

# Dental Anthropology

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# Quantification of Dental Occlusal Variation: A Review of Methods

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**ABSTRACT** Occlusion—how the teeth fit together within and between the arches—has important consequences functionally and especially esthetically. Occlusal variation is considerable in modern westernized societies, but the occurrence and extent of the variation appear to be lower in the past and lower in non-westernized groups. This methodological paper describes several commonly-used variables that, collectively,

characterize occlusal variation. Methods are described from the literature that measure the location and extent of tooth relations in all three planes of space. Our goal is that, by describing methods in a single source, it will pique the interest of dental researchers to collect these data, so that the space-time distributions of occlusal variations can be known in more detail. *Dental Anthropology* 2008;21(1):1-11.

Dental “occlusion” refers to how well the teeth are arranged individually and one-to-another within and between the dental arches. Grainger (1967) suggests that, “malocclusion is any disharmonious variation from the accepted or theoretical normal arrangements of the teeth. But, in nature some degree of variation among individuals of a species is always present.”

Proper (ideal) occlusion provides several benefits over maloccluded teeth. Perhaps foremost in contemporary western society, proper occlusion carries an esthetic benefit. People with good occlusion are rated as more attractive, more intelligent, and more desirable employees and spouses than people with malocclusions (Shaw *et al.*, 1979; Shaw, 1981; Shaw *et al.*, 1985; Birkeland *et al.*, 2000; Cerny, 2005; Traebert and Peres, 2007). Proper occlusion involves more tooth-to-tooth contacts, which produces more complete trituration of food (Owens *et al.*, 2002). It is easier to maintain oral health around properly aligned teeth, so health of the periodontium tends to be better and tooth decay may be lessened (*e.g.*, Sergio and Hawley, 1999; Kao *et al.*, 2000; Klages *et al.*, 2007). Above all, a toothy smile is highly sought after in the modern Western world. Morrey and Nelsen (1972:190-198) depict orthodontic interventions. Good articulation and phonation should also be mentioned here, since making certain sounds depends on correct tongue-to-tooth relationships (*e.g.*, Van Norman, 1997; Mohlin and Kurol, 2003). There has been discussion, for example, about the origin of the consonant “f” and how agriculturally (hence, recently) it arose due to maxillary incisor overjet (Corruccini 1987).

“Malocclusion” is a common term, but it has a couple of shortcomings. There is no clear demarcation between

a good or adequate occlusion and malocclusion; any distinction is one of degree rather than kind. More importantly, virtually everyone has some sort of “malocclusion,” so it is misleading to talk about normal or proper occlusion when we actually mean idealized, perfect occlusion. “Occlusal variation” is a more appropriate, neutral term to refer to the positional variations of teeth and tooth relationships that are found in most people in the absence of orthodontic treatment. Lombardi and Bailit (1972:283) offer a more-involved description:

The term “malocclusion,” encompassing all deviations of the teeth and jaws from normal alignment, includes a number of distinct conditions which may or may not be independent: malpositioning of individual teeth (rotation, tipping, over- and undereruption); discrepancies between tooth and jaw size (crowding and spacing); and malrelations of the dental arches (sagittal, transverse and vertical). Dental arch malrelations may reflect abnormalities in the dentition, the jaws, or both.

A fundamental dichotomy can be drawn as to the sources of malocclusion, and these two sources can be labeled bone-based and tooth-based (*e.g.*, Harris and Johnson, 1991; Harris, 2008). That is, one way of developing improper occlusion is for the supporting bones of the two jaws to grow “inappropriately.” If, for example, the mandible grows forward much more

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than the maxilla, the teeth supported by these bony elements will not properly interdigitate. Comparably, if the palatal plane of the midface is canted up in the front, the anterior teeth cannot couple between the jaws resulting in an anterior openbite. Bone-based malrelationships can occur in any combination of the three planes of space (e.g., Moyers, 1988; Proffit, 2007), and, given the familial resemblances in the sizes and shapes of the facial bones (e.g., Nakata *et al.*, 1974a,b; Harris, 1975), these “bone-based” causes of malocclusion tend to be under genetic control. Distinct from this are the familiar “crooked teeth,” where it is the actual positions of teeth in the alveolar bone that create esthetic and functional problems. These “tooth-based” issues involve the locations, rotations, and angulations of teeth unto themselves as well as one to another. These tooth-based variables appear to be under little genetic control and, conversely, seem to be a consequence of the environment (Corruccini and Potter, 1980; Harris and Smith, 1980).

This dichotomy between bone- and tooth-based causes of malocclusion is not absolute; problems with the sizes of the supporting jaws can preclude proper interdigitation of the teeth—leading to tooth-based occlusal issues. Still, we contend that much of the conflict in the literature about the etiology of malocclusion stems from uncritical lumping of bone- and tooth-based kinds of malocclusion.

The present paper focuses primarily on recording these latter, tooth-based sorts of malocclusion, and these are variables readily measured from inspection of the dental arches (or dental casts) themselves rather than the skeletodental facial complexes (e.g., Athanasiou, 1995).

The purpose of the present paper is to describe some of the methods used by orthodontists and epidemiologists to quantify the extent of a person’s occlusal variation. These dimensions are chosen because they can be made with sliding calipers (or a ruler) rather than more complex instrumentation, so the data are at least interval scale (Ellis, 1966) but are fairly simple to collect. Several dimensions can be measured *in vivo*, but it is much easier on the subject and more consistent and accurate to collect the data from skulls or full-mouth dental casts. The variables can be compounded into a variety of indices expressing overall deviation from the ideal; Kelly and Harvey (1977:Appendix I) present particularly useful details for scoring the “Treatment Priority Index.” Our intent is that, by describing these variables, more dental researchers will collect data on malocclusion, providing a richer store of information about the advent, extent, and sorts of malocclusion through human history.

### Centric Relation and Centric Occlusion

Dentists recognize two dental relationships, termed centric relation (CR) and centric occlusion (CO). CR is

a stable, reproducible position, where the condyles are seated in their superior-most and rear-most positions in the glenoid fossae (Ramfjord and Ash, 1971). There are, however, mixed views concerning the “best” condyle-fossa relationship for CR (e.g., Davies *et al.*, 2001). The concept of CR is founded in prosthodontic aspects of dentistry, notably when the patient is edentulous and the dentist requires a reproducible reference position for building a denture. CR also is encountered in research by gnathologists, where the focus often is on rehabilitating a person’s dentition to relieve bruxism, temporomandibular dysfunctions, myofacial pain, or other problems. CR can only be determined in living persons; it cannot be determined from dental casts or with skeletal material (because the meniscus and cartilaginous joint linings are absent).

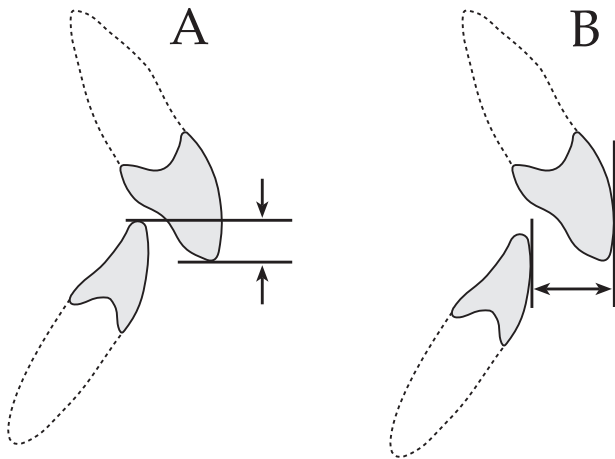
Centric occlusion (CO), in contrast, is a person’s habitual bite, and this is the same as maximum intercuspation. CO can generally be determined from casts alone, though the casts may fit together in various ways if the occlusion is particularly poor.

It is of little consequence when measuring occlusal variation, but CR and CO often do not coincide. There often is a “slide” from CR forward to CO, but details are beyond this overview (Ramfjord and Ash, 1971). The convention throughout the present review is to place the teeth (or casts) in maximum interdigitation or, synonymously, habitual bite.

### Incisor Overbite and Overjet

The incisal edge of the lower central incisor should be quite close to the lingual contour of the upper incisor when the dentition is in maximum intercuspation. This can be measured vertically (overbite) and horizontally (overjet). Incisor overbite is the vertical (craniocaudal, occlusogingival) distance between the incisal edges of the central incisors (Fig. 1A) measured perpendicular to the occlusal plane. The easiest way to measure this (Baume *et al.*, 1973) is (1) to place the casts in maximum intercuspation, (2) use a fine lead pencil to mark where the incisal edge of the upper incisor occludes over the lower incisor, (3) separate the casts, and (4) use the depth gauge of the calipers to measure how far the pencil mark is from the incisal edge of the lower incisor. One convention is to measure either the left or right central incisors with the greater overbite; others (e.g., Smith and Bailit, 1977) measure both sides and record the average. When the incisors do not meet and there is an anterior openbite (also termed negative overbite and apertognathia), the gap between the incisor edges in the two jaws is measured perpendicular to the occlusal plane, and the value is recorded as a negative value.

Overbite will be underestimated if the incisors are incompletely erupted and also if there is occlusal attrition that has worn down the crown heights. Indeed, considerable attrition—as is common with abrasive



**Fig. 1.** Lateral view of the central incisors, showing (A) the method of measuring overbite, measured normal to Downs' occlusal plane and (B) overjet measured parallel with Downs' occlusal plane. Incisors with no vertical overlap have a negative overbite (openbite). Incisors in anterior crossbite have a negative value for overjet. Conventionally, the quadrant with the greater deviation is recorded.

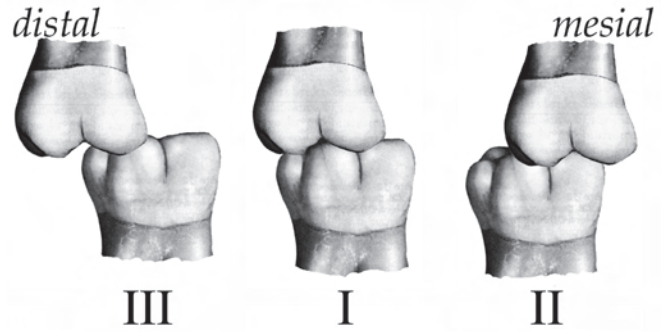
diets—will cause the loss of tooth substance to the point that the mandible autorotates into an edge-to-edge incisal bite. Brace (1977) argues this edge-to-edge bite is actually the preindustrial norm.

Overjet refers to the horizontal (dorsoventral or labiolingual) distance between the facial tangents of the central incisors in the two arches (Fig. 1B). With the casts interdigitated, the depth gauge of sliding calipers can be used to measure the distance from the labial surface of the more prominent maxillary central incisor distally to the face of the mandibular antagonist.

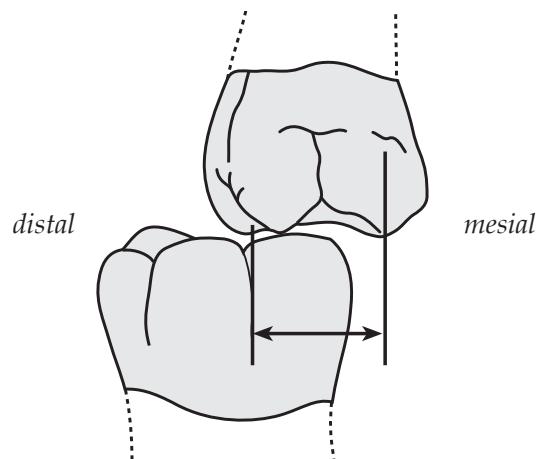
If the mandible is very prominent or the maxilla is undersize (or both), the mandibular incisors can be in front of (labial to) the upper incisors (*i.e.*, anterior crossbite). This "underbite" is measured in the same manner as overbite, but the distance is recorded as negative. This occasional situation is variously labeled underjet, negative overjet, reverse overjet, anterior crossbite and mandibular overjet with the last two being most commonly encountered (Grainger, 1967).

