frequencies of winging are usually found in Sinodont dentitions, especially groups in northeast Siberia and North America. The people of Java are labeled Sundadont, and some data suggest that Sundadont groups may also have high frequencies of winging. The Sunda Pacific group is suggested to exhibit winging on the order of 15% to 28% (Scott and Turner, 2000). Incisor winging occurred in 15% of the present sample (Table 2), so it is comparable to the Sunda Pacific group as described by Scott and Turner.

Expression of tuberculum dentale was weak to moderate, and most individuals—47%—lacked tuberculum dentale on their central incisors (Table 2). Only 3% exhibited a more pronounced—score 3—grade of tuberculum dentale. This is neither characteristic of Sino Americas nor Sahul Pacific, but more like that of Sunda Pacific groups.

According to Scott and Turner (2000), the Sunda-Pacific people—including Southeast Asians—have frequencies of 25% to 35% with interruption grooves on the second incisors. However, interruption grooves on the upper second incisors occurred in only 12% of the current sample (Table 2). This low frequency of interruption grooves is more similar to Sahul Pacific groups.

Upper lateral incisors can undergo rotation, crowding, or reduced size (Table 2), and the uncommon shape or placement of lateral incisors occurred in a small number of the sample (2%). Instead of having uncommon shape/ size of lateral incisors—as is more common in Caucasian samples, Mongoloids seem to have more cases of winging of central incisors (C. G. Turner, pers. comm.).

No Bushmen canine was found in the sample. Canine distal accessory ridge occurred in 69% of the sample (Table 3). The occurrence of distal accessory ridges on

TABLE 3. Percentages of distal accessory ridge (DAR) and the Bushmen canine[†]

Score	DAR UC	DAR LC	Bushmen UC
0	31.1	88.5	100.0
1	49.2	11.5	0.0
2	19.7	0.0	0.0
Missing	0.0	0.0	0.0
Total	100.0	100.0	100.0

[†]U = upper, L = lower, C = canine

the lower canine was less common (12% of the sample). Research is needed to find out whether there is sexual dimorphism in this particular trait.

There was an indication of sexual dimorphism—males having larger cusps—for Carabelli's trait (Khraisat *et al*., 2007). According to Mavrodisz *et al*. (2007), there is a genetic influence on the Carabelli's trait. There also is a positive association between Carabelli's cusp and tooth crown size (Garn *et al*., 1966; Harris, 2007). Carabelli's trait complex was expressed in more than 70% of the cases (Table 4), with the degree of expression ranging from 0 to 7. The high percentage of Carabelli's cusp is the characteristic of both Sunda Pacific and Sahul Pacific. However, according to Scott and Turner (2000), the percentage may reach 25%, but not as high as 70%. This outstanding occurrence of Carabelli's cusp may be related to some other factors, such as the size of the tooth crown (Harris, 2007) or sampling fluctuation. Further research in this matter may be conducted in the near future.

The parastyle occurred on 2% (M3) to 6% (M2) of the molars, while no parastyle nor cusp 5 was found on M1 (Table 4). The absence of cusp 5 certainly is not a characteristic of Sahul Pacific groups; it is more characteristic of Sino Americans according to Scott and Turner (2000).

The groove pattern was mostly of the X pattern (Table 5). The Dryopithecus pattern (Y pattern LM2) was found in 7% of the sample. The frequency of the Y pattern of Australians (Sahul Pacific group) is approximately 21%. The percentage of Y pattern on LM2 in China Mongolia and North and South America (Sino Americas group) is around 8-9%, and in the Sunda Pacific is around 19% (Scott and Turner, 2000), so the percentage of the Y pattern in this sample was closer to the Sino American condition.

Cusp 6 was found in 6% of the sample, and no cusp 7 was found (Table 5). The closest percentage of cusp 6 occurrence was the New Guinea people (Sahul Pacific) that has around 18% of people with the dental trait. The south Siberian (Sino American group) has 20%, and the Southeast Asians (Sunda Pacific group) 32% (Scott and Turner, 2000). Cusp 7 is a common characteristic in Sub-Saharan peoples, while low frequencies (0-10%) generally occur in the Sino Americas, Sahul Pacific, and Sunda Pacific groups (Scott and Turner, 2000), so this accessory cusp is, not surprisingly, absent in this Javanese sample.

Most of the sample (above 90%) had no deflecting wrinkle or anterior fovea (Table 5). Deflecting wrinkle was found in 3%, and anterior fovea was in 7% of the sample. The closest percentage of deflecting wrinkle was found in the New Guinean people—around 5% of the people. The recent Southeast Asian (Sunda Pacific group) has 15%, and other Sino Americas around 30% and above (Scott and Turner, 2000).

The protostylid occurred predominately on M1, with a frequency above 50% (Table 5). Similar to the Carabelli cusp, the protostylid also is positively associated with crown size (Scott and Turner, 2000). Further they stated that the protostylid was frequently expressed on LM1—which was true for this sample, but when it appeared on LM2 the size often was bigger.

Accessory ridge was found in 10% to 29% of the upper premolars in the sample (Table 6), while the percentage of sample having accessory ridges on the lower premolars was even less, namely 1-2% (Table 7) as expected. There were no odontomes (Table 6 and 7), although Scott and Turner (2000) estimated that 1 to 4% of recent Southeast

TABLE 4. Trait percentages on the upper molars[†]

Score	UM1C	UM2C	UM1C5	UM1PA	UM2PA	UM3PA
0	20.9	71.4	100.0	100.0	93.3	17.6
1	40.7	15.4	0.0	0.0	5.6	2.2
2	20.9	12.1	0.0	0.0	0.0	0.0
3	9.9	0.0	0.0	0.0	0.0	0.0
4	2.2	0.0	0.0	0.0	0.0	0.0
5	2.2	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0
7	3.3	0.0	0.0	0.0	0.0	0.0
Missing	0.0	1.1	0.0	0.0	1.1	80.2
Total	100.0	100.0	100.0	100.0	100.0	100.0

