Reading the dental record : a dental anthropological approach to foodways, health and disease, and crafting in the pre-Columbian Caribbean

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Chapter 4 Approach and Methods

4.1 Approach

As outlined in Chapter 1, the approach used in this research is multi-disciplinary, in which multiple lines of evidence from different research disciplines are combined in order to answer the research questions. The reason for this approach is threefold. Firstly, as explained in Chapter 1, I am of the opinion that the closer integration of dental anthropological research in archaeology, and vice versa, is of importance to both disciplines. By closer integration, I mean that dental anthropologists (and osteologists in general) must cultivate a thorough understanding of the social and cultural context of the materials they study, or in other words analyze the material as if they were an archaeologist. Only when one understands the archaeological context of the materials, can sensible interpretations be made. Secondly, when dealing with broad research topics such as diet and subsistence practices, human health and disease, and craft activities no single source of evidence can be exhaustive, and using multiple lines of evidence enriches interpretations of the data. This is not to say, as is too often assumed, that a multi-disciplinary approach is by definition somehow better than a mono-disciplinary approach. But specifically in the Caribbean where little previous dental anthropological work has been done, comparison of results with results from other lines of investigation and the results of research from other regions is incredibly fruitful. Thirdly, as explained in Chapter 1, with regards to diet and subsistence practices, dental (macro)wear and pathology are highly appropriate for researching broad trends and/or changes over time. Very subtle differences between groups are detected only when samples sizes are large, which facilitates certain statistical analyses. In this case, other lines of evidence may provide contextual information to interpret subtle variations within the dataset. An example here is ethnographic information, which may provide examples of labour divisions or dietary differences between males and females that could lead to very slight differences in wear and pathology between the sexes. Another example is evidence from modern dentistry on dental erosion, which may provide the basis for an alternative interpretation of LSAMAT. The disciplines incorporated in this multi-disciplinary approach are dental anthropology, archaeology, osteology, ethnography, and ethnohistory; although to define them as separate entities in itself defies the holistic sentiment of multi-disciplinarity. The dataset is composed of dental anthropological and osteological quantifiable measurements (i.e., dental wear patterns, dental pathology, age, and sex) and structured according to the norms for these disciplines, but with the individual person as primary unit of analysis. Both archaeological (i.e., site, region, period, etc.) and osteological (i.e., sex, age, etc.) data form the basis for comparison of subsets within the main dataset; i.e., different sites from different periods are compared to each other, as are males and females within and between these sites. More importantly, archaeology provides appropriate research questions, by defining the cultural and geographical area of interest, and by defining fields of inquiry (for example craft activities) to which the study can contribute. Dentistry provides examples of clinical studies in living populations, meaning the precise aetiology of patterns of wear and pathology can be explored. Ethnography likewise offers the opportunity to observe living populations in similar sociocultural settings. Ethnohistory allows for insights into Caribbean Amerindian communities before their almost complete demise, albeit at a tumultuous period in their history.

4.2 Methods of Classifying

4.2.1 Age-at-death and biological sex estimation

Skeletal age-at-death and biological sex estimation of the individuals from the majority of the larger assemblages included in this study are based on analyses by physical anthropologist Dr. Darlene Weston. These sites are Anse à la Gourde, Chorro de Maíta, Kelbey's Ridge, Lavoutte, Maisabel, and Manzanilla (Valcárcel Rojas et al. 2011; Weston 2010, 2011a. 2011b, 2012; Weston and Schats 2010; Darlene Weston, personal communication 2010, 2011).

	Weston	Crespo Torres	Tacoma
Juvenile	<0	0–4	
	<1	5–9	
	1–4	10–14	
	5–9		
	10–14		
	15–17		
Adult	18+ (adult)	15–19	17–25
	18–25 (young)	20–24	25–35
	26–35 (young middle)	25–29	33–45
	36–45 (old middle)	30–34	45+
	46+ (mature)	35–39	
		40–44	
		45–49	
		50–54	
		55–59	
		60+	

Table 4.1 Age-at-death groups assigned by Weston, Crespo Torres, and Tacoma.