**Buccal Segment Relationship**

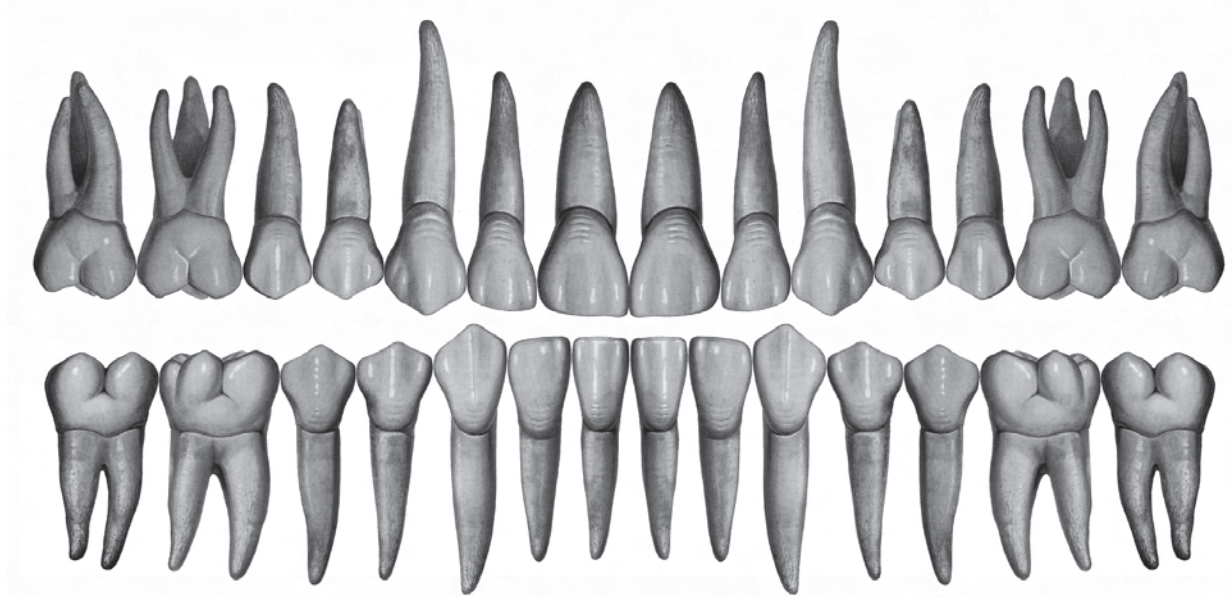
How the molars, particularly the first molar in each arch, fit together in the mesiodistal (parasagittal) plane depends on several factors, including how the teeth are positioned on the supporting basal bone of each arch, but also on the sizes of the upper and lower jaws. "Proper" occlusion occurs when the mesiobuccal cusp of the maxillary first molar is positioned parasagittally in the buccal groove of the mandibular



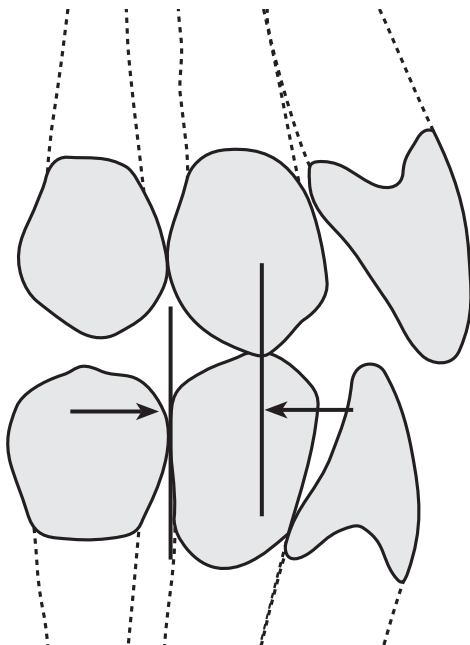
**Fig. 2.** These buccal views of the permanent first molars depict Edward H. Angle's time-honored three classes of molar relationship. *Left:* A full-cusp Class III (mesiocclusion) relationship occurs when the maxillary tooth is too distal or, more commonly, the mandibular tooth is too mesial. *Center:* The desired molar relationship (neutroclusion) has the mesiobuccal cusp of the upper molar aligned in the buccal groove of the lower molar. *Right:* A full-step Class II relationship (distocclusion) is shown, commonly (but not necessarily) due to insufficient horizontal growth of the mandible. It is not necessary to have such extreme (full-cusp) discrepancies to achieve Angle's Class II or III relationships.



**Fig. 3.** Buccal segment relationship (BSR) is measured on an interval-scale as the distance (parallel with the occlusal plane) between the mesiobuccal cusp of the upper molar and the buccal groove of the mandibular molar. By convention, the distance is positive in cases of mesiocclusion (Class III), negative with distocclusion (Class II), and zero with neutroclusion (Class I). An example of distocclusion is illustrated.

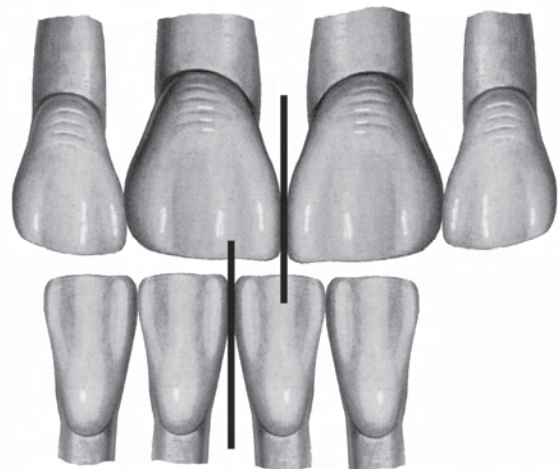


**Fig. 4.** The mesiodistal crown dimensions of all of these teeth are drawn to the same scale, showing that when a Class I BSR occurs at the first molars, there is a better chance that all of the teeth will be properly aligned within each arch and properly interdigitate between the arches.

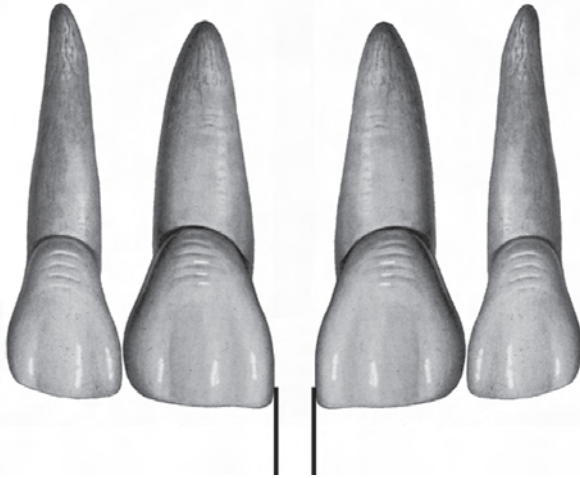


**Fig. 5.** Lateral view of the canines, showing the method of measuring canine discrepancy, which is the horizontal deviation of the maxillary canine's cusp tip relative to the mandibular canine-first premolar embrasure. The horizontal discrepancy is measured with sliding calipers. If, as diagrammed here, the mandibular canine-premolar embrasure is distal of its ideal position (Class II), the distance is labeled negative.

first molar. This is the Angle Class I relation commonly evaluated by orthodontists (Fig. 2). This classification was developed by Edward H. Angle, a historically prominent orthodontist in the late 18th century (*e.g.*, Angle, 1899). Consequently, no "angle" is involved in this categorization of molar relationships. Angle's molar classification can be described more accurately using a continuous scheme that is termed buccal



**Fig. 6.** Diagram of the labial view of the incisors, showing the method of measuring the deviation of the maxillary and mandibular dental midlines. If the midlines are coincident, the discrepancy is zero. The horizontal discrepancy can be measured with sliding calipers. Mandibular shifts to the right are labeled positive (Harris and Bodford, 2007).



**Fig. 7.** A diastema occasionally occurs between the maxillary central incisors, often due to a fibrous band of gingival tissue that keeps the teeth apart. Width of the diastema is measured, as shown, between the medial anatomic contact points of the central incisors parallel with the occlusal plane.

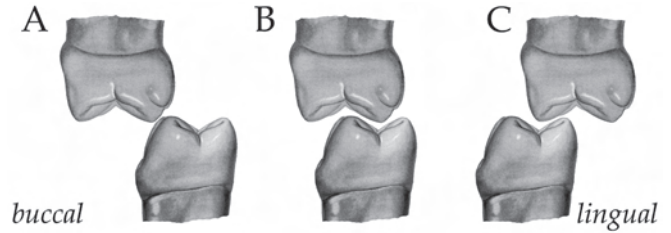
segment relationship (BSR; Fig. 3).

Given characteristic mesiodistal crown size relationships for a person's teeth, a Class I molar relationship goes far towards assuring that all of the teeth mesial to the permanent first molars will interdigitate properly between the two arches (Fig. 4). Angle's three-grade classification is a valuable descriptive method, but recording BSR on a continuous scale (Fig. 3) is more informative for most research efforts. When the mesiobuccal cusp (paracone) is "socked into" (symmetrically overlaps) the buccal groove, BSR is zero. This corresponds to ideal occlusion of the protocone in the mandibular antagonist's central occlusal fovea and of the hypoconid in the maxillary antagonist's central occlusal fovea (see Hillson 1996:Chapter 4). The value is negative when the lower molar groove is distal of the upper molar's cusp (distocclusion); the value is positive when the groove is mesial to the upper molar's cusp tip (mesiocclusion). Left-right asymmetries are common, so it can be useful to score BSR on both sides of the arch (Siegel, 2002).

In practice, the buccal groove extends fairly far down the molar's crown, so it is identifiable with moderate occlusal attrition. The cusp tip can be extrapolated from the wear facet if the upper molar is not severely worn.

**Canine relationship**

Analogous with BSR, the parasagittal position of the cusp tip of the maxillary canine can be measured relative to the canine-first premolar embrasure in



**Fig. 8.** Facial views of the first molars showing transverse relationships: (A) buccal crossbite; (B) normal mediolateral relationship, with the upper buccal cusp overhanging the mandibular cusp and the upper lingual cusp occluding in the lower molar's central fovea, and (C) lingual crossbite.

the mandible. With ideal interdigitation, the canine's cusp tip should fit into this embrasure (Fig. 5). When the canine is distal of the embrasure, the distance is recorded as negative; otherwise positive (Harris and Bodford, 2007).

**Midline deviation**

The dental midlines of the two jaws should be coincident, and, in the living, the dental midline (at the embrasure of the central incisors) also should be coincident with the frenulum in the superior labial vestibule. Midline deviations indicate left-right arch asymmetries. By convention (Harris and Bodford, 2007), when the mandibular dental midline deviates to the right of the maxillary midline, the distance (measured with calipers) is labeled positive; otherwise negative (Fig. 6). When the dental midlines are coincident, the "deviation" is zero.

**Midline diastema**

A diastema is a space between teeth, such as occurs between tooth types in many species. In dentistry, a diastema refers specifically to a space or gap between the maxillary central incisors (Fig. 7). A diastema—defined as a space at least 2 mm wide—was recorded as part of the U.S. National Health Examination Survey (NHANES III; NCHS, 1994). Care has to be taken in contemporary groups that the diastema was not closed orthodontically or restoratively (with, e.g., crowns or composite). The frequency is about 6% in American whites, but twice that in African Americans (Brunelle *et al.*, 1996).

Figure 7 shows how the width of the diastema is measured millimetrically. It also is important to distinguish between a midline space created by axial deviations of the central incisors that separates these teeth labiolingually versus a true diastema of a mediolateral separation of the incisors' locations in the supporting alveolar bone. Beware also of incisor



**Fig. 9.** Tooth rotations are scored as (A) the number of teeth rotated less than  $45^\circ$  relative to the idealized arch form plus (B) twice the number of teeth rotated  $45^\circ$  or more. Teeth throughout the dentition are scored. This example shows the rotation of the lower right central incisor of less than  $45^\circ$  relative to the arch form.



**Fig. 10.** Tooth displacements are scored as (A) the number of teeth displaced out of the idealized arch form plus (B) twice the number of teeth displaced more than 2 mm out of the arch form. Teeth throughout the dentition are scored. This example shows a labial displacement of more than 2 mm of the mandibular lateral incisor.

“winging,” which may be genetic and unrelated to occlusal variation (*cf.* Enoki and Dahlberg, 1958). Interdental spacing in the anterior region is much more common in the deciduous dentition, but the larger permanent successors generally use up the space. Some people with a diastema have a fibrous band of gingival tissue that maintains the space.

#### Posterior Crossbite

Normally the buccal cusps of the teeth in the maxillary buccal segment (the premolars and molars) should extend laterally and overhang the buccal cusps of the lower “contained” arch (Wheeler, 1965; Ramfjord and Ash, 1971). A posterior buccal crossbite occurs when the maxillary teeth extend too far laterally compared to the mandibular antagonists. Conversely, and more commonly, posterior lingual crossbites occur when the maxillary buccal cusps occlude too lingually.