[†]U = upper, M = molar, C = Carabelli's cusp, C5 = cusp 5, PA = parastyle

TABLE 5. Percentage of traits in lower molars†

Score	LM2GP	LM1C6	LM1C7	LM1DW	LM1AF	LM1PO	LM2PO	LM3PO
0	24.6	94.3	100.0	96.2	92.6	47.3	65.6	13.2
1	6.6	5.7	0.0	3.8	7.4	52.7	34.4	4.4
2	65.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	3.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Missing	0.0	0.0	0.0	0.0	0.0	0.0	0.0	82.4
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

†L=lower, M=molar, GP=groove pattern, score 0: unclear groove/missing tooth, score 1: Dryopithecus pattern, score 2: X pattern, score 3: + pattern; C6=cusp 6, C7=cusp 7, DW=deflecting wrinkle, AF=anterior fovea, PO = protostylid

Asian people have odontomes. Multiple lingual cusps were found mostly on the lower second premolar. The cusps were also more complicated on the second lower premolars (Table 7).

CONCLUSION

Based on the finding in this Javanese sample, the trait frequencies were more like Sunda Pacific. The Sundadont people who have higher frequency of derived traits are thought to have evolved on Sundaland during Upper Pleistocene. They exhibit a “more conservative pattern, typified by trait retention rather than elaboration” (Scott and Turner, 2000). The traits with frequencies similar to the Sunda Pacific group were shoveling, double shovel, winging, and tuberculum dentale.

However, other percentages mirror those of the Sino Americas, and still others those of Sahul Pacific. Trait frequencies similar to Sino Americas were cusp 5 and the Y pattern. Percentages similar to Sahul Pacific were interruption grooves, cusp 6, and deflecting wrinkle. Consequently, this sample of Javanese is not monolithic as regards either the Sinodont or Sundadont dental patterns. Instead, they exhibit some features of each, probably because of the millennia of human migrations through this region.

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TABLE 6. The percentage of traits in upper premolars†

Score	UP1AR	UP2AR	UP1OD	UP2OD
0	90.0	71.4	100.0	100.0
1	10.0	28.6	0.0	0.0
Missing	0.0	0.0	0.0	0.0
Total	100.0	100.0	100.0	100.0

†U = upper, P = premolar, AR = accessory ridge, OD = odontome

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TABLE 7. Trait percentage on the lower premolars†

Score	LP1AR	LP2AR	LP1OD	LP2OD	LP1MLC	LP2MLC
0	98.4	98.3	100.0	100.0	94.8	36.2
1	1.6	1.7	0.0	0.0	5.2	37.9
2	0.0	0.0	0.0	0.0	0.0	22.4
3	0.0	0.0	0.0	0.0	0.0	3.4
Missing	0.0	0.0	0.0	0.0	0.0	0.0
Total	100.0	100.0	100.0	100.0	100.0	100.0

†L = lower, P = premolar, AR = accessory ridge, OD = odontome, MLC = multiple lingual cusps

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Impacted Lower First Molar and Labial Ectopic Upper Canine Eruption in an Individual from the Prehistoric American Southwest

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ABSTRACT Tooth impactions and other positional anomalies are commonly encountered in clinical situations but are much less frequently seen in, or reported from, prehistoric archaeologically derived contexts. This report examines the occurrence of two positional anomalies, lower first molar impaction and upper canine labial ectopic eruption, in a single individual from the Ancestral Pueblo Gallina Phase (1100-1275 AD) of northern New Mexico. Although outwardly dissimilar, appearing as they do in different tooth classes and both the mandible and maxilla, their underlying similarity implies a common etiology. The co-occurrence of these anomalies presents an opportunity to explore the etiological basis of positional anomalies and possibly provide some insight into the very early stages of dental morphogenesis. *Dental Anthropology* 23(3):79-82.

Although probably occurring in frequencies similar to those found in modern clinical samples, eruption disturbances are rarely reported from archaeologically derived skeletal series. Several factors lead to this underreporting including lack of recognition by workers unfamiliar with dental anatomy and eruptive processes and the associated fact that low natural occurrence frequencies lead to extreme rarity in the often small population samples anthropologists commonly study. In addition, when eruptive disturbances are found they frequently appear in a single individual so have little evolutionary or predictive value.

However, when two eruption disturbances, affecting both mandible and maxilla and different tooth classes, appear in a single individual further investigation and reporting is warranted, particularly when one is considered quite rare by clinical standards. In this short communication I explore a case of lower first molar impaction in an individual from the Ancestral Puebloan Gallina phase of north central New Mexico dating to approximately 750 years ago. This individual also expresses labial ectopic alveolar eruption of the left maxillary canine.

According to Pindborg (1970) and Andreasen *et al*. (1997) impaction of the lower first molar is the rarest of eruptive disturbances with occurrence frequencies reported to be between 0.00 and 0.063 percent (Dachi and Howell, 1961; Kramer and Williams, 1970; Shah *et al*., 1978; Grover and Lorton, 1985). Because of its rarity, documentation and description of LM1 impaction in an individual from a prehistoric context may shed some light on the etiology of the anomaly and its developmental background.

In contrast to M_1 impaction, ectopic eruption of maxillary canines is relatively common at least among positional developmental anomalies. The maxillary canine is one of the most frequently malerupted teeth and palatal and labial ectopic eruption is well documented (Pindborg, 1970; Peck *et al*., 1994; Becker and Chaushu, 2000; Chaushu *et al*., 2003; Camilleri *et al*., 2008). In addition, transposition of maxillary canines and third premolars is one of the best documented dental anomalies among prehistoric skeletal series (Nelson, 1992; Burnett and Weets, 2001).