Weston based age-at-death estimation on anthroposcopic changes in the pubic symphyses (Katz and Suchey 1986; Todd 1921a, 1921b), the auricular surfaces of the os coxae (Lovejoy et al. 1985), and the sternal ends of the ribs (Işcan and Loth 1986a, 1986b). Other methods used include the degree of cranial suture closure (Meindl and Lovejoy 1985) and dental attrition (Brothwell 1981). Juvenile age estimations are based predominantly on the eruption sequence of the dentition

(Smith 1991), the lengths of the long bones (Sundick 1978; Ubelaker 1989), and the degree of epiphyseal fusion (Scheuer and Black 2000). Weston assigned both adult and juvenile skeletons to standard age groups. These age groups can be found in Table 4.1.

Weston's determination of biological sex of adult individuals was based on numerous anthroposcopic and metric methods; anthroposcopic features of the skull (Ascádi and Nemeskéri 1970; Buikstra and Ubelaker 1994) and pelvis (Buikstra and Ubelaker 1994; Phenice 1969), the measurements of numerous bones, including the clavicle (Jit and Singh 1966), femur (Pearson and Bell 1917/1919; Stewart 1979), humerus (Stewart 1979), and scapula (Iordanidis 1961).

Age and sex estimations of individuals from the remaining assemblages used in this study are based on previous published and unpublished physical anthropological studies.

For the site of Punta Macao, the results of an unpublished study by Tavarez María (2004) were consulted. Tavarez María based adult age-at-death estimations on the degree of cranial suture closure, epiphyseal fusion in the long bones, and degree of dental wear (Bass 1995). She did not assign standard age groups. Juvenile age estimations were based on mean diaphyseal length (Johnston 1962). Biological sex estimation in adults was based on anthroposcopic features of the skull and pelvis, general skeletal robustness and traces of muscle attachments and measurements of the femoral heads (Bass 1995).

For the sites of Esperanza, Hacienda Grande, La Mina, Punta Candalero, and Santa Elena (Toa Baja 2), a series of published and unpublished results from analyses by Edwin Crespo Torres were consulted (Crespo Torres 1991, 2000; Edwin Crespo Torres, personal communication 2011). Crespo Torres based determinations of adult skeletal age on dental wear, epiphyseal fusion of the long bones, and cranial suture closure (Meindl and Lovejoy 1985), and the auricular surfaces of the os coxae (Bedford et al. 1993; Lovejoy et al. 1985; Lovejoy et al. 1997). Crespo Torres assigned both adult and juvenile skeletons to standard age groups, using 5 year intervals (Table 4.1). Estimations of biological sex were based on methods outlined by Ubelaker (1989).

Age and sex estimations for the small number of individuals from Point de Caille are taken from the results of physical anthropological observations in Fabrizii-Reuer and Reuer (2005) Age-at-death was determined using methods outlined in Nemeskéri et al. (1960) and Ubelaker (1978). Estimation of adult biological sex followed Ubelaker (1978).

For Tutu results of osteological assessments by Sandford et al. (2002) were used. Sandford et al. based adult age estimations on anthroposcopic changes in the pubic symphyses (Brooks and Suchey 1990) and the auricular surfaces of the os coxae (Lovejoy et al. 1985). Cranial suture closure (Meindl and Lovejoy 1985) was used in only a small number of cases, as many of the crania were damaged during construction works at the site prior to excavation (Sandford et al. 2002). Standard age categories were not used, although most adults were placed in 10 year age ranges.