Several methods of scoring crossbites have been suggested. Baume *et al.* (1973) propose a simple three-grade ordinal classification of posterior crossbites (Fig. 8). This diagram illustrates full-cusp crossbites (either buccal or lingual), but cases do not have to be this extreme to be counted. Grainger (1967) and Kelly and Harvey (1977) simply count the number of teeth in the premolar-molar arch segments that are buccally or lingually displaced out of the projected arch form, giving special emphasis to deviations of “cusp to cusp” or worse (*e.g.*, paracone apex occludes on the lingual aspect of the protoconid and hypoconid). Smith and Bailit (1977) suggest that the occurrences of lingual and buccal crossbites should be recorded separately.

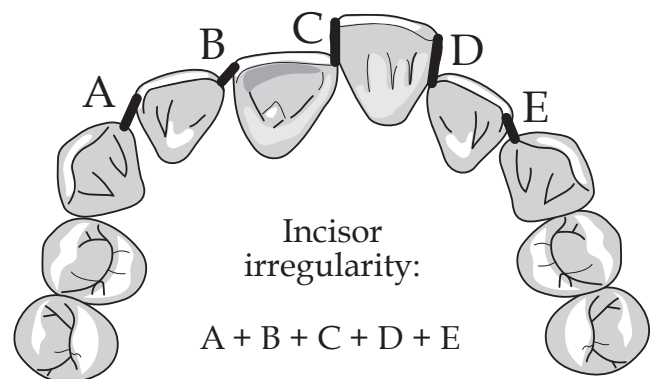
#### Tooth Rotations

A tooth can be located in its ideal position in the dental arch, but rotated around its long axis. The degrees of rotation can be measured (as with a protractor), but most epidemiological studies have opted to use an ordinal scoring scheme (Fig. 9). An unrotated tooth has a rotation score of zero, while rotations can be “minor” or “major.” A minor rotation is defined as less than  $45^\circ$

and is given a score of 1. A major rotation is  $\geq 45^\circ$  relative to the arch form and is given a score of 2. Rotation score is the sum for the whole mouth (optionally excluding third molars). In other words, a person’s rotation score is the number of teeth with minor rotations plus twice the number of teeth with major rotations (Grainger, 1967; Kelly and Harvey, 1977).

#### Tooth Displacements

Teeth can be ectopically positioned out of alignment (Fig. 10). That is, the tooth is effectively in its idealized axial inclination (not tipped) and in its idealized position rotationally, but it is displaced out of the arch form. Van Vark and Pennell (1959) developed an ordinal scale for quantifying tooth displacements. If, visually, a tooth is in its idealized position in the dental arch, its score is zero. If, instead, the tooth is slightly displaced—up to 2 mm—its displacement score is 1. If the displacement is  $> 2$  mm, its score is 2. The displacement score for the whole mouth (presumably 28 teeth) is the sum of the scores. Grainger (1967), Kelly and Harvey (1977),



**Fig. 11.** Incisor irregularity is the millimetric sum of the five anatomic contacts among the six anterior teeth. The maxillary is shown here, though Little (1976) devised the index for measuring crowding in the mandible. When all five contacts are approximated, the index is zero.



and Smith and Bailit (1977) promote this same scoring method.

### Incisor Irregularity

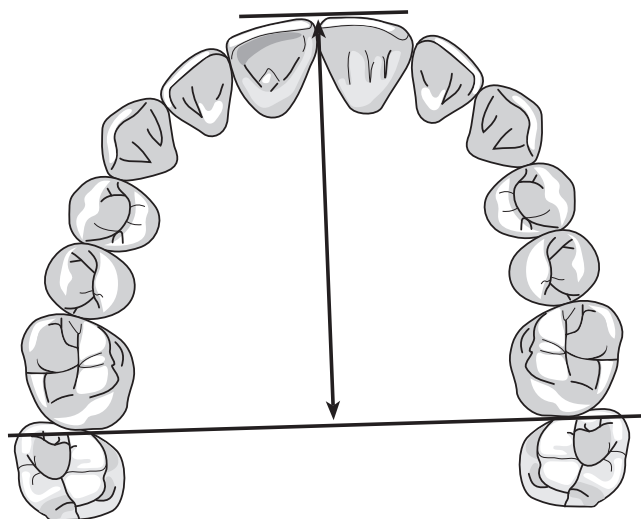
The most common sort of malocclusion in contemporary westernized populations is incisor crowding (*e.g.*, Brunelle *et al.*, 1996), where there is inadequate supporting arch space for proper alignment of the anterior teeth in one or both arches. Nowadays, the most broadly applied method of quantifying anterior crowding is Little’s Incisor Irregularity (Little, 1975). This method was developed for the mandibular arch, but it is equally applicable to the maxillary arcade. As illustrated in Figure 11, there are five interdental contacts between the four incisors plus the adjacent canines in an arcade. In proper occlusion, the anatomic contacts of the adjacent incisors and canines should be closed – so the anatomic contacts of adjacent teeth are together. The greater the dental crowding – reflected as rotations, displacements, and altered axial inclinations of the teeth – the greater the summed distances across the five contacts. The millimetric distances between all open contacts between incisors and canines are measured parallel with the occlusal plane, and the sum is the Incisor Irregularity. Incisor Irregularity can range from zero (when all of the contacts are approximated) to some ill-defined upper limit of “crooked” teeth.

While quite practical, there are at least two shortcomings of Incisor Irregularity. One, the sum is insensitive to “accordioned” teeth, where the teeth themselves are rotated about their long axes, but reciprocally, so the anatomic contacts remain close together. Secondly, Incisor Irregularity is insensitive to interdental spacing. In our experience (*e.g.*, Turner, 2007), it is best to score cases exhibiting interdental spacing – where the open contacts are due to excess arch space for the given tooth widths – as a separate category of malocclusion.

Epidemiological studies (*e.g.*, Grainger, 1967; Baume *et al.*, 1973; Jenny and Cons, 1996) suggest scoring (measuring) just the most deviant tooth, but their emphasis is on facial esthetics and on abbreviating data collection. In our experience, using just the extreme deviation as a proxy for irregularity throughout the anterior segments is coarse and precludes much analysis (Harris *et al.*, 1987). Experience suggests that Incisor Irregularity is a much more comprehensive measure of dental irregularity.

### Arch Depth

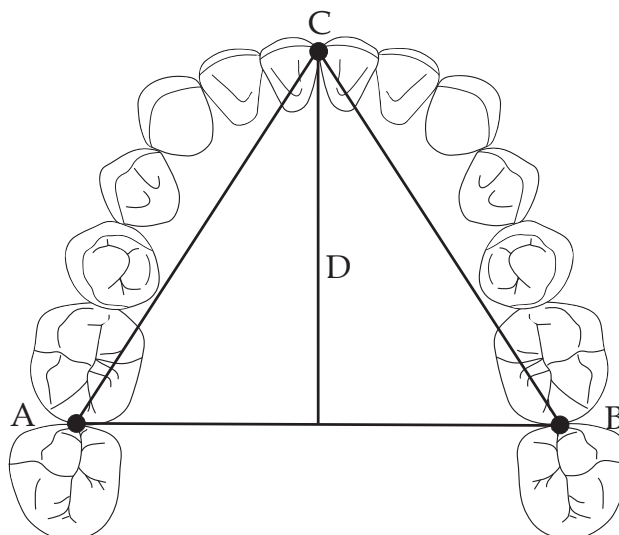
Arch depth (*e.g.*, Harris, 1997) is the mesiodistal distance from the labial surface of the central incisors back to the distal margins of the first molar (Fig. 12) along the midline. The anatomic midline of the palate is evident as the midline raphe in the maxilla (or the intermaxillary suture in skeletal material). The midline



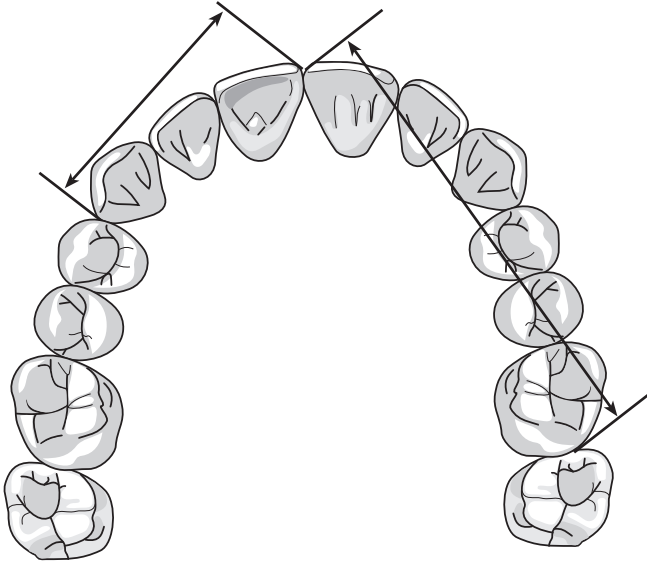
**Fig. 12.** Diagrammatic illustration of maxillary arch depth. Depth can be measured independently on the maxillary and mandibular arches. Operationally, a straight-edge is positioned against the distal heels of the permanent first molars (so there may be some dentoalveolar asymmetry) and the depth is measured from the labial of the central incisors, along the median raphe, to the back of the first molars.

needs to be estimated in the mandible. Various authors (*e.g.*, Mills, 1964) label this dimension arch length.

Knott (1961), DeKock (1972), and others have employed geometry to determine arch depth as the formula for the median of a triangle with known sides. Using the dental landmarks of A, B, and C in Figure 13, arch depth D is calculated from the formula



**Fig. 13.** Once the arch chords AC and BC and arch width AB are known, arch depth (D) can be calculated as the median height of the triangle (see text).

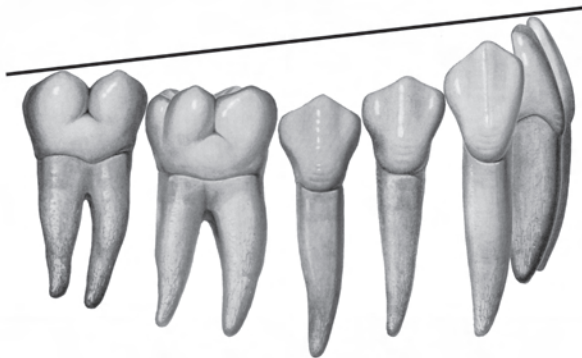


**Fig. 14.** Diagrammatic illustration of a maxillary dental arch, showing the manner that, with sliding calipers, the incisor-to-canine (1-3) and the incisor-to-molar (1-6) arch chords are measured. In practice, both of these chords can be measured on the left and right sides of both the maxillary and mandibular arches.

$$D = \sqrt{\frac{AC^2 + BC^2}{2} - \frac{AB^2}{4}}$$

#### Arch Chords

Measures of arch chords (Moorrees and Reed, 1954; Sillman, 1964; Knott, 1972) are included here because their measurement in each quadrant can disclose arch asymmetries. Cassidy *et al.* (1988) suggested two chord



**Fig. 15.** The curve of Spee is measured as the maximum distance from a plane defined by the most occlusal anterior and posterior teeth. As diagrammed here, this would be in the region of the second premolar.

dimensions, one that they labeled a 1-3 chord. This is from the midline embrasure of the central incisors obliquely to the distal heel of the canine (Fig. 14). This would be measured in the corresponding left and right quadrants, and the greater the difference, the greater the bilateral asymmetry. The second chord, labeled the 1-6 chord, is from the same midline embrasure of the central incisors obliquely back to the distobuccal heel of the first molar (Fig. 14). Likewise, this can be done in both quadrants of both arches.

#### Curve of Spee

The curve of Spee is the curve defined by the occlusal surfaces of the mandibular teeth in the occlusolingival plane. This eponym refers to Ferdinand Graf von Spee who described the curve as a segment of a circle. Strictly, Spee's curve extends between the canine and the terminal molar. However, the incisors often are included in the measurement (*e.g.*, Bernstein *et al.*, 2007).

The maximum depth of the curve is measured (Fig. 15). A flat object, like a ruler, is laid on the mandibular occlusal surfaces, and the depth of the tooth farthest from this plane—commonly a premolar—is recorded. Oftentimes the incisors are super-erupted, so a greater distance (depth of the curve) is obtained than when excluding the incisors. A shallow curve of Spee is thought to be an integral part of a sound occlusion. The curve deepens as teeth slip their anatomic contacts occlusolingivally.

#### DISCUSSION

Any number of anatomical, muscular, behavioral, physiological and other factors can divert one or more teeth out of their "proper" occlusal positions. These factors can be in force as the tooth forms in its crypt, during eruption, and/or after occlusion has been established. The topics of how and why malocclusion develops (and progresses with age) are too complex to be dealt with here (*e.g.*, Proffit, 1985; Harris, 1997; Corruccini, 1999). Instead, our intent is to review some of the common methods used to quantify the nature and extent of occlusal variation.