Context of the Burial

The Gallina were an Ancestral Pueblo group who occupied a fairly restricted geographic area of northern New Mexico during the Pueblo III period (approximately 1100-1300 AD). Centered in the Llaves valley the Gallina were maize horticulturalists who were greatly impacted by extended droughts of the thirteenth century and who disappear between 1260 and 1300 AD (Ellis, 1988; Crown *et al*., 1996). The BMG site is an unexcavated habitation site occupying a small ridge on the western flanks of the Llaves valley that was surveyed during summer 2006. During this survey a skeleton was discovered eroding out just west of the ridge top and collected. The individual, BMG-1, is a female of approximately 19-23 years of age based on dental wear and tooth eruption and iliac crest

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fusion (Buikstra and Ubelaker, 1994; Bass, 1995). Upon curation and cleaning in the lab four skeletal elements representing a neonate were discovered (BMG-1a).

Description of gnathic elements

Dental and gnathic remains of BMG-1 include most of the mandible, the left maxilla, and three isolated maxillary teeth. The mandibular corpus (Fig. 1) is broken in the right premolar area such that the posterior portion of the right corpus does not connect with the remainder of the mandible although both RP$_3$ and RP$_4$ are present. The anterior portion of the RP$_3$ socket remains allowing correct placement of this tooth within the arcade. All teeth are present except for LM$_3$, RM$_2$, and RM$_3$. The sockets

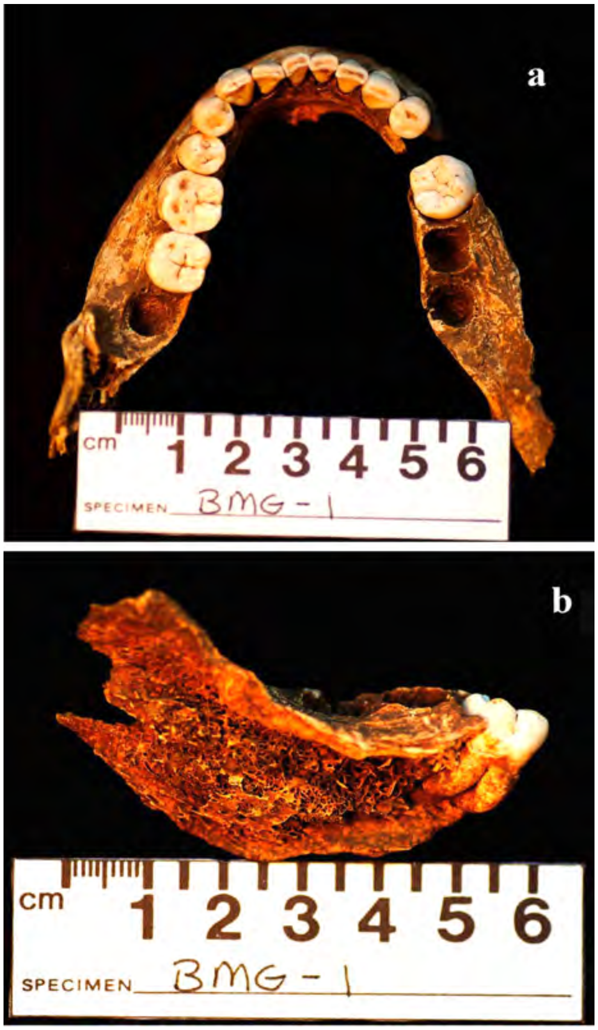

Fig. 1. Mandible of BMG-1. (***a***) Superior view of mandible and dental arcade with impacted RM$_1$. Note wear differential between LM$_1$ and RM$_1$. RP$_4$ was recovered but destruction of corpus precludes reattachment. (***b***)Lateral view of right corpus with RM$_1$ exposed. It can be seen in this lateral view that the occlusal surface of RM$_1$ is at the level of he alveolus even though the roots are fully formed. Scale in cm.

Fig. 2. Left maxilla of BMG-1. (***a***) Lateral view. (***b***) Anterior view. (***c***) Superior view, arrow points to canine root in floor of nasal cavity. Scale in cm.

of the missing molars are complete and there is a distal interproximal facet on LM_2 indicating the third molars had fully erupted. Both rami are missing and the lateral outer table of the posterior right corpus has broken away revealing the cancellous bone.

The alveolar portion of the left maxilla (Fig. 2) is complete and retains the ectopically erupting L^C and the LM^1 and LM^2. The LP^3 is loose but fits into its partial socket while LI^1, LI^2, LP^4, and LM^3 are missing but were lost postmortem. The only remains of the right maxilla are the RI^2, R^C, and RP^3. Wear is moderate with dentine exposure on the lower incisors and dentine patches on the major cusps of the LM_1 (Fig. 1a). Although extreme by modern standards for an individual of this age, advanced wear is common for prehistoric maize horticulturalists whose teeth were greatly impacted by grinding stone grit. The wear pattern for this individual is typical except for the almost complete lack of wear on the LP_3 and LP_4 which reflects the noneruption of the maxillary left canine and the corresponding gap in the maxillary arcade.

Lower Right First Molar Impaction.

The breakage of the posterior right mandibular corpus, although unfortunate as far as integrity of the remains is concerned, does allow visualization of the entire impacted right first molar (Fig. 1b). The tooth lies approximately 20° off the vertical and appears to have been impacted against the RP4 although there are no contact facets on the distal root or crown of this tooth. Because of the position of the tooth within the corpus, the crown level with the alveolar border and the fact that there is no polish on the cusps, the tooth was probably never continually exposed to the oral environment. Although the corpus mesial to RM_1 and distal to RP_3 is broken and missing, both premolars appear to have erupted normally indicating that rdm_2 was not retained, as can be common in M_1 impactions (Bjerklin and Kurol, 1983). The distal border of the RM_1 socket exhibits some remodeling indicating that although the M1 had not erupted periodontal disease was causing minor resorptive bone loss.

Upper Left Canine Ectopic Eruption.