Age estimation in juveniles and sub-adults was based on the dental eruption sequence, following Bass (1987) and Ubelaker (1989), and the degree of epiphyseal fusion (Webb and Suchey 1985; Krogman and Işcan 1986; Ubelaker 1989).
Estimations of biological sex were based on anthroposcopic features of the skull and pelvis outlined in numerous studies (Bass 1987; Buikstra and Ubelaker 1994; Krogman and Işcan 1986; Phenice 1969; Ubelaker 1989; White 1991). Other morphometric indicators used by Sandford et al. (2002) for determination of biological sex include the diameter of the femur head, femoral shaft circumference, diameter of the humerus head, and height of the glenoid fossa.
For the sites of Canashito and Malmok the results of a study by physical anthropologist Jouke Tacoma were used (Versteeg et al. 1990). Tacoma based determinations of biological sex in adults on the guidelines set out by the Workshop of European anthropologists in (1980), with some adaptations regarding the hierarchical sequence of importance given to the individual characteristics used in sex determination (Versteeg et al. 1990:53–54). Determination of age-at-death in adults was based on the degree of dental wear (Brothwell 1981), as poor preservation of the material meant that anthroposcopic changes in the pubic symphyses and degree of cranial suture closure could not be used. Determination of age-at-death in children was based on the sequence of dental eruption. Tacoma assigned adult skeletons to standard age groups (Table 4.1).
For the most of the skeletal material housed at the Yale Peabody Museum, New Haven, Connecticut (including Camaguey, Cañas, Clarence town cave, Collores, Diale 1, Gordon Hill caves, Imperial lighthouse caves, Managas Saladero, María de la Cruz, Monserrate, Santa Elena [Toa Baja 2], Santa Isabel [Cayito], Yauco 1, and Wemyss Bight cave) age and sex estimations were derived from analyses done by Rose Drew (2009). Drew used White (2000) and Bass (1995) for assessment of age-at-death and biological sex, along with Buikstra and Ubelaker (1994). Age-at-death was determined according to the degree and completeness of long bone epiphyseal fusion, degree of cranial suture closure, presence and severity of age-related pathology including osteoarthritis, and dental wear.
For the other Aruban sites of Ceru Noka, Savaneta, Santa Cruz, and Tanki Flip, basic age and sex estimations were done by the author. Biological sex estimation was done following guidelines set out by Buikstra and Ubelaker (1994). Age-at-death was estimated using the degree of molar wear sequence set out by Brothwell (1981).
Similarly, for the sites of Argyle 2, Bellavista, Buccament West, Cacoq 2, La Caleta, Caliey, Dario Yune, Escape, Heywoods, Higuey (unknown site), Indian Creek, Juan Dolio, Manigat cave, St. Croix (unknown site), and St. Kitts (unknown site) biological sex and age-at-death estimation was performed by the author (Brothwell 1981; Buikstra and Ubelaker 1994). In the case of Heywoods, an extensive report of osteological analysis exists (Drewett 2000), however the material at the author's disposal could not be reliably linked to these data.
Table 4.2 gives a brief overview of sources used for age-at-death and biological sex

estimations in this study.

4.2.2 Dental wear

Dental wear is the wearing away and loss of the occlusal (and interproximal) surfaces of the tooth crowns. Dental wear is a normal process in mammals, which results from a combination of factors and affects individuals progressively throughout their lifetime. Dental wear in humans can be caused by alimentary or non-alimentary actions. Alimentary wear is caused by the abrasive properties of the food and inclusions in food, such as sand and grit, or small stone particles from grinding implements (Hinton 1981; Molnar 1972; Smith 1984). Non-alimentary wear can be caused by using the teeth as tools, bruxism (habitually grinding or clenching the teeth together), or by wearing oral ornamentation such as labrets (Alt and Pichler 1998; Santoni et al. 2006; Torres-Rouff 2003). Once dental tissues are lost due to wear, they are not replaced or repaired. As such, the observed degree and pattern of dental wear at any stage in an individual's life is the result of all wear on the teeth since their eruption and functional occlusion, and wear on the teeth may become erased by later wear.

In dental anthropology, which deals with all aspects of primate, fossil hominid, and modern human teeth, dental wear is categorized according to the agent causing the wear. Attrition is the result of tooth-on-tooth contact, which causes wear facets at the points where teeth come into contact. Abrasion is caused by contact with foreign materials, such as food, abrasives in food, and non-food objects put in the mouth.

Erosion is the chemical dissolution of the enamel, dentine, and cementum by acids in the mouth. In clinical dentistry, distinguishing between the different factors causing dental wear is sometimes necessary for therapeutic reasons. In archaeological material, however, this is generally not possible (Alt and Pichler 1998; Bell et al. 1998; Hillson 1996; Kaidonis 2008).