Deviations of tooth positions from the ideal are far more the rule than the exception among current westernized populations. National surveys of U.S. youths suggest that only about 1 teenager in 10 develops naturally-occurring good occlusion, and fully a third of youths develop malocclusions labeled "severe" and "handicapping" (Kelly and Harvey, 1977; Brunelle *et al.*, 1996). Consequently, "proper" or idealized occlusion is much less common in the absence of treatment than "normal" or average occlusion. Hillson (2005:281-284) argues that occlusal variation is also much higher in domestic than in wild nonhuman animals. With human malocclusions being so common (and probably

continuing to rise), it is a valuable research question to ask what sorts of malocclusions occur and their severity. Clinically, quantification of the kind and severity of malocclusion is driven by (1) the need to best allocate public funds for treatment of financially disadvantaged citizens, but also (2) to evaluate the difficulty and prognosis of treatment. These efforts are different from the interests of basic scientists who aim to assess the impact of malocclusion on societies, and its population variation through time and space (*e.g.*, Corruccini, 1984; Brunelle *et al.*, 1996).

As we mentioned, the impetus for delineating these measures of occlusal variation is to stimulate interest among dental researchers concerning how these dimensions vary in their own data. It is worth commenting in this vein that several dental considerations can deflect the development of “proper” occlusion. Some developmental considerations, such as eruptive pathways (*e.g.*, Barberia-Leache *et al.*, 2005), patterns of eruption (*e.g.*, Tompkins, 1996), and premature loss of primary teeth (*e.g.*, Fanning, 1962) are difficult or impossible to reconstruct from subjects evaluated in the full dentition, but other developmental factors are more persistent. Data may need to be categorized by age grade, and the variables described here are generally specific to the permanent dentition rather than the mixed dentition because of ongoing changes as the permanent teeth erupt (*e.g.*, Baume, 1950; Moorrees, 1959). For archeological remains (where age at death has to be estimated), the degree of occlusal wear can be a useful proxy (*e.g.*, Smith, 1984) since wear affects occlusal relationships. Also, it generally is useful also to collect data on other, abnormal dental conditions that can affect occlusion, notably (1) congenitally absent teeth, (2) supernumerary teeth, (3) abnormal crown size and form (*e.g.*, macrodontia, microdontia), (4) impacted teeth (and retained primary teeth), and (5) transposed teeth (Baume *et al.*, 1973). Particularly with older subjects, issues of tooth loss due to caries, trauma, and/or periodontal involvement also may impact the occlusal findings because of the life-long effects of the anterior component of force (Southard *et al.*, 1989) and the tension of trans-septal fibers (Picton and Moss, 1973) that shift teeth in areas of interproximal attrition and tooth loss.

Little is known about the effects of occlusal and interproximal attrition on occlusal variation, but abrasion doubtlessly affects the occlusion of adults living with a lot of grit in their diet (*e.g.*, Begg, 1954; Sengupta *et al.*, 1999; Brook *et al.*, 2006). Interproximal attrition reduces the space required for the teeth, and this translates into reduced arch length (*e.g.*, Lysell, 1958; Fishman, 1973), though not as much as claimed by Begg (*cf.* Murphy, 1964; Corruccini, 1999). Additionally, occlusal attrition reduces crown heights and, consequently, reduces lower face height

(Fishman, 1973). In turn, reduced crown heights allow the mandible to autorotate forward-and-upward, one consequence being that incisor overjet often is replaced by an edge-to-edge bite with horizontal wear on the incisal contacts (*e.g.*, Begg, 1954). A related clinical issue is third molar impaction (Mucci 1982), like most occlusal variation a result simply of insufficient alveolar space for proper eruption, but this topic is usually treated differently because it is the province of a different clinical specialty, oral surgery as opposed to orthodontics.

In summary, this paper describes methods useful for quantifying the nature and extent of occlusal variation. Variations (“malocclusions”) are very common in contemporary humans, but their origins, kinds, and geographic distributions are not well documented.

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# For Whom the Coin Tolls: Green Stained Teeth and Jaws In Medieval and Post-Medieval Spanish Burials

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**ABSTRACT:** While observing dental characteristics in Spanish and Basque skeletons from the Cathedral of Santa Maria in Vitoria, Spain, an unusual pattern of staining was evident in 18 of 206 individuals. The stain, which permeated bone, dentine, calculus, and/or enamel, varied in color from bright green to turquoise. Males and females, all age categories, and medieval and post-medieval skeletons were equally affected. The green stain was the result of an ancient practice going back to Greek times that involved placing a silver or gold coin (obol) in the mouth of the deceased prior to burial for

the purpose of paying the boatman (Charon) for passage across the river of woe (Acheron). In Spain, bronze coins substituted for silver and gold. The copper component of the bronze reacted with the acidic environment caused by decomposition creating basic copper carbonate. The copper carbonate then seeped into the porous spaces of the bones and teeth or replaced the mineral portion of the bone. The duration of this practice provides evidence that a seemingly 'pagan' ritual was preserved long after Christianity spread throughout Spain. *Dental Anthropology* 2008;21(1):12-17.

Santa Maria Cathedral in Vitoria, Spain, began as a simple parish church in 900 CE. Additional construction over the next thousand years eventually compromised the church's structural stability. This necessitated major renovations that began in 1997 and continue to the present. To stabilize the foundations, excavations within and around the cathedral displaced over 1,500 burials. In 2006, a dental study was initiated on skeletons from burial sites dating to medieval and post-medieval times. While making observations on tooth size, morphology, and pathology, an unusual phenomenon was observed. Eighteen individuals had jaws, teeth, and, on two occasions, hyoid bones that had been stained varying shades of green (Fig. 1).

The staining was inferred to be the result of copper leeching out of grave goods placed in close proximity to the affected areas. Direct evidence for this relationship was provided when a bronze coin was found fused to the occlusal surface of an upper left second molar (Fig. 2). Chemical modeling supports the conclusion that the green staining was caused by the copper component of bronze coins placed in the mouths of individuals prior to burial.

## SAMPLES

The Santa Maria Cathedral burials came from two temporally and geographically distinct areas. Series 17, dating to medieval times (<1,500 CE), was excavated immediately outside the cathedral. Series 11 and 22 contain post-medieval (>1,500 CE) remains buried directly under the floors of the cathedral. The medieval sample numbered 77 individuals while the

post-medieval sample consisted of 129 individuals (Table 1). Only skeletons that possessed the anatomical areas most likely to be subject to staining, the skull and mandible, are included in these samples. In the medieval sample, 9 of 77 (11.7%) individuals exhibited green staining while 9 of 129 (7.0%) skeletons showed staining in the post-medieval sample. There was no significant difference in the frequency of green staining between the two time periods ( $\chi^2 = 1.37$ ;  $P > 0.05$ ). When the medieval and post-medieval samples were pooled, 6 of 68 males (8.8%) and 8 of 89 females (9.0%) exhibited green staining. The difference between the sexes is not significant ( $\chi^2 = 0.00$ ;  $P > 0.05$ ). Additionally, 4 of 39 (10.2%) children of unknown sex exhibited staining. Although the total sample of stained jaws and teeth is relatively small, there were no discernable significant differences by time, sex, or age.

## BURIALS, BRONZE COINS AND THE BOATMAN

The explanation for putting coins in the mouth at death is found in classical Greek mythology. The ritual of "paying the boatman" stems from the myth of Charon who ferried the souls of the dead across an underground river to Hades, the final destination for all souls, sinner and saint alike. The name of the fabled waterway that had to be crossed was the Styx ('Hated')

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TABLE 1. Frequencies of staining, by temporal phase

| Sex           | n   | Affected | Percent |
|---------------|-----|----------|---------|
| Medieval      |     |          |         |
| Male          | 23  | 3        | 13.0    |
| Female        | 29  | 5        | 17.2    |
| Unknown       | 25  | 1        | 4.0     |
| Total         | 77  | 9        | 11.7    |
| Post-Medieval |     |          |         |
| Male          | 45  | 3        | 6.6     |
| Female        | 60  | 3        | 5.0     |
| Unknown       | 24  | 3        | 12.5    |
| Total         | 129 | 9        | 7.0     |
| Combined      |     |          |         |
| Male          | 68  | 6        | 8.8     |
| Female        | 89  | 8        | 9.0     |
| Unknown       | 49  | 4        | 8.2     |
| Total         | 206 | 18       | 8.7     |

or the Acheron ('Morning' or 'Woe').

Charon does not figure as prominently as other supernatural beings in early Greek literature or artwork. There are possible allusions to Charon in some of Homer's works, and the boatman was likely a part of Greek oral tradition before he is first referenced in literature (Sullivan, 1950). The few early depictions describe him as a man poling a raft full of shades, making him a rarely mentioned but crucial part of the soul's journey (Fig. 3). He would charge the souls an obol (Athenian coins from the 5th-6th century BCE) to be ferried to the afterlife. The obol was placed in the mouth of the dead before burial so that upon their arrival at the riverbank, they would already have the fee. Those who lacked the fee were doomed to wander the banks for one hundred years (Fairbanks, 1912), a fate similar to limbo in Catholicism.

Early Roman mythology also included Charon as the Romans adopted much of Greek religious tradition. Virgil's epic poem, *The Aeneid*, describes Charon as an elderly man "repulsive in frightening filth ... [with] a matted and wolf-grey beard ... [and] dirt-soiled clothes" (Ahl, 2007:37). The only Latin novel that survived in its entirety, Apuleius' *Metamorphose*, written in the mid to late second century CE, refers to Charon as an avaricious and filthy old man who gathers tolls and ferries souls across the river (Butler, 1910). As the Romans invaded and conquered other lands this myth was integrated into new cultures. From the 2nd century BCE to the 5th century CE, the Romans had a major impact on northern Spain.

Ultimately, the Romans were as responsible for the decline of this burial custom as they were for

its introduction. Roman Emperor Constantine I introduced and legitimized mainstream Christianity to Europe in the 4th century CE. Eventually the Christian hierarchy stigmatized 'pagan' rituals that were part of the dogma of competing religions. During the late 6th and early 7th centuries, Pope Saint Gregory I created many Christian superstitions and legends about death and the afterlife. These legends were used to reach the faithful and eradicate lingering pagan myths by using a simple language that the lower classes could understand. One of St. Gregory's stories involved a dead soldier who, upon his resurrection, described his passage to the afterlife as being facilitated by a bridge that was suspended over a dark and rancid river (Gurevich, 1992). Theoretically, the 'pagan' ferryman had been replaced by a Christian bridge and coins were no longer necessary to pass into the hereafter.

Not all Christian authorities sought to exorcise Charon from stories about the afterlife. It became the practice of many medieval and Renaissance writers to appropriate figures from pagan mythology into their ecclesiastical writings, transforming them into demons. Charon was no longer an integral and necessary part of the death process ferrying souls to their respective fates. Instead, he was transformed into a demon that transported only the damned to Hell. Christian poet Dante described him as "Charon the demon, with eyes like glowing coals ... he beats with his oar whoever lingers" (Durling, 1996). This metamorphosis can be seen in Church sanctioned artwork such as Michelangelo's depiction of Charon from the "Last Judgment" (Fig. 4).

Despite the power of the Catholic Church, the pagan belief of paying the boatman survived into medieval and post-medieval times, though at a reduced rate. At Santa Maria, 8.7% of the individuals had green staining on their jaws and/or teeth. This shows the ritual of placing coins in the mouths of the dead, even though it had survived, was not widely practiced between 900 and 1,850 CE.



Fig. 1. Stained mandible of child (Medieval period).