The canine is erupting through the alveolus between the roots of the LI^2 and LP^3 and is oriented perpendicular to the tooth row with the root appearing in the floor of the left nasal cavity (Fig. 2c). The sockets for the LI^1 and LI^2 are normal in form and position while the LP^3 is rotated approximately 30° distally. There is a gap between the LI^2 and LP^3 indicating that space was available for the L^C had it been properly oriented (Fig. 2a, b). Additionally, the alveolus between the LI^2 and LP^3 is retained and shows no indication of dl^C retention.

DISCUSSION

The appearance of anomalies of dental development and eruption in prehistoric skeletal series allows us to examine their occurrence outside of a clinical setting and can provide insight into their etiology and development. Although an in-depth examination of the ultimate cause of these anomalies is beyond the scope of this investigation an exploration into the occurrence of two anomalies in one individual might lend some insight into the developmental processes and genetic underpinnings of dental morphogenesis. Although prior research into cooccurrence shows little or no correspondence between ectopic canine eruption and M1 impaction (Baccetti, 1998, 2000) the possibility that similar genetic or developmental pathways lead to these positional anomalies is intriguing.

With BMG-1 we are presented with two instances of positional anomalies that do not appear to have been caused by common environmental perturbations such as retention of deciduous teeth or crowding. In both cases the original orientation of the tooth bud seems to have been rotated from its normal position causing the tooth to grow in the wrong direction. These cases of anomalous placement within the gnathic elements indicate disruption of the developmental pathway very early in embryogenesis possibly at the placode stage or even earlier when the cells that are to become the tooth bud are first differentiating (Thesleff, 2000, 2003). This implies that along the ectoderm/mesenchyme boundary at the point of contact between the signaling molecules (such as Shh) and their receptors and target genes there is a malfunction in the mechanism which orients the tooth in space. Whether the anomalous orientation is due to a breakdown in the cellular matrix and tissue structure or in the genetic signaling is unknown. One clue may be found in the observation that although within the dental arcade the axes of misorientation are different, labio-lingual for the canine and mesio-distal for the molar, in space the axes are the same, i.e. antero-posterior with the crown directed anteriorly. This similarity in orientation in space may offer insight both into which element within the developmental genetic cascade involved in tooth formation misfires and whether these molar and canine positional anomalies are related etiologically.

If the misorientation of the two teeth is etiologically related then the failure could be due to several factors including, (1) a misalignment of the target cells within either the epithelial or mesenchymal tissue, depending on when in the genetic cascade it occurs (2) misorientation of the placode upon initial budding to the mesenchyme and (3) a kink in the epithelial/mesenchyme tissue complex within the already developing maxilla and mandible. It is also important to note that the crowns and roots of both teeth are normal, with cusps in the proper form and location, indicating no disruption of genetic communication after the initial budding of the placode to the mesenchyme or in the actual development of the tooth.

For the time being many questions concerning the ultimate cause of these positional anomalies must remain unanswered. However, insights gained from the case of BMG-1 may allow the focus to be narrowed down to a small developmental window early in tooth morphogenesis during the period at or before the placode buds to the mesenchyme. Because of the large number of signaling and target genes involved in the genetic cascade responsible for the earliest stages of dental development it may be difficult to pinpoint exactly which combination results in locating the developing tooth in space.

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American Black-White Differences in Primary Tooth Crown Shape: The Crown Index

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ABSTRACT: The purpose of this tooth-size study was to compare the crown index—the ratio of buccolingual to mesiodistal crown size—in the primary teeth of contemporary American blacks and whites. Maximum MD and BL drown dimensions were obtained with sliding calipers from dental casts of children attending the graduate pedodontic and orthodontic clinics at the University of Tennessee, Memphis (n = 226). The crown index (BL/MD times 100) was calculated for all 10 tooth types (left and right sides were averaged prior to calculation). Only the maxillary first molar exhibited a significant sex difference (girls have a higher crown index). In contrast, 9 of the 10 tooth types have signficantly higher crown indices in blacks than whites. Analysis of the MD and BL crown diameters reveals that the race differencs are due exclusively to differences in mesiodistal crown lengths; the buccolingual crown breadths do not differ between these two races. Consequently, the crown indices are higher in blacks because of their larger MD dimensions. Differences in the indices conform to prior findings that American blacks have larger tooth crowns than whites in both the primary and permanent dentitions, and this study shows that the differences are due to the MD not the BL crown axis. Study of the crown components will shed light on how the crown shapes differ between these two races. *Dental Anthropology* 2010;23(3):83-88.

It is commonly appreciated that teeth differ among human groups both as regards shape as well as size. Part of this is due to differences in the prevalence and degree of crown traits, such as incisor shoveling (Hrdlička, 1920) and molar cusp number (Harris and Bailit, 1980), but other differences involve the proportionality of crown components such as relative cusp sizes (Turner *et al.*, 1991; Townsend *et al.*, 2003; Harris and Dinh, 2006)

Two of the prominent races in the United States are blacks and whites. The 2000 Census of the U.S. lists self-assessed proportions of blacks and whites at about 13% and 65%, respectively. The dental anthropology of American blacks is not known as well as for the majority whites, partly because blacks are unevenly distributed geographically, being concentrated in the Southeast. Anthropological dental studies are primarily limited to tooth eruption and crown sizes. Studies document the early development of teeth in American blacks *vis-à-vis* American whites. We are aware of two studies of the primary dentition (both dealing with tooth emergence); both show a precedence of American blacks compared to American whites (Ferguson *et al.*, 1957; Infante, 1974). The serial study of children from Tuskeegee, Alabama (Steggerda and Hill, 1942) and national U.S. epidemiological studies have collected data on the ages of emergence of the permanent teeth (Garn *et al.*, 1972, 1973), but fewer data are available on crown sizes. The study by Richardson and Malhotra (1975, 1976) based on the Meharry growth study (Nashville, Tennessee) probably is the best known and most commonly cited study for the permanent teeth of American blacks (n ≈ 160). Ferguson *et al*. (1978; Macko *et al*., 1979) reported on a sample of blacks (n ≈ 113) from the University of Connecticut. Keene (1979) described mesiodistal crown lengths in black male U.S. Navy recruits (also Keene, 1967).