Dental wear in hominins is known to be strongly related to age: the older an individual becomes, the greater the amount of wear that will have accumulated on the teeth (Brothwell 1963; Hillson 1996; Miles 1963). For this reason the degree of wear on the dentition (particularly the molars) is commonly used in age estimation. However, the rate of dental wear in any human individual is also strongly related to the physical properties of the food (i.e., tough, unrefined, fibrous, versus soft, sticky, refined), contaminants in the food (i.e., sand, grit, stone particles), and food preparation techniques (i.e., grinding, baking, boiling) (Cucina and Tiesler 2003; Eshed et al. 2006; Jurmain 1990; Kaifu 1999; Larsen 1997; Macchiarelli 1989; Molleson and Jones 1991; Molnar 1972; Powell 1985; Rose and Ungar 1998; Sealy and van der Merwe 1988; Smith 1972, 1984; Walker and Erlandson 1986). As such, young individuals in a given population may exhibit extreme dental wear, or alternatively older individuals may exhibit very slight dental wear. Any comparison of the effects of food consistency and/or food preparation techniques on dental wear between populations must therefore take the relation between age-at-death and

Site	Sources	Methods
Anse à la Gourde Chorro de Maíta Kelbey's Ridge Lavoutte Maisabel Manzanilla	Valcárcel Rojas et al. 2011 Weston 2010, 2011a. 2011b Weston and Schats 2010 Weston pers. comm. 2010, 2011	Ascádi and Nemeskéri 1970; Brothwell 1981; Buikstra and Ubelaker 1994; Iordanidis 1961; Işcan and Loth 1986a, 1986b; Jit and Singh 1966; Katz and Suchey 1986; Lovejoy et al. 1985; Meindl and Lovejoy 1985; Pearson and Bell 1917/1919; Phenice 1969; Scheuer and Black 2000; Smith 1991; Stewart 1979; Sundick 1978; Todd 1921a, 1921b; Ubelaker 1989
Punta Macao	Tavarez María 2004	Bass 1995; Johnston 1962
Esperanza Hacienda Grande La Mina Punta Candalero Toa Baja 2	Crespo Torres 1991, 2000 Crespo Torres pers. comm. 2011	Bedford et al. 1993; Lovejoy et al. 1985; Lovejoy et al. 1997; Meindl and Lovejoy 1985; Ubelaker 1989
Point de Caille	Fabrizii-Reuer and Reuer 2005	Nemeskéri et al. 1960; Ubelaker 1978
Tutu	Sandford et al. 2002	Bass 1987; Brooks and Suchey 1990; Buikstra and Ubelaker 1994; Krogman and Işcan 1986; Lovejoy et al. 1985; Meindl and Lovejoy 1985; Phenice 1969; Ubelaker 1989; Webb and Suchey 1985; White 1991
Canashito Malmok	Versteeg et al. 1990	Brothwell 1981; Workshop of European anthropologists in (1980)
Camaguey Cañas Clarence town cave Collores Diale 1 Gordon Hill caves Imperial lighthouse caves Managas Saladero María de la Cruz Monserrate Santa Isabel Toa Baja Yauco 1 Wemyss Bight cave	Drew 2009	Bass (1995); Buikstra and Ubelaker (1994); White (2000)

Site	Sources	Methods
Argyle 2 Bellavista Buccament West Cacoq 2 La Caleta Caliey Ceru Noka Dario Yune Escape Heywoods Higuey Indian Creek Juan Dolio Manigat cave Savaneta Santa Cruz St. Croix St. Kitts Tanki Flip	Assessment by Mickleburgh	Buikstra and Ubelaker 1994; Brothwell 1981

Table 4.2 Sources and methods used for age-at-death and biological sex estimations.

degree of wear on the dentition into account (Chattah and Smith 2006; Hillson 2001; Scott 1979a, 1979b; Smith 1972; Watson et al. 2011). Differences in group age profiles are a significantly complicating factor, as well as the fact that absolute age-at-death (i.e., the precise age in years at which an individual died) is rarely known for archaeological specimens. Generally, estimations of age-at-death in adult skeletons are made based on a number of changes in the skeleton, such as on anthroposcopic changes in the pubic symphyses (Katz and Suchey 1986; Todd 1921a, 1921b), the auricular surfaces of the os coxae (Lovejoy et al. 1985), and the sternal ends of the ribs (Işcan and Loth 1986a, 1986b). Other methods used include the degree of cranial suture closure (Meindl and Lovejoy 1985) and degree of dental wear (Brothwell 1981). Estimation of age based on degree of dental wear is based on the assumption that rates of wear are constant throughout life, and generally the same within populations living in the same environment and with the same or similar foodways. Estimated ages are presented as a range (i.e., 18–25 years, 26–35 years, etc.), which means that the individuals in a certain age category may represent any combination of absolute ages within that category, and as such the use of such age estimation ranges can potentially bias comparisons between groups quite significantly. Therefore, comparisons of the rate of dental wear between individuals and groups must be based on factors that can be assessed independently of such estimated ranges of age-at-death, and independently of group age profiles (which may differ significantly). Similarly, the condition of preservation and completeness of the skeletal assemblage greatly affects intergroup comparisons of rate of wear, particularly in cases where the condition of the material is too poor to estimate age-at-death or where the dentitions are incomplete; often the case in archaeological assemblages (Hillson 2001, 2008b; Smith 1972)