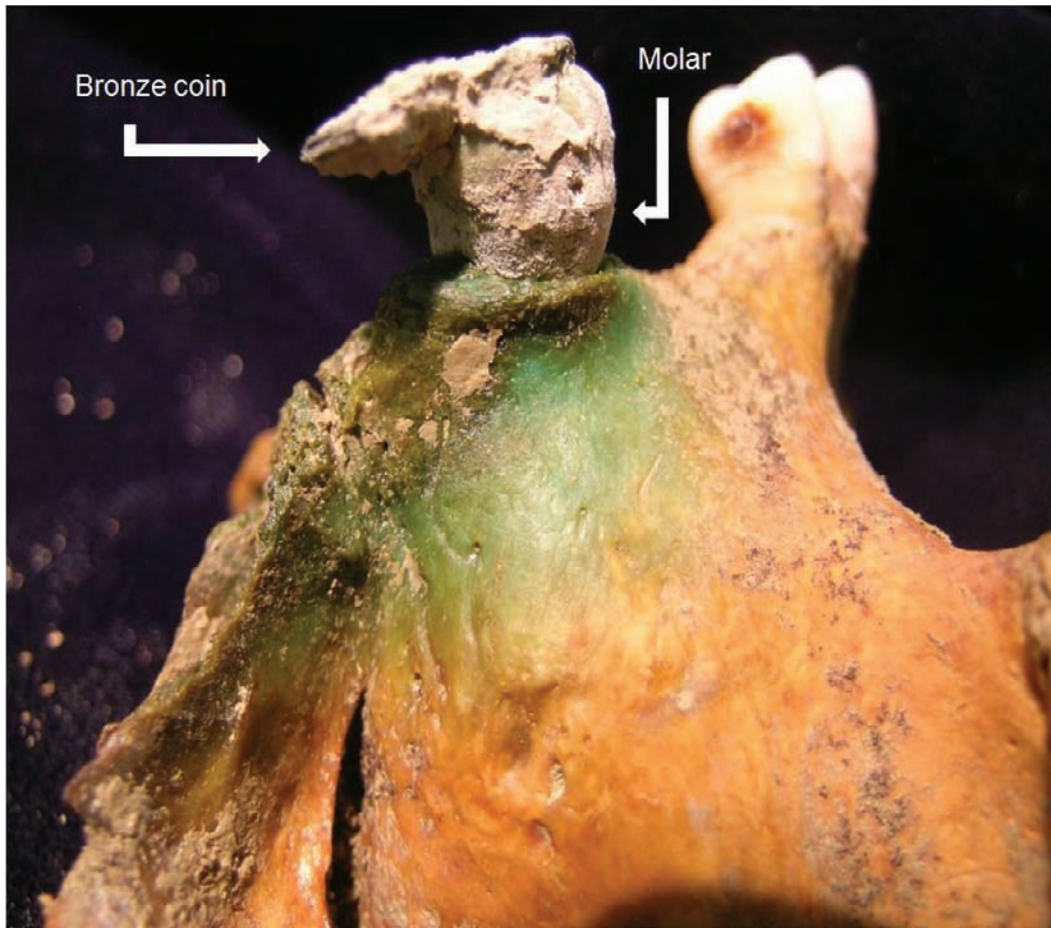
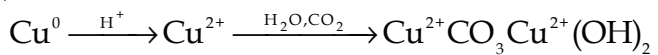


Fig. 2. Bronze coin fused to upper second molar (Medieval period).

## CHEMISTRY AND COPPER

### Formation of Copper Carbonate

There are two possible chemical causes for the green stain. Explanations begin with the premise that the copper component ( $\text{Cu}^0$ ) of the bronze coins (Fig. 5) reacted with  $\text{H}^+$  ions, resulting in the formation of  $\text{Cu}^{2+}$ .  $\text{Cu}^{2+}$  then reacted with water and carbon dioxide to create basic copper carbonate ( $\text{Cu}^{2+}\text{CO}_3 \cdot \text{Cu}^{2+}(\text{OH})_2$ ), commonly known as patina (Sax and Lewis, 1987). This greenish-grey compound is the normal result of copper oxidation. The  $\text{H}^+$  ions, water and  $\text{CO}_2$  are all normal byproducts of body decomposition. The creation of basic copper carbonate is shown in the following chemical reaction:



Patina, evident in Fig. 6, is resting on the biological material but is not incorporated into the bone. Incorporation could be the result of two different processes.

### Explanation 1: Absorption of Copper Carbonate

The basic copper carbonate, in an aqueous instead of solid form, may be seeping into the porous spaces of the bones and teeth. If simple absorption were occurring, it would be expected that the affected biological material would resemble the copper carbonate in color.

### Explanation 2: Formation of Pseudomalachite

An alternative explanation is that copper replaced the calcium component of the bone and turned the mineral portion of the bones and teeth, hydroxylapatite (Sax and Lewis, 1987), into pseudomalachite. Pseudomalachite, named for its chemical and physical similarities to true malachite (Bailey, 1929), is a different color from basic copper carbonate. The latter is a grayish blue-green while the former ranges from a pale green, a yellow green, or an almost black color when concentrated. This gradient may be represented in Fig. 7, although the black portion of the tooth may reflect decomposition. The fact that the stained bones and teeth resemble the green of pseudomalachite in color



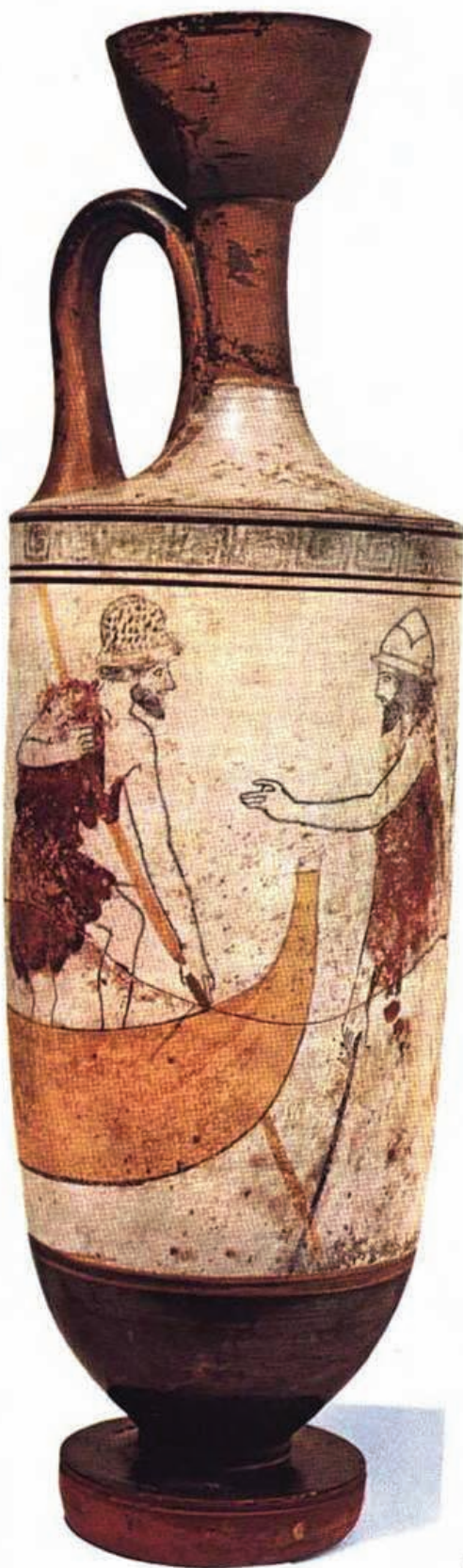
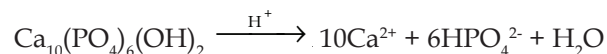


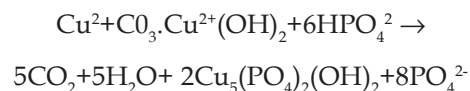
Fig. 3. Greek pot depicting the boatman Charon (the Lekythos Vase, housed at the National Archaeological Museum, Athens, Greece).

instead of the grayish blue-green of copper carbonate supports this second explanation.

In the first part of this process, the mineral portion of the bone and teeth, hydroxylapatite, reacts with  $H^+$  ions already present as a result of normal body decomposition. This results in the creation of free calcium ( $Ca^{2+}$ ), hydrogen phosphate ( $HPO_4^{2-}$ ) and water ( $H_2O$ ). The chemical process is as follows:



The free calcium is washed away by groundwater or other liquids created during the decomposition process. The basic copper carbonate created during the first chemical reaction then combines with the hydrogen phosphate to create carbon dioxide, water, free phosphate, and pseudomalachite. The chemical formula for pseudomalachite is the same as that of hydroxylapatite, the only difference being that copper replaces calcium. The chemical process for the incorporation of copper into the mineral composition of bone is as follows:



### CONCLUSIONS

There are other possible explanations for the presence of green stained jaws and teeth in the Santa Maria burials, including copper in the soil, groundwater or other grave goods. However, the localization of the green stain in the oral cavity and associated anatomical areas, as well as the presence of one bronze coin found adhering to a tooth, support the proposition that family members were placing bronze coins in the mouths of their loved ones at death. This speaks to the fact that the influence of the Christian church, at least in medieval and post-medieval Spain, was not all encompassing. Almost 10% of the congregation of the cathedral combined elements of both Christian and 'pagan' burial practices, hedging their bets on what would be required during their journey to the afterlife.

### ACKNOWLEDGEMENTS

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Fig. 4. Michaelangelo's depiction of Charon from the Sistine Chapel (Lamarche Vadal, 1986).

the molar equations shown in the text.

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Fig. 5. Bronze coin recovered from oral cavity of burial from Santa Maria Cathedral.



**Fig. 6.** Basic copper carbonate adhering to mandible (Medieval Period).



**Fig. 7.** Possible pseudomalachite gradient around a carious lesion on the lower molars (Medieval Period).

# Short Communication: The Biology of Natfa People: Bones and Teeth

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**ABSTRACT:** The archeological site of Natfa is a rural late-antiquity site in northern Jordan. The tomb typology points to two social ranks: the public compared to the few elites who might have controlled wealth allocation. The people died at young ages (under 35 years of age).

The 3rd century AD was a turning point in late antiquity as the Roman Empire collapsed economically due to military invasions by Germanic tribesmen, civil wars, and plague. As a result, the military remained unfunded, and emperors confiscated goods, imposed heavy taxes, and exacted forced labor to overcome the crises. The accumulation of factors resulted in economic havoc and famine (Jones, 1964). The third century crises and weakness of the Roman Empire lessened its authority in the east, where turmoil and instability would have occurred. Many of the people in the east Empire were pushed into marginal lands away from cities to seek their livelihoods in food production.

During this time, the majority of people lived in small rural sites that became economically independent. Economic prosperity was obvious in many rural sites in Jordan and the region (Kingsley and Decker, 2001; Mango, 1980; Parker, 1999; Ward-Perkins, 2000a,b; Watson, 2001). This prosperity included wine trade, the import of skilled craftsmen, and the building of fancy tombs.

The present study reviews the tomb architecture and the human skeletons at Natfa in northern Jordan. The site is located 4 km west of the city of Irbid on a fertile landscape with a varied terrain, where the elevation ranges from 620 to about 695 m above sea level. Cemeteries were found on the steep slopes of two opposing mountains at an elevation of about 650 m. The site was excavated jointly by Yarmouk University and the University of Arkansas starting in the summer of 2005. This is a rural late antiquity site in the north of Jordan. Successive excavations have revealed tombs, artifacts, cisterns, and archeological structures.

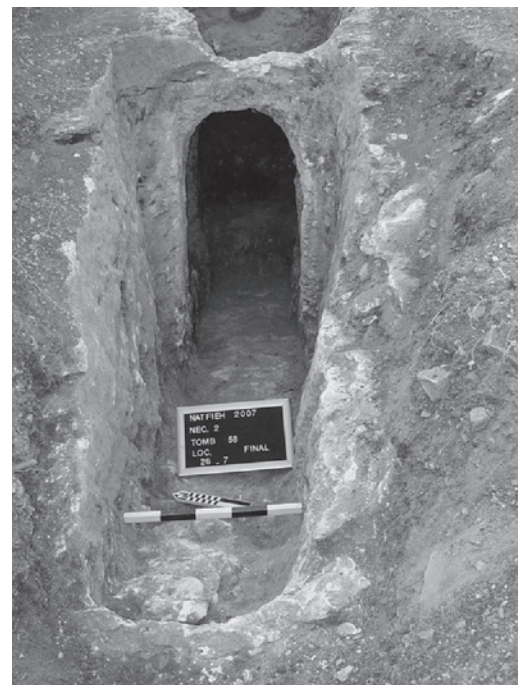
There are 39 excavated tombs at the site, and all are horizontal shaft tombs with or without an arched entrance sometimes leading to loculi (Fig. 1) except for tomb 21 that is a horizontal chamber tomb with radiating loculi (Fig. 2). There is evidence of tomb robbing both in antiquity and in modern times. The recovered bones

There seems to be reliance on hard food particles rich in carbohydrates, which increased the occurrence of interproximal caries. A few oblique dental caries are reported, probably caused by using teeth as tools. *Dental Anthropology* 2008;21(1):18-20.

were commingled except for 5 individuals.