As for the primary dentition, Moss and colleagues (1966a,b) published data on Liberian (west-central Africa) primary tooth sizes, but sample sizes were small (8 to 19 extracted teeth per type, sexes combined). Hanihara (1976) studied a sample of blacks (n ≈ 65) at the University of Chicago. Vaughan and Harris (1992) described a sample of 100 blacks collected at the University of Tennessee. Anderson (2005, 2006, 2007) described tooth crown sizes of a large sample (n ≈ 1,124) of American blacks from Howard University (Washington, D.C.)

To our knowledge, prior studies have been limited to the mesiodistal (MD) and buccolingual (BL) dimensions themselves, though Hanihara did employ multivariate statistics. The purpose of the present study is to compare tooth crown shapes—ratios of BL width to MD depth—in the primary teeth from samples of American blacks and whites from the U.S. Mid-South. This report was stimulated by exploratory findings that suggested that blacks have significantly different crown indices than whites, and the present study explores that finding in more detail.

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MATERIALS AND METHODS

Full-mouth hydrocolloid casts were taken on children in the primary or early mixed dentitions. These were poured immediately in dental stone. Children were routine, phenotypically normal children attending the graduate pediatric or orthodontic dental clinic at the University of Tennessee, Memphis. Race (either black or white) was based on the parent's self-assessment (Edgar and Hunley 2009).

Total sample size was 226 with proportionate samples by race and sex. Maximum mesiodistal and buccolingual crown dimensions were measured as described by Seipel (1946) using sliding calipers with an electronic-readout precision of 0.005 mm. Data were collated in an Excel® spreadsheet (Microsoft Corporation, Redmond, WA), and then uploaded to JMP® version 9 (SAS Institute Inc., Cary, NC) for statistical analysis.

All measurements were obtained twice. When the repeated measures differed by more than 0.2 mm, which was rare, a third measurement was taken with the two closest values being averaged. Teeth were measured on both the left and right sides, and analysis is based on the left-right averages.

The random component of the intra-observer repeatability was calculated using the standard Dahlberg statistic:

$$\mathrm{ME} = \sqrt{\frac{\sum_{i=1}^{n}\left(X_{1i}-X_{2i}\right)^2}{2n}}$$

where X_{1i} and X_{2i} are the repeated measurements for case "i" and n is the number of cases (Dahlberg, 1940) and "ME" stands for method error. The Dahlberg statistic is 0.012 mm. In other words, the standard error of the technical error of measurement (*i.e.*, the error due to variability in measuring the teeth) is about one-hundredth of a millimeter. This is very small, and it does not account for any of the differences claimed to be significant statistically.

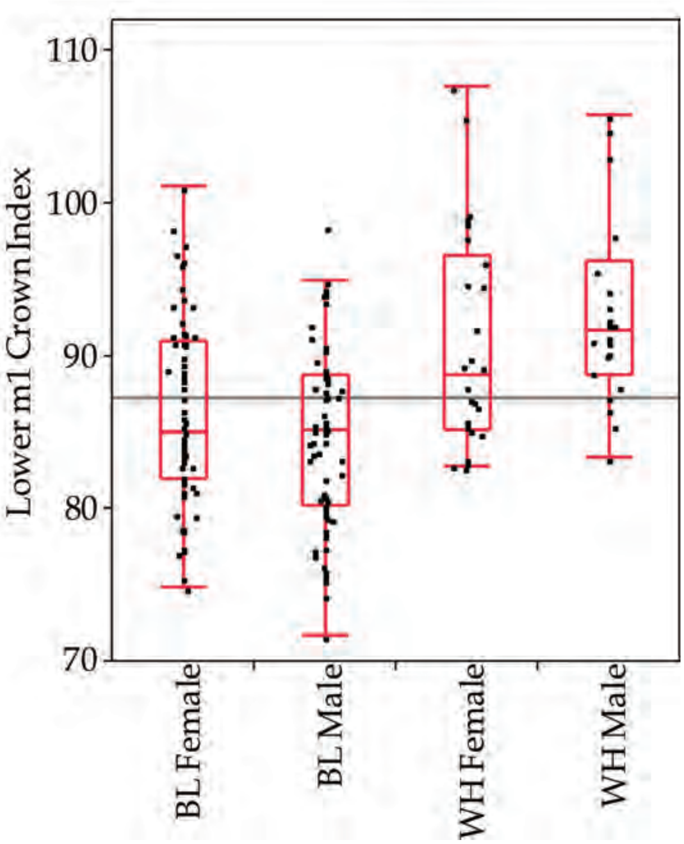

Fig 2. Boxplots for the crown index of the lower first molar. This tooth type has the largest F-ratio, and "race" accounts for 17% of the total variance. The race-by-sex interaction for this variable (Table 2) is due to the higher crown index in white girls compared to white boys, whereas there is no sex difference in the samples of blacks. The smaller index in blacks than whites is due to their greater MD crown length rather than any difference in BL breadth.