To avoid age-at-death as a factor, it is possible to use intra-individual rates of wear, as opposed to group averages of degrees of wear (Smith 1972). In wear gradient analysis, the rate of wear is measured as the gradient between the degree of wear of the adjacent permanent molars within individuals: M1, M2, and M3. This is possible due to the fact that the eruption sequence is generally the same in all humans (Hillson 1996). The molars erupt at certain intervals in all humans – although the third molars show a greater variation in eruption age – which means that the difference between adjacent molars reflects the amount of wear accumulated in those 6 years (Hillson 1996; Smith 1972). Based on the assumption that the rate of wear remains constant during life, this difference will remain present regardless of age. The use of wear gradients based on differences of wear between adjacent molars represents an age independent method of comparing wear rates between individuals and groups (Benfer and Edwards 1991; Bernal et al. 2007; Chattah and Smith 2006; Scott 1979a; Scott and Turner 1988; Smith 1972; Watson et al. 2011). Since the method is age independent, differences are assumed to result from other factors which influence the rate of wear, such as food consistency, food preparation techniques, and (unintended) inclusions such as grit and sand.

Scoring dental wear

Various dental wear scoring techniques have been designed and used in the past. Research by Murphy (1959a, 1959b) on the pattern of dentine exposure in human dental wear led to an array of studies of the process of dental wear in humans and its variation across populations (e.g., Brothwell 1963; Miles 1963; Molnar 1971; Scott 1979a, 1979b; Smith 1984). A number of methods for scoring dental wear in past human populations were developed as a result. The most commonly used of these methods in archaeology today are Brothwell's (1981), Scott's (1979b), and Smith's (1984) (Hillson 1996).

Brothwell's (1981) scoring method was originally devised for early medieval British material, but has been widely used throughout the world (Hillson 1996). The method, which was devised as a simple and rapid aging technique, distinguishes four stages of molar wear that are each assigned an age category (17–25, 25–35, 35–45, and about 45). Differences between the age categories are based on the amount of dentine exposure, and variations are given for the pattern of molar dentine exposure in each group (Brothwell 1981).

Scott's (1979b) method involves the use of a quadrant system which visually divides the occlusal molar surfaces into four sections. Each quadrant is given a score based on the amount of enamel present in the quadrant, on a scale from 1–10. The sum of the scores for the four quadrants represents the score for the entire tooth, which ranges from 4–40. Scott uses the amount of enamel present in his quadrants, as opposed to the amount of exposed dentine (which is used in most other ordinal scoring methods), since he argues that the presence of enamel best reflects the "functional life of the tooth" (Scott 1979a:213). An advantage of Scott's method is the fact that it distinguishes four different categories of wear without dentine exposure. Methods that are based on the pattern of dentine exposure tend to assign only one or two classes to wear without exposed dentine patches (e.g., Molnar 1971; Smith 1984), meaning that subtle differences in the earliest stages of wear are partially obscured. Scott's method also allows for comparison of degree of wear between the different quadrants, for example in obliquely worn teeth (see also Watson 2008; Watson et al. 2011).

Smith's (1984) method represents one of the most frequently used dental wear scoring methods in investigations of archaeological material. Smith adapted the method from that the eight score method developed by Murphy (1959a, 1959b). Murphy's system was based on assemblages of Australian aboriginal dental material, and was adapted by Smith for use in Amerindian materials, as well as other human groups. Smith's scoring method distinguishes eight stages of wear that are each assigned a number: stage 1 represents no wear at all; stage 8 represents a tooth which has lost all enamel, except for perhaps a very slim rim around the edge of the tooth. Smith's method is an ordinal scoring system that allows rapid collection of data. The method is also comparable to other scoring methods (e.g., Molnar 1971).