## RESULTS AND DISCUSSION

Due to the nature of the bones, we were able to sex 9 skeletons using the standards of Buikstra and Ubelaker (1994); 4 were female and 5 male. Seven of the burials could be aged, with a range of from 7 to 35 years. None of these human remains show any paleopathological lesion except for an osteophytosis in one lumbar vertebra.



**Fig. 1.** A horizontal shaft tomb from Natfa with an arched entrance.

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The examined teeth showed marked hypoplasia on most of the anterior teeth (Fig. 4). The average dental wear score for the anterior teeth is 6 (namely, large dentine area with enamel rim lost on one side), and average dental wear on the posterior teeth is 23 (moderate dentine exposure). The few recovered teeth show only interproximal caries in an advanced stage of wear (*i.e.*, exposed pulp cavities).

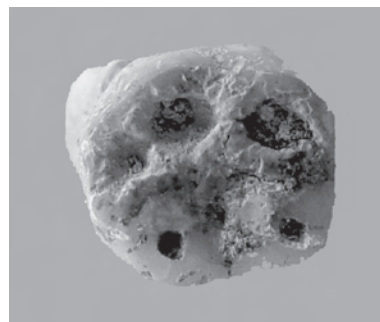
A few cases of oblique dental wear were recorded, where enamel was lost obliquely down to the labial and buccal root cervix (Fig. 5).

Excluding tomb 21, the tomb typology at the site of Natfa was simple (horizontal shafts) and did not require extensive energy expenditure for construction. According to Binford (1971) and Tainter (1975) greater energy expenditure in tomb construction (and tomb complexity) corresponds to higher social rank of the deceased. This probably means that the horizontal shaft tombs were constructed for the public, while tomb 21 was for elites.

Based on the biological data extracted from the skeletal remains and teeth, the diet of the people of Natfa was moderately hard as the average score of dental wear for the posterior teeth is moderate. This type of wear has been associated with abrasive diets of a vegetable type rich in carbohydrates, mostly cereals. Considerable amounts of cereals and legumes were present in the diets of the Mediterranean region during the Roman period (Prowse *et al.*, 2004; Garnsey, 1999), which extensively wear the enamel.

The interproximal caries are explained by dental wear; in groups whose nutrition is based on foods that abrade grinding surfaces, higher frequencies of interproximal caries are recorded (Calgjar *et al.*, 2007) because the wear removes food particles and bacteria.

Although the number of recorded oblique dental wear is few, it stresses the use of teeth as tools. Oblique dental wear is noticed in societies who used their teeth in nonalimentary activities such as tooth-tool use and the use of teeth as a third hand (Minozzi *et al.*, 2003), including leather processing by Eskimos (Merbs, 1983),



**Fig. 3.** The moderate dental wear on the posterior teeth.

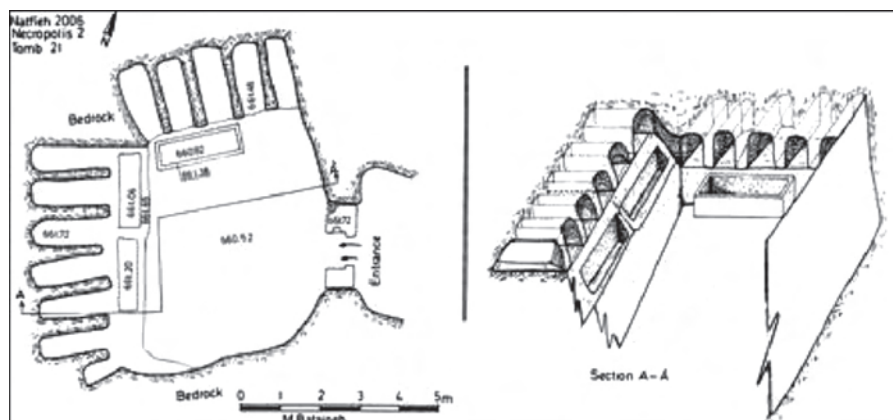
sinew processing by Australian aboriginals (Brown and Molnar, 1990), basket production by Native American Paiute (Wheat, 1967), and weaving by the Byzantines in Khirbit Yajuz, Jordan (Al-Shorman and Khalil, 2006).

## CONCLUSIONS

The late Roman people of Natfa experienced environmental stresses. They died at young ages, evidently by around 35 years. As their skeletal remains were healthy, nothing could be inferred about the cause of death. The society was stratified into wealthy and poor. Rural sites such as Natfa may have established their economic independence at the expense of quality of life.

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**Fig. 2.** (Left) Top plan and a 3-dimensional representation of tomb 21; (right) a horizontal chamber tomb at Natfa.

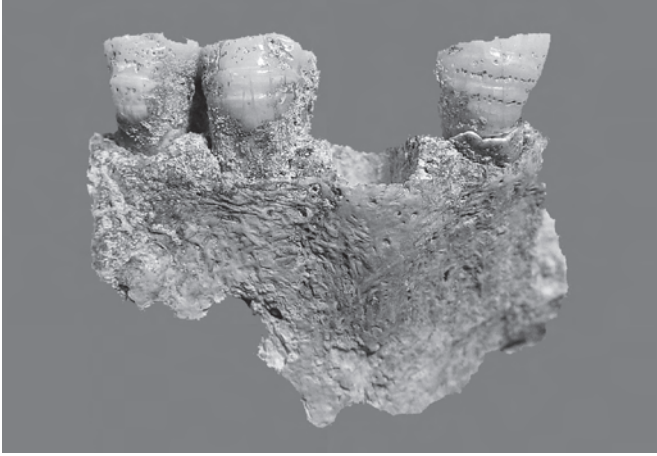


Fig. 4. Marked hypoplasia on the anterior teeth.



Fig. 5. Oblique dental wear on the upper first premolar.



Fig. 6. Interproximal caries in a lower third molar.

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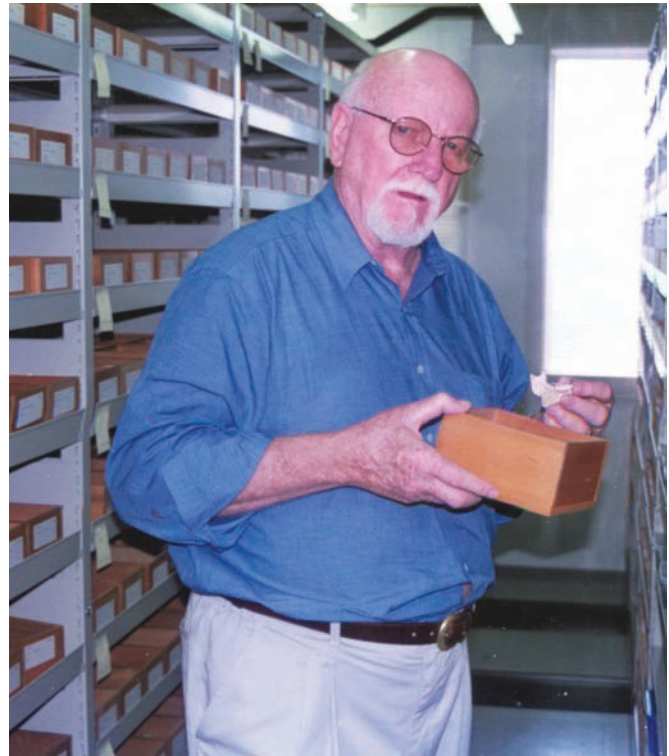
## Obituary: Daris R. Swindler (1925-2007)

Daris R. Swindler, Professor Emeritus of Anthropology at the University of Washington, Seattle, passed away on December 6, 2007, after a brief acute illness in Spokane. He was 82 years old. Much of his scientific work was related to dental anthropology and craniofacial growth and development. A long-time member of the Dental Anthropology Association, Swindler served as its president from 1990 to 1992. From 1996 to 2001 he belonged to the Editorial Board of *Dental Anthropology*. With his death dental anthropology has lost one of its finest scholars and supporters. The 14th International Symposium on Dental Morphology in Greifswald, Germany in August 2008 will commemorate his life and will honor his most valuable contribution to Dental Anthropology.

Daris R. Swindler was born in Morgantown, West Virginia in 1925. Since his junior years in highschool, Swindler had been interested in the evolution and the diversity of recent humankind. This interest was greatly fostered by the reading of "On the Trail of Ancient Man" by Roy Chapman Andrews. Interrupted by his volunteer service for the US Navy during the Second World War, Swindler began his higher education at the University of West Virginia. As a graduate student at the University of Pennsylvania he studied with Drs. Wilton H. Krogman, Loren Eiseley and Carleton Coon. Especially influential was his acquaintance with Krogman that inspired his continuing interest in craniofacial growth and development, and especially of teeth.

In 1954 he participated in an expedition to New Britain with Ward Goodenough, Ann Chowning and Charles A. Valentine. This had a great impact on Daris Swindler's future work. Not only was his doctoral dissertation in Anthropology, which he completed in 1959, largely based on the material that he collected during these five months, but the time he spent with the Lakalai people assured him of his career choice as a physical anthropologist. In his most recent book "New Britain Diary, 1954: An Anthropologist's Journal", Daris R. Swindler reflects his encounter with the Lakalai [p. 34] "As I walked back along the beach that evening, all that had happened today was swimming about in my head: thoughts about our earth and its many people, its many religions and cultures, and then I realized: this is why I became an anthropologist."

Though he was never able to return to New Britain, his interest in the various cultural regions of the Pacific continued. In 1996 he joined an Italian Expedition to Easter Island as a Field Consultant in Dental



**Fig. 1.** Daris R. Swindler studying primate dentitions in Inuyama, Japan, in 1998.

Anthropology and one year later accepted an invitation to lecture on Micronesian Anthropology on the Oceanic Grace Cruise Line through Micronesia.

From 1954 to 1968 Swindler taught human anatomy at several academic institutions including the University of Pennsylvania Graduate School of Medicine, Cornell University Medical School, West Virginia University Medical School, the Medical College of South Carolina, and Michigan State University. In 1968 Swindler was appointed full professor at the Department of Anthropology, University of Washington. Over this same time period he was also an Adjunct Curator of Primate Anatomy, Burke Memorial Washington State Museum. After his retirement in 1991 he was invited to be Visiting Professor by the University of Zurich, Switzerland (1992), the University of Padua, Italy (1994), and by the Okayama University School of Dentistry, Japan (1998).

Swindler's research interests included primate anatomy, early primate dental development, comparative dental morphology and odontometrics of living and fossil primates, as well as Pacific dental anthropology. Several field expeditions took him to important sites such as the Big Horn Basin, Wyoming



**Fig. 2.** Daris R. Swindler researching in Inuyama, Japan, 1998.

(1984-1990), Pakistan (1989), as well as to the Valley of the Kings, Egypt (1991). In recent years he carried out forensic work in Cyprus for Physicians for Human Rights.

His time in Seattle was very productive. Several research grants from the National Institutes of Health (NIH) allowed Swindler to conduct unique longitudinal studies on craniofacial growth and development of two primate species, the pigtailed macaque (*Macaca nemestrina*) and the yellow baboon (*Papio cynocephalus*). Huge datasets accrued from X-ray-films, dental casts, body and head measurements, which were studied extensively by Swindler and his graduate students, most notably Dr. Joyce Sirianni. In addition to Swindler's classic work in 1973, "An Atlas of Comparative Primate Gross Anatomy, Baboon, Chimpanzee, and Man" (reprinted by Robert E. Krieger in 1982), with medical illustrator Charles D. Wood, Swindler and Sirianni published a substantial body of data in 1985 as an impressive book, "Longitudinal Growth and Development of the Pigtailed Macaque (*Macaca nemestrina*)" CRC Press, Boca Raton, Florida. Daris Swindler never refused scholars access to his original data. On the contrary, he often went out of his way to promote new research that made continuing use of his own data base. In 2007, shortly before his death, Daris decided to donate his enormous collection of dental casts, X-ray films, skeletons, etc. to the New York University. At the same time New York University formally established the "Daris R. Swindler Collection" of dental primate material available for study at their Center for the Study of Human Origins (<http://www.nyu.edu/gsas/dept/anthro/programs/csho/center.html>). This gave Daris a great sense of pride and the assurance of a productive future for his collections.

Swindler received many honors in his life, notably the Alexander Von Humboldt Senior Scientist Award from Germany; the Washington Governor's Writer's Day Award for his "An Atlas of Primate Gross Anatomy: Baboon, Chimpanzee and Man"; the Senior Award for the Visiting Scholar Exchange from the Peoples Republic of China; Vice President of the American Association of Physical Anthropologists; President of the Dental Anthropology Association. He was a member of the editorial boards of several journals including *Journal of Dental Research* and the *Yearbook of Physical Anthropology*. He was elected a Fellow of The American Association for the Advancement of Science in 1961 and in 1992 became a Fellow of The Explorer's Club.