TABLE 1. Results of two-way analysis of variance for each of the 10 tooth types testing for a race and/or sex difference in the crown index

Tooth	Race			Sex			Interaction		
type	df	F	P value	df	F	P value	df	F	P value
Maxilla									
i1	1	4.22	0.0421	1	0.01	0.9249	1	0.32	0.5742
i2	1	11.86	0.0008	1	1.89	0.1714	1	0.62	0.4332
c	1	0.03	0.8658	1	1.02	0.3139	1	0.29	0.5902
m1	1	7.97	0.0053	1	11.99	0.0007	1	3.26	0.0728
m2	1	18.04	<0.0001	1	2.27	0.1336	1	0.00	0.9470
Mandible									
i1	1	10.95	0.0013	1	0.27	0.6031	1	1.84	0.1781
i2	1	4.66	0.0326	1	0.03	0.8588	1	0.65	0.4220
c	1	10.50	0.0014	1	0.49	0.4859	1	0.02	0.8890
m1	1	40.20	<0.0001	1	0.40	0.5302	1	5.36	0.0217
m2	1	16.18	<0.0001	1	1.83	0.1773	1	0.47	0.4950

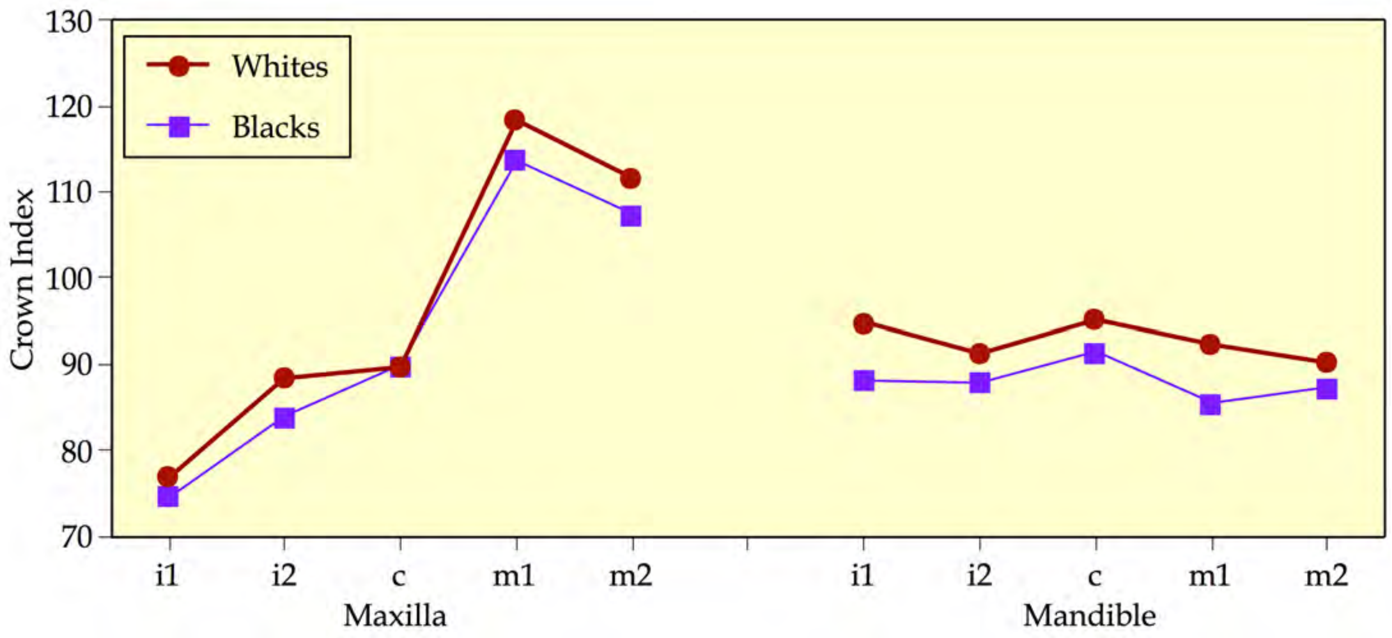

Fig. 1. Plot of the crown index, by race and tooth type (sexes pooled). The index is significantly lower in blacks for all tooth types excepting the maxillary canine. Only the maxillary molars exhibit indices greater than one (where BL breadth is larger than MD length).

In a complementary fashion, the percentage of measurement size due to technical error of measurement (Sokal and Rohlf, 1991) also was computed. The formula is:

$$\frac{|X_1 - X_2|}{\left(\frac{X_1 + X_2}{2}\right)} \times 100$$

The average difference is 0.18%, meaning that the average percent of tooth size attributable to TEM is much less than 1% of the tooth's diameter.

The crown index (*e.g.*, Hrdlička, 1923; Thomsen, 1955; Hillson, 1996) is a measure of crown shape based on the two commonly-measured crown dimensions, namely maximum mesiodistal and buccolingual diameters. This index is buccolingual crown size expressed as a percentage of mesiodistal crown size,

$$\left(\frac{BL}{MD}\right) \times 100$$

A tooth with a large crown index has a buccolingually broad crown relative to its mesiodistal length; conversely, a small crown index means the tooth is narrow in relation to it length.

Analysis relied on analysis of variance (Winer *et al.*, 1991; Sokal and Rohlf, 1995). Initial tests used two-way ANOVA to evaluate race and sex differences, but sex differences are uncommon, so a one-way model was used to simplify presentation and recover the degrees of freedom. Statistical significance was set at the conventional level of alpha = 0.05, and no correction was made for multiple comparisons.

TABLE 2. Results of one-way ANOVA testing for black-white differences in the crown index (sexes pooled)

Tooth	r^2 (%)	n	F ratio	P value
		Maxilla		
i1	3.25	125	4.13	0.0442
i2	7.01	148	11.01	0.0011
c	0.01	182	0.02	0.8816
m1	4.91	183	9.35	0.0026
m2	9.49	179	18.57	<0.0001
		Mandible		
i1	10.18	108	12.02	0.0008
i2	3.54	137	4.96	0.0276
c	5.55	188	10.93	0.0011
m1	17.57	181	38.16	<0.0001
m2	7.86	184	15.53	0.0001

RESULTS

Applying two-way ANOVA to the 10 tooth types (Table 1) disclosed that sex differences are uncommon (only the lower first molar), but that black-white race differences are prevalent. Indeed, of the 10 tooth types, only the maxillary canine fails to exhibit a significant black-white difference in the crown index. Consequently, "sex" was dropped from the model, and the one-way ANOVA results (Table 2) produce the same interpretation, namely that the crown index is consistently lower in blacks than whites—that the crowns are mesiodistally longer in blacks than whites relative to their buccolingual crown widths. In terms of explained variance (r^2), the largest F-ratio is for the mandibular first molar (Fig. 1), where "race" accounts for 17% of the total variance. This percentage is less than 10% for the other tooth types.