The scoring methods devised by Brothwell (1981), Scott (1979b), and Smith (1984) are ordinal scoring systems, based on ordinal categories of wear. A number of researchers have suggested that ordinal scoring systems for the study of dental wear should not be used in comparisons between populations, and quantitative indices of wear should be used instead (Deter 2006, 2009; Lunt 1978; Walker 1978). The main points of critique stated by these researchers consist of issues of standardization and reproducibility. Since the differences between the scales of the ordinal ranking system are not measurable, it is felt that assigning scores is overly subjective, and as a result poorly standardized. As such, these methods may be influenced by inter-observer differences, leaving data collected by different researchers incomparable (Deter 2006; Molnar et al. 1983; Walker 1978; Walker et al. 1991).

The use of continuous measurements of dental wear is advocated to resolve these issues. The amount of dentine exposure is measured in relation to the total area of the occlusal surface and expressed as a percentage thereof. Today, this technique involves taking high resolution images of the occlusal surfaces, which are subsequently analyzed using a software package that counts the number of pixels in the area of exposed dentine and the total occlusal surface area in order to calculate the desired percentage (Deter 2006, 2009; Hillson 1996; Richards and Brown 1981; Walker 1978; Walker et al. 1991).

Despite the advantages of using quantitative indices for rates of dental wear, this method involves the collection of continuous measurements of the surface area of exposed dentine, which requires elaborate photography equipment and software to process images, and is far more time consuming overall than using ordinal scoring techniques to document dental wear. Furthermore, the borders between exposed dentine and enamel can be hard to define (Walker et al. 1991). Chipped teeth, particularly those with chipping along the occlusal rim, must be excluded from the analyses, since the loss of enamel distorts the ratio between the area of exposed dentine and the entire occlusal surface area. Furthermore, teeth that are very heavily worn, i.e., where most or all of the enamel has been lost, must be excluded, since the exposed dentine comprises (most of) the entire surface. As a result the difference values between adjacent teeth decrease as a tooth's wear increases in comparison to its highly worn neighbour. Teeth without exposed dentine must similarly be excluded, because only when there is some dentine exposure on both adjacent teeth can difference values be assessed (Deter 2006; Walker 1978).

For the current study, the rapid and effective collection of data in variable working conditions and variably preserved dental material was required. Based on previous experience with pre-Columbian Caribbean dental material (Mickleburgh 2007), the proportion of (very) heavily worn and chipped teeth was predicted to be very high. For these reasons, the use of an ordinal scoring method was deemed most appropriate. The risk of inter-observer differences due to the subjective nature of such methods is avoided, since all observations and recording of dental wear was performed by the author. In each assemblage, a random sample of 10% of the total number of individuals (or in assemblages comprising four or fewer individuals, the total assemblage) was re-analyzed at least a week after the initial analysis. The repeatability of observations was over 90% in all cases.

Molnar's scoring method

In this study, documentation of both the degree of wear and the angle and shape of occlusal surface wear follows a scoring method developed by Stephan Molnar (1971). Molnar devised a scoring method that not only records tooth crown loss and dentine exposure but also records other aspects such as the direction of wear of the occlusal surface, and occlusal surface shape. The direction of molar wear – the angle of the occlusal surface – is known to be related to the proportion of processed (e.g., ground, boiled) foods in the diet (Eshed et al. 2006; Smith 1984). Studies have shown that in agricultural populations, who consumed large amounts of refined plant foods, the molars tend to be worn more obliquely than in populations subsisting on tougher, more fibrous diets (such as some hunter-gatherers) (Chattah and Smith 2006; Deter 2006; Smith 1984; Watson 2008; Watson et al. 2011).The greater the reliance on refined (agricultural) foods, the greater the angle of molar wear was found to be (Smith 1984), however the angle of wear has also been found to be correlated with age (Deter 2006). A large proportion of soft, refined agricultural foods in the diet has also been suggested to be related to the formation of cupped molar surfaces, thought to result from small particles from grinding implements in the otherwise soft and pliable foods (Smith 1984).