Swindler was a gifted writer, who published constantly over more than 50 years. His first publication was in 1955 on the absence of sickle cell anemia in Melanesia. "A review of dental morphological traits in Oceania" was a chapter in a Festschrift (2005) for Ann Chowning. Apart from those already mentioned, other outstanding publications include his widely acclaimed books, "The Dentition of Living Primates" Academic Press, London, 1976; "Introduction to Primates" The University of Washington Press, Seattle and London, 1998; "Primate Dentition: An Introduction to the Teeth of Nonhuman Primates" Cambridge University Press London, 2002. Daris himself said he especially enjoyed his work as the major editor of "Systematics, Evolution and Anatomy", Vol. 1 of Comparative Primate Biology, Alan R. Liss Publishing Company, 1986 (with J. Erwin as Series Editor).

Apart from his outstanding contribution to dental



**Fig. 3.** Daris R. Swindler (left) and C. Loring Brace, both past-presidents of the Dental Anthropology Association. Picture taken at the AAPA meeting, 1996 (courtesy of E. F. Harris).



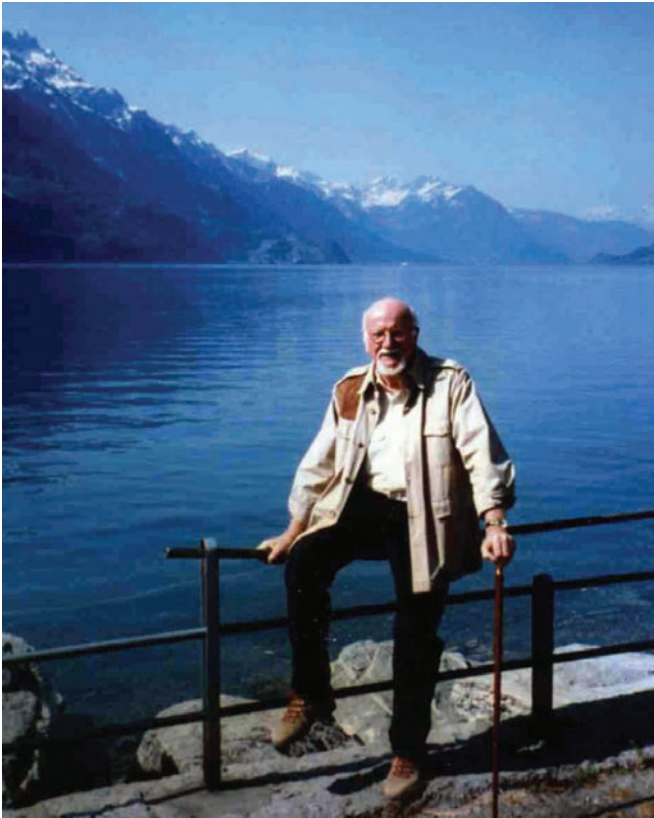


Fig. 4. Daris R. Swindler in Switzerland.

morphology and primate anatomy, Swindler was known for his passion for teaching. His courses on Comparative Primate Anatomy were particularly popular with his students. Shortly before his death, Daris was honored by the establishment of the Daris R. Swindler Fellowship in Biocultural Anthropology in the Department of Anthropology of the University of Washington. This fellowship marks a lasting contribution to Anthropology in his name and will provide a great opportunity for many future students at the University of Washington.

As a truly biological anthropologist, Daris R. Swindler enjoyed life and its many facets to the fullest. He was always fascinated about all aspects of evolutionary biology, and loved to chat about his many interests, most notably about primate teeth. From all of the many meetings he attended, he especially favored the International Symposia on Dental Morphology because of their special flavor and small size which encourages scientific discussions about so many aspects of dental morphology both in primates and other vertebrates. He was especially passionate about key historical figures, none more so than Charles Darwin and was never prouder than when he could extend his private library with another book on the subject. He and his wife Kathy Swindler were great hosts not just for well-known

and established academics, but also for many young researchers who were still at the start of their careers. Many felt, and still feel, part of Daris and Kathy's extended scientific family and many, through their friendship and support, were inspired to keep going. Daris had an overwhelming trust in the future and his friends felt his love for his academic family. Apart from science he loved fishing in the Puget Sound and was almost fanatical about American Football.

Daris R. Swindler is survived by his wife Kathryn Rantala Swindler of Spokane, seven children and seven grandchildren. Everyone who knew him will agree that Daris was a wonderful person. He will deeply be missed by all those to have shared so much with him and have learned so much from him though he will remain a part of dental anthropology for a very long time to come.

Christopher Dean  
University College London  
United Kingdom  
and  
Thomas Koppe  
Ernst Moritz Arndt University  
Greifswald  
Germany

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[An electronic version of this bibliography is available on request. *Editor*]

## The Daris Swindler Primate Dental Cast Collection

In August 2006 Daris agreed to donate his collection of primate dental casts to the Center for Human Origins, New York University. The collection consists of more than 2,000 casts representing every primate species known (and some non-primate relatives), as well as several human populations. The Daris Swindler Primate Dental Cast Collection is now housed in the Anthropology Department of NYU. Undergraduate volunteers are in the process of inventorying the collection and comparing it against Daris' catalog. Inventory is expected to be complete by December of 2008. The collection has already been used for a number of undergraduate and graduate student projects. In addition, researchers who are members of the New York Consortium for Evolutionary Primatology have begun scanning some of the ape casts for comparative study. Ultimately, NYU plans to scan the entire collection in three-dimensions and make it virtually available for remote researchers via an internet database. The collections will provide the foundation for developing standards for scoring non-human primate dental morphological variation. Many important studies of human and non-human primate variation as well as growth and development are in the works. NYU now anticipates working with Kathy Swindler to arrange the transfer of the remaining collection, which includes measurements and radiographs from an 8-year growth study of *Macaca nemestrina*, several hundred tooth buds from several species of non-human primates, and additional human collections from New Guinea Highlands and New Britain. NYU and Dr. Bailey, in particular, are greatly indebted to Daris for this generous donation.

Shara Bailey  
New York University  
E-mail: sbailey@nyu.edu

## Obituary: Professor Ebba During 1937—2007

We are deeply saddened by the death of Professor Ebba During on May 15, 2007.

Ebba (born August 21, 1937) started her career in the 1970s at the Osteological Research Laboratory, Stockholm University, under the supervision of the discipline's Swedish pioneer, late Professor Nils-Gustav Gejvall.

Her doctoral thesis in 1986 dealt with the faunal remains from the Neolithic pile dwelling of Alvastra in eastern Sweden. This was a unique cult centre with artefacts connected both to the Funnel Beaker culture as well as the Pitted Ware culture. Ebba reconstructed life and fauna on the 5,000-year-old site. She also thoroughly discussed methodological problems related to the interpretation of zooarchaeological assemblages. Her later investigations of the human remains from the same site revealed exceptional information about Neolithic rites.

In the late 1980s and early 1990s Ebba was deeply involved in her study of the victims from the battle ships Vasa and Kronan. The Vasa sunk in Stockholm harbour on its maiden voyage on August 10th 1628 and was salvaged in 1961. The Kronan exploded and quickly sank during the Scanian War with Denmark on June 1st, 1676. Her work revealed new information about the crew of each ship in particular and more generally on the state of health in the 17th century. Perimortem sharp force trauma from the Kronan remains raised new questions concerning the events preceding the catastrophe.

In addition to writing articles, Ebba taught classes, supervised Ph.D. students, and conducted research projects. For almost 30 years she was active as lecturer at the Osteoarchaeological Research Laboratory. As head of the laboratory, she had an essential role at all levels of teaching and administration. In the 1990s, she was one of the initiators of the osteology subject at Gotland University. Her many students during the years, both in Stockholm and Gotland, bear witness of her great commitment.

Ebba was talented in conveying her research to the larger public through all sorts of media in ways that

drew a crowd. She was a multitasking researcher and teacher but perhaps we remember her most for her vitality and wit, for her intellect and great humor, and for her thoughtfulness and good sense. She was loved and deeply cherished by her students and her colleagues.

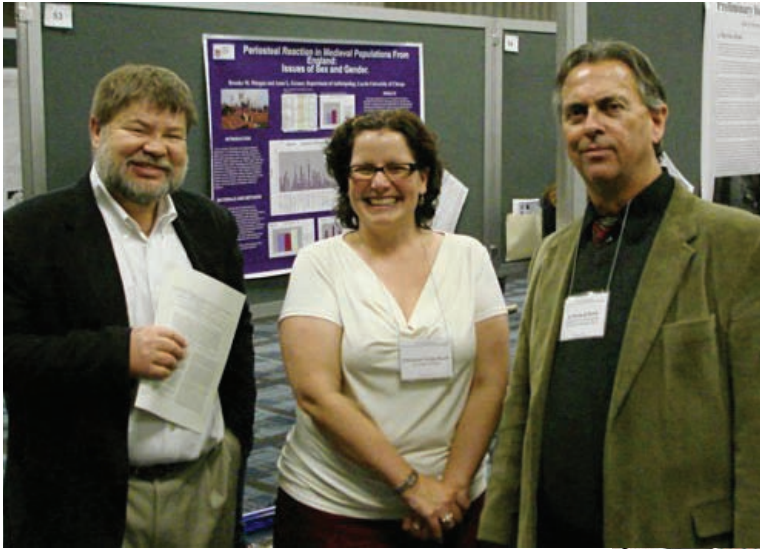
*Submitted by:*

Colleagues and friends at the  
Osteoarchaeological Research  
Laboratory, Stockholm University,  
Sweden



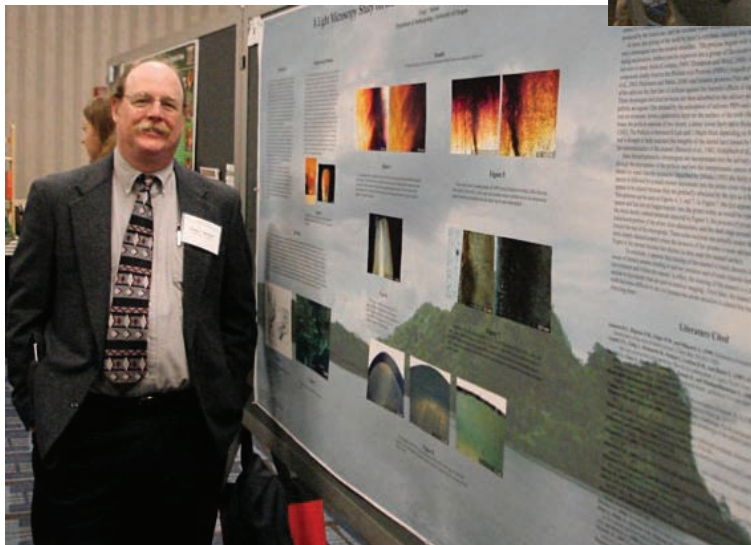
Ebba During, 1937-2007.

## Dental Anthropology Members at the AAPA Meeting, Columbus, Ohio, March, 2008



Edward Harris (*left*) poses with Christina Torres-Rouff and Richard Scott (*right*) at a poster session. Edward is editor of *Dental Anthropology* and Richard is president-elect of the Association.

Richard Scott (*right*) stands with two of his students, Sarah Yeats (*left*) and Kimberly Hopkinson, as they display their poster. These women currently are graduate students at University of Nevada, Las Vegas, where Richard is on the faculty.