The patterns of crown indices among tooth types are illustrated in Figure 2. The patterns differ between arches, notably because of the high values for the two maxillary molars, which are the only teeth with indices above 100% (BL breadths > MD lengths). Based on paired t-tests, the index is significantly higher for the upper lateral incisor than the adjacent central incisor both in blacks and whites ($P < 0.0001$). Comparably, the index is significantly lower for the upper second molar than the first ($P < 0.0001$)

The pattern is less consistent in the mandible. Evaluated with paired t-tests, the crown index for i1 and i2 is virtually identical in blacks ($P = 0.996$), but there is a significant i1-to-i2 drop in the white sample ($P = 0.03$). Between the lower molars, blacks exhibit a significant m1-to-m2 increase in the index ($P = 0.0003$) whereas this gradient drops significantly in whites ($P = 0.04$).

As with any ratio, there are at least three possibilities for the race differences in crown indices: The numerators may differ between groups, the denominators may differ, or both. All 20 of the tooth dimensions were surveyed (Table 3), and none of the 10 buccolingual dimensions was significantly different between blacks and whites. In contrast, 7 of the 10 mesiodistal dimensions were significantly different between these two groups. The interpretation of differences in the crown index between blacks and whites is, thus, greatly simplified; the differences in the crown indices are due to blacks possessing teeth that are disproportionately long in relation to their buccolingual breadths.

DISCUSSION

The crown index has historically been used to characterize the width-length relationship of the molars, but there is no conceptual reason for this. The index is equally informative across all tooth types (*e.g.*, Garcia-Godoy and Townsend, 1984; Foster and Harris, 2009).

It was unanticipated that the crown indices would be statistically identical between boys and girls (Table 1) because this suggests that sexual dimorphism does not measurably influence tooth shape. The level of dimorphism is less in the primary than the permanent dentition (Harris and Lease, 2005), but it certainly exists, and some authors (DeVito and Saunders, 1990; Zadzińska *et al.*, 2008; Adler

TABLE 3. Results of two-way ANOVAs testing for race and sex differences in crown size

	Race		Sex		Interaction		Adjusted
Tooth	F	P	F	P	F	P	Percent r^2
			Mesiodistal				
Maxillary							
i1	8.33	0.0046	20.54	<0.0001	1.95	0.1652	19.87
i2	8.81	0.0035	17.97	<0.0001	7.62	0.0065	15.63
c	1.15	0.2842	19.20	<0.0001	0.00	0.9759	11.92
m1	14.32	0.0002	17.20	<0.0001	0.85	0.3581	15.27
m2	11.77	0.0008	8.35	0.0043	0.30	0.5874	11.09
Mandibular							
i1	8.31	0.0048	9.15	0.0031	0.05	0.8219	16.28
i2	0.18	0.6714	1.18	0.2802	1.28	0.2595	2.60
c	0.59	0.4428	8.85	0.0033	0.31	0.5780	6.07
m1	23.59	<0.0001	6.20	0.0137	2.39	0.1240	16.94
m2	15.36	0.0001	13.27	0.0004	0.39	0.5348	15.79
			Buccolingual				
Maxillary							
i1	0.74	0.3898	15.62	0.0001	2.22	0.1385	10.89
i2	0.75	0.3868	18.99	<0.0001	7.60	0.0066	9.76
c	1.03	0.3119	9.27	0.0027	0.24	0.6265	4.87
m1	2.60	0.1087	1.92	0.1674	0.68	0.4105	2.52
m2	0.17	0.6809	4.77	0.0303	0.27	0.6030	2.75
Mandibular							
i1	0.33	0.5676	3.80	0.0540	1.75	0.1888	7.46
i2	2.08	0.1518	2.09	0.1505	3.07	0.0822	8.27
c	4.18	0.0423	3.90	0.0496	0.21	0.6457	3.82
m1	2.61	0.1080	7.14	0.0082	0.75	0.3868	3.40
m2	0.18	0.6708	15.01	0.0001	0.01	0.9352	8.64

and Donlon, 2010) have explored its use in estimating the sex of human remains in forensic settings. The present results suggest that, at least by this metric, the larger teeth of boys are isometrically enlarged versions of the crown shapes in girls.

These results raise the issue of population differences: This study found essentially no evidence of sexual dimorphism in either the black or white sample. In contrast, Margetts and Brown (1978) study of Yuendumu Australians found that the indices of primary teeth tend to be higher in boys. Garcia-Godoy and Townsend (1984), in contrast, found higher indices in girls in their sample of Dominican mulatto (black-white) children. These population differences discount stereotypes that humans are monomorphic. Early extrapolations to all groups (*e.g.*, Garn *et al*., 1967a,b) actually stemmed from the paucity of information on racial differences.

Nine of the 10 black-white comparisons by tooth type (Table 2) are highly significant statistically. Only the maxillary canine has the same shape relationship in the two groups. For all of the other tooth types, blacks have a significantly lower crown index. It is well appreciated that American blacks have larger crown dimensions than whites absolutely—both as regards the primary (*e.g.*, Vaughan and Harris, 1992; Anderson, 2005) and permanent (Richardson and Malhotra, 1975) dentitions—and the results here indicate that the groups also differ in their width-to-length relationships. Interestingly, interpretation is greatly simplified when (Table 3) it is noted that none of the buccolingual crown dimensions differs significantly. This shows that the lower crown indices seen in blacks are due to the mesiodistal dimension. The primary teeth in American blacks have smaller crown indices than whites because their tooth crowns are larger mesiodistally.