Molnar developed different scoring scales for the different tooth classes (incisors and canines, premolars, and molars) as these teeth are subject to different patterns and processes of wear. The degree of crown loss and dentine exposure is therefore evaluated using a different scale for each of the three different types of teeth. The numerical code given for degree of crown loss and dentine exposure is the first digit in a three-digit code which is assigned to each individual tooth. The scale runs from 1–8, with 1 representing 'unworn' teeth and 8 representing 'roots functioning in the occlusal surface'. The second digit is used to describe the direction of the wear, i.e., natural form, horizontal, oblique, etc. The third digit is used to describe the occlusal surface shape. Molnar recognizes six different categories of occlusal surface shape, however I have added two categories (one half of surface rounded and other) because not all of the teeth in the present sample could be categorized using the six categories given by Molnar (Mickleburgh 2007).

The first digit in Molnar's scoring method, indicating the degree of wear, corresponds broadly to other evaluation methods which have commonly been used, such those devised by Brothwell (1981), Murphy (1959), and Smith (1984). The three-digit code which is assigned to each tooth is simple to use and well suited to use in databases. Table 4.3 presents the categories used in Molnar's dental wear scoring method (Molnar 1971).

Dental wear was assessed by the author both macroscopically and microscopically

Degree of dentine exposure			**Direction of wear**	**Occlusal surface form**
Incisors & Canines	**Premolars**	**Molars**		
1. Unworn	1. Unworn.	1. Unworn	1. Natural form	1. Natural form
2. Minimal wear facets	2. Wear facets, no dentine exposure	2. Wear facets, no dentine exposure	2. Oblique, buccal-lingual	2. Flat surface
3. Cusp pattern obliterated, possible small dentine patches.	3. Cusp pattern obliterated, small dentine patches	3. Cusp pattern obliterated, small dentine patches	3. Oblique, lingual-buccal	3. One-half of surface cupped
4. Dentine patch minimal	4. Two or more dentine patches, one of large size	4. Three or more small dentine patches	4. Oblique, mesial-distal	4. Entire surface cupped
5. Dentine patch extensive	5. Two or more dentine patches, possible slight secondary dentine	5. Three or more large dentine patches, secondary dentine no to slight	5. Oblique, distal-mesial	5. Notched
6. Secondary dentine moderate to extensive	6. Secondary dentine moderate to extensive	6. Secondary dentine moderate to extensive	6. Horizontal	6. Rounded
7. Crown enamel worn away on at least one side	7. Crown enamel worn away on at least one side	7. Crown enamel worn away on at least one side	7. Rounded, buccal-lingual	7. One-half of surface rounded*
8. Roots functioning in occlusal surface	8. Roots functioning in occlusal surface	8. Roots functioning in occlusal surface	8. Rounded, mesial-distal	8. Other*

Table 4.3 Dental wear evaluation method (Molnar 1971), with two added categories (*) (Mickleburgh 2007).

using a BMS 143 Trino Zoom stereo microscope with attached digital camera and a digital Dino Lite 413TZ polarizing microscope. A small number of teeth were studied for patterns of microwear using a Scanning Electron Microscope (SEM).

Principle axis analysis

As discussed above, food consistency and food preparation techniques strongly influence the abrasivity of foods and as such significantly affect occlusal dental wear. The degree of dental wear is also known to be strongly associated with age. Comparisons between the rates of dental wear in different groups must be based on factors that can be assessed independently of age (i.e., estimated ranges of age-at-death, and group age profiles which may differ significantly).

Using principle axis analysis, this study compares intra-individual rates of wear, measured using the difference in degree of wear between the adjacent permanent molars. This is possible due to the fact that these teeth erupt at approximately 6-year intervals in all humans, which means inter-individual and inter-group comparisons can be made (Bernal et al. 2007; Chattah and Smith 2006; Hillson 1996; Scott and Turner 1988; Smith 1972; Watson et al. 2011). Although some studies have used both adjacent M1–M2 and adjacent M2–M3 comparisons, this study uses only adjacent M1–M2 comparisons. The reason for this is that although the eruption timing for the first and second molars shows relatively little variation across human populations, the eruption of the third molars shows a much broader range, meaning that the interval between eruption of the M2 and M3 varies significantly more than the M1–M2 interval. Calculations of the rate of wear based on this interval will be affected by this broader range, and are therefore excluded from the comparisons made here (Bernal et al. 2007; Hillson 1996; Scott 1979b).

In dental wear studies, the principle (or major) axis analysis test is used to measure the rate of occlusal surface wear on the molars and identify whether there are differences in how fast molars wear between groups. Scott (