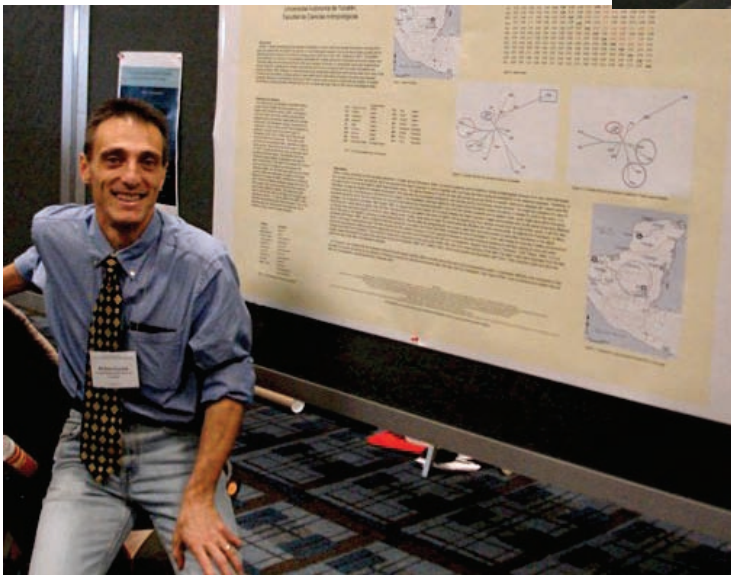
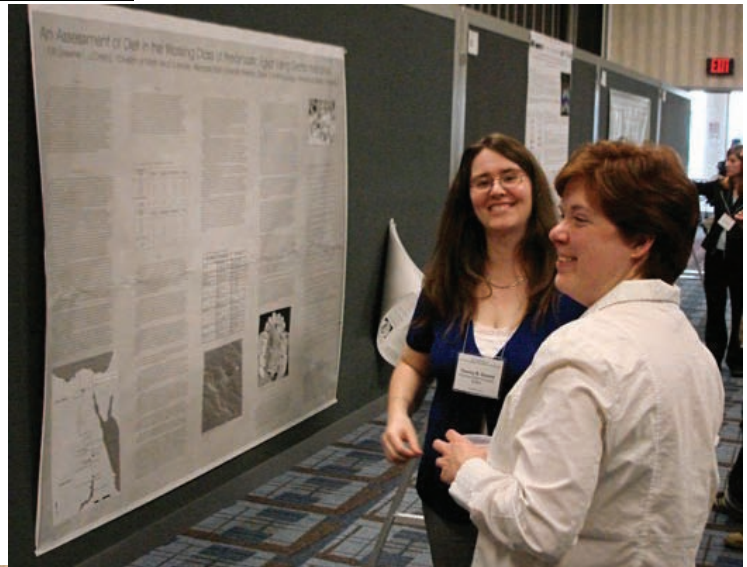


Greg Nelson beams in front of his poster entitled *Light microscopy study of the effect of betel nut chewing on enamel microstructure*. Greg (University of Oregon) is book review editor for *Dental Anthropology*



Joel Irish (*front, left*) and Greg Nelson proudly show off their edited volume, *Technique and Application in Dental Anthropology*, newly published (2008) by Cambridge University Press. Dr. Dominic Lewis, bioanthropology editor for Cambridge Press, is standing behind the book display. Their volume is based on papers presented at the AAPA meeting in Milwaukee, Wisconsin, (2005) at the symposium sponsored by the Dental Anthropology Association, titled *Dental Anthropology 20 Years After: The State of the Science*. As implied, the symposium was in recognition of the 20th anniversary of the DAA.

Tammy Greene (*left*) discusses her poster *Working class diet in Predynastic Egypt: as examined through dental indicators*. Tammy is on the faculty at Arkansas State University, Beebe. Joel Irish was also an author on the poster.



Andrea Cucina (Universidad Autónoma de Yucatán) takes a short break from discussing his poster *Morphological affinities and migratory patterns in Precontact Maya populations from the Yucatan Peninsula: a dental non-metric analysis* (coauthored with V. Tiesler).

## **Minutes of the 23rd Annual Dental Anthropology Association Business Meeting: April 11, 2008, Columbus, Ohio**

### Call to Order:

The meeting was called to order at 8:00 P.M., by President Brian Hemphill.

### Old Business:

None.

### New Business:

#### 1. President's address

President Brian Hemphill welcomed the attendees, and discussed several goals for the upcoming year. Four specific aims are:

1. For various reasons, the DAA has not previously sought tax-exempt status. This lack of status creates problems, especially for the Secretary-Treasurer, in accounting for the annual dues and expenditures. The plan is to attain tax-exempt status during this academic year, which will resolve several accounting issues.
2. Members of the executive committee pointed out that, flowing from the problem above, the contact e-mail for DAA officers, especially the Secretary-Treasurer, changes with each election. Consequently, it becomes difficult for members and other anthropologists interested in the association to contact the current officers. The Executive committee recommends that the association obtain a permanent Yahoo e-mail account that will provide the association the same benefit of greater continuity despite the inevitable changes in the composition of the Executive committee over time. A Yahoo or similar e-mail account won't be tied to a specific educational or research institution, so it won't matter who the elected officials is, for the account will remain the same.
3. The DAA currently maintains a checking account, but, regardless of the banking institution, maintenance fees and other costs associated with this account have become increasingly exorbitant and are billed against the DAA regardless of the level of use. The Executive committee will determine whether it is cheaper for the association to establish an account through PayPal, or a similar software payment company, to collect subscription fees at a reduced cost to the association.
4. In order to further enhance the visibility of the DAA within the AAPA, we will venture to sponsor an annual symposium at the annual AAPA meetings. Several potential topics were discussed. These include (1) New Thinking about Biodistance Analysis, (2) Dental Disease and Dietary Reconstruction, (3) A Fresh Look at Stress, (4) New Insights into Primate and Nonhuman Dental Variation, and (5) New Methods in Dental Anthropology. The Executive committee requests the membership to offer additional potential topics, and it thanks Debbie Guatelli-Steinberg and Chris Schmitt for volunteering to chair a DAA-sponsored symposium at the 2009 annual meetings and thanks Richard Scott for volunteering to chair a DAA-sponsored symposium at the 2010 annual meetings (see below).

#### 3. Election of New Officer:

One new officer was elected: G. Richard Scott from the University of Nevada, Reno (President-Elect).

*Continued*

## 4. AA Dahlberg Student Prize:

No competition was conducted this academic year. In the future, plans are to distribute the announcement in August of each year, with the deadline for submission the following January.

## 5. Secretary-Treasurer's Report:

As of April 5th, 2008, the DAA has a balance of \$3,252.33 for operations and \$1,375.58 in the AA Dahlberg Prize fund. We have 103 active members (dues paid through 2007). A call for dues and members was made. It was discussed that dues notices cited in *Dental Anthropology* generally go unnoticed, so a direct mailing of a form will be sent each year in the early Fall.

## 6. Additional Announcements:

- a. Announcement of the passing of Daris R. Swindler, Professor Emeritus at the University of Washington, Seattle, and founding member of the Dental Anthropology Association.
- b. Debbie Guatelli-Steinberg and Chris Schmitt volunteered to be co-Chairs and co-Organizers of the 2009 DAA Symposium in honor of Daris Swindler at the Chicago, IL meetings.
- c. Richard Scott volunteered to Chair and Organize the DAA Symposium for the 2010 meetings to be held in Albuquerque, NM.
- d. Discussion ensued regarding the publication of dental anthropology papers and posters from the annual AAPA meetings; some form of notification and details of the DAA symposia also should be published in *Dental Anthropology*.

## 7. New Motions:

- a. Motion for extension of officers' terms: The motion for 3-year terms passed. The motivation was that the Association would achieve greater continuity with extended terms. The By-Laws will be updated to reflect these changes in the terms of office:

|                        |         |
|------------------------|---------|
| President              | 3 years |
| President-Elect        | 3 years |
| Secretary-Treasurer    | 4 years |
| Editor                 | 4 years |
| Executive Board Member | 3 years |

- b. Motion for a graduate student to sit on Executive Committee. This motion passed. The addition of a graduate student to the Committee will provide graduate student input into the Association's affairs.
- c. Motion for graduate student to be elected from the floor during the annual DAA meeting in 2009. This motion passed.

## 8. Report from the SAA on the state of dental anthropology in Contract Archaeology:

Heather Edgar, University of New Mexico, discussed the need for training in field methods related to the identification, recording, and excavation of human skeletal remains from archeological contexts (see news box on page 31).

*Submitted by:*  
Loren R. Lease  
DAA Secretary-Treasurer



## **Dental anthropology of newly excavated human remains: Concerns about data collection and consistency**

NAPGRA and other state and federal laws have changed the way bioarchaeological analyses are often performed. Most new excavations of human remains occur under the auspices of cultural resource management firms, not as academic investigations. Osteological and odontological analyses of newly excavated materials now occur under a wide variety of conditions. On occasion, human skeletal material is excavated and stored in museums to be available for future research. However, it is often the case that human remains are only excavated with planned reinterment scheduled in advance. In some cases, through prior agreement, excavation and reinterment must occur on the same day, sometimes without photography or drawings being permitted.

The field of contract archeology has made strides in dealing with the analysis of human remains under these new, highly variable conditions. Many companies now keep a qualified osteologist on staff full time. Others work with osteologists as contractors, or have affiliations with organizations, such as universities or museums, that can provide a group of skilled osteological workers with short notice. Field guides and databases help guide these workers as well as allow semi-skilled personnel to collect data in a relatively standardized way.

Unfortunately, the progress that has been made in adapting osteological analyses to present-day conditions has not been matched by progress related to dental analyses. Other than the description of minimum data collection presented by Buikstra and Ubelaker (1994), there is no "field guide" to dental anthropology. Further, dental anthropological training is not as consistent or consistently required as part of university training and biological anthropology or archaeology as is human osteology. The result is that dental analyses of human remains encountered in contemporary excavations are not conducted, or, when they are done, are often performed by well intentioned but inexperienced people.

The factors described above became apparent to me in discussions with participants in bioarchaeological sessions and symposia at the 2008 meetings of the Society for American Archaeology. Contract archeology principal investigators, osteologists and field crews are aware and concerned about the issues surrounding dental data collection and analysis. The opinion was expressed to me several times that a field guide was needed, but would be useless without the specific education necessary to use it. Several people mentioned to me that a series of national and regional workshops could be helpful and would be well attended.

I brought these concerns to the Dental Anthropology Association Business meeting, and was gratified to find the membership responsive, interested, and thoughtful. I am certainly open to ideas about how to proceed with attempts to improve the situation. As a first thought, maybe we could meet to devise a "dental anthropology standards for the 21st century." A guide such as this could be accompanied by a national workshop, which could also develop guidelines about how individuals or groups could host regional and local outreach workshops. At the moment, I'd like to propose that interested persons contact me at [osteolab@unm.edu](mailto:osteolab@unm.edu).

Heather J. H. Edgar  
University of New Mexico

### **Reference**

Buikstra JE, Ubelaker D, editors. 1994. Standards for data collection from human skeletal remains: proceedings of a seminar at the Field Museum of Natural History. Fayetteville, AR: Arkansas Archaeological Survey Press.



# RESEARCH COMPETITION in DENTAL ANTHROPOLOGY

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## THE ALBERT A. DAHLBERG PRIZE

The Albert A. Dahlberg Prize is awarded annually to the best student paper submitted to the *Dental Anthropology Association (DAA)*. Dr. Dahlberg was a professor at the University of Chicago, one of the founders of the International Dental Morphology Symposia, and among the first modern researchers to describe variations in dental morphology and to write cogently about these variations, their origins, and importance. The prize is endowed from the Albert A. Dahlberg Fund established through generous gifts by Mrs. Thelma Dahlberg and other members of the association.

Papers may be on any subject related to dental anthropology. The recipient of the Albert A. Dahlberg Student prize will receive a cash award of \$200.00, a one-year membership in the Dental Anthropology Association, and an invitation to publish the paper in *Dental Anthropology*, the journal of the association.

Students should submit three copies of their papers in English to the President of the *DAA* (*below*). Manuscripts must be received by January 31 of the year that the prize will be awarded, in this case January 31, 2009. The format must follow that of *Dental Anthropology*, which effectively the style of the *American Journal of Physical Anthropology*. The Style Guide to Authors also is available at the web site for the *AJPA* (<http://www.physanth.org>).

The manuscript should be accompanied by a letter from the student's supervisor indicating that the individual is the primary author of the research and the paper. Multiple authorship is acceptable, but the majority of the research and writing must be the obvious work of the student applying for the prize. Send enquiries and submissions to the President of the *DAA*:

Professor Brian E. Hemphill  
Department of Sociology and Anthropology  
9000 Stockdale Highway  
California State University, Bakersfield  
Bakersfield, California 93311-1099 U.S.A.  
*e-mail*: [bhemphill@csub.edu](mailto:bhemphill@csub.edu)

The *DAA* reserves the right to select more than one paper, in which case the prize money will be shared equally among the winners. They also reserve the right to not select a winner in a particular year.

The winner of the Albert A. Dahlberg Student Prize will be announced at the Annual Meeting of the *DAA*, which is held in conjunction with the annual meeting of the American Association of Physical Anthropologists. In 2009, the meeting will be held in Chicago, Illinois, April 1-4.

## 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       | Tables         |
| Abstract         | Figure Legends |
| Text             | Figures        |
| Literature Cited |                |

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. Submit three (3) copies—the original and two copies—to the Editor at the address above (or see Electronic Submission, below). 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 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 *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 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 21, Number 1, 2008

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