All of the primary teeth are established and begin crown mineralization during the second trimester *in utero* (Lunt and Law, 1974), so whatever the causes of mesiodistally larger teeth in American blacks—such as up-regulation of mitotic rates—are initiated early in development. Nothing is known about the primary teeth, but the permanent teeth form and emerge faster in blacks than whites (Steggerda and Hill, 1942; Harris and McKee, 1990), even though the teeth are larger. Making larger teeth in a shorter time suggests that the mitotic rates are faster; there seem to be no data suggesting that the quality of enamel or dentin differ between blacks and whites. Hall *et al*. (2007) found that enamel was thicker in blacks than whites—which again suggests a difference in growth tempos—though the differences in enamel do not account for the larger overall crown differences.

One might suppose that mesiodistally larger teeth would translate into a greater risk of crowding—where arch size (determined by the supporting basal bones) is inadequate for proper alignment of the larger teeth. In fact, dental crowding (inadequate arch size) is not more common in American blacks than whites (Kelly and Harvey, 1977; Brunelle *et al*., 1996). On the contrary, the prevalence of interdental spacing is appreciably higher in blacks than whites. The lack of an increased risk of crowding is due to the disproportionately large arches in blacks (Burris and Harris, 1998). As Ross-Powell and Harris (2001) show, this race difference is ostensible from early in the primary dentition.

Prior work in our lab (Harris *et al*., 2001) suggest that differences in the crown sizes of American blacks and whites are primarily due to differences in size of the dental pulps. Developmentally, size of the pulp is defined by the growth of the enamel epithelium—which, in the mature tooth, is the interface between the enamel and dentine—prior to mineralization. The present results suggest that growth of the premineralized tooth bud is different in blacks and whites—that growth favors the mesiodistal axis in blacks, creating a different crown shape.

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Minutes of the 25th Dental Anthropology Association Business Meeting: April 15, 2010, Albuquerque, New Mexico

Call to Order:

President Brian Hemphill called the meeting to order at 7:08 P.M. There were 35 members in attendance.

President:

- Brian Hemphill welcomed all to the meeting and remarked that the Dental Anthropology Association was formed 24 years ago in Albuquerque. There were four founding members present at this meeting.
- We are saddened to note that several members have passed within the last year, notably A. M. "Sue" Haeussler and Thelma Dahlberg. Thelma was the wife of Dr. Albert A. Dahlberg, a world-renown dental anthropologist and one of the founding members of the Association. Thelma continued her financial support to the Association even after Al's passing. [*Editor's note*: Christy Turner has published an obituary for Sue: *Dental Anthropology* 2010:23(1):33-35.]
- A new editorial board has been formed due to retirements and the passing of several members.
- The *Dental Anthropology Association* is selling molar pins, the order forms are available on the web site.
- The 2010 Dalhberg Prize was awarded to Michaela Huffman of The Ohio State University. Congratulations Michaela! [*Editor's note*: Michaela's paper occurs as the lead article in this issue of DA.]
- The gavel was passed from Brian Hemphill to Richard Scott as the new President. Richard discussed briefly the success of the Dental Morphology Workshop. He suggested that other Workshops should be held every couple of years.

Reports:

Journal Editor:

Volume 22 of *Dental Anthropology* was published during the calendar year of 2009. Three issues were published consisting of a total of 96 pages of text. Eleven original research papers were published, along with book reviews, an obituary (Dr. Shelley Saunders 1950-2008), and several items relating to association business.

Each issue of *Dental Anthropology* is provided, in color, as a PDF by e-mail to all members. In addition, printed copies (in black-and-white) are mailed to those members wishing to receive a hard copy of the journal. Most members have been satisfied with the electronic version alone.

The Ohio State University continues to sponsor the DAA's web site, maintained by Sarah Martin, and all issues of *Dental Anthropology* are available there on an open-access basis.

Quality of the articles in *Dental Anthropology* depends on the expertise of our Editorial Board (see inside front cover), and they are to be commended. Quality also depends on the submission of well-reasoned articles, and the Editor requests that members of the Association support this journal by using *Dental Anthropology* for their publication needs.

Continued

Secretary/Treasurer:

- Total membership: 137 members; approximately 60 international members; and 8 institutions.

- The credit card through Wells Fargo, will be discontinued as soon as the Paypal payment option is available on the DAA web site.

Communication Officer:

- Membership will be updated at the beginning of the month.

- There are still 'bugs' in the OSU servers, due to an upgrade, please report any errors you come across.

- Announcements regarding awards, recent publications, and collections will continue to be sent out.

Old Business:

Annual dues have been raised to cover the increased cost of the journal:

Regular members:	$25.00
Student members:	$15.00

The approval to change the dues occurred in 2009 and will begin after the publication of the minutes. Note: Members who either prepaid for several years or paid prior to the 2010 meetings (April) will not have to pay the difference.

New Business:

- Next year is the 25th Anniversary of the Dental Anthropology Association. Members of the executive committee are considering several options to commemorate this anniversary.

- Creation of a "Related Links" section on the DAA web page with links to members home pages is occurring. Asking for submissions will begin in May.

- Beginning the posting of recently published dental anthropology articles, with links to appropriate publishers, if you would like to post a PDF of an article, please e-mail:

  martin.1451@buckeyemail.osu.edu

- The Association plans to sell T-shirts at the 2011 meetings with a "dental" theme.

- There was discussion of going to an on-line journal only. Membership will be e-mailed regarding this.

The meeting adjourned at 8:35 P.M. Next year's DAA meeting will, as usual, meet during the Annual Meeting of the American Association of Physical Anthropologists (April 12-16, 2011, Minneapolis, Minnesota). (This will be the 80th annual meeting of the AAPA.)

Submitted by:
Loren R. Lease
DAA Secretary-Treasurer

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@uthsc.edu**). Electronic submissions by e-mail are strongly encouraged.

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. 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 (or e-mailed) 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 hard-copy journal does not support color illustrations, but the PDF version does. Print each table on a separate page. Each table consists of (a) a table legend (at top) explaining the contents of the table, (b) the table proper, and (c) any footnotes (at the bottom) needed to clarify contents of the table. 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. Current guidelines are available at the AAPA web site. *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 *instead 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 alternatively 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 include your name in each file label.

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Original Articles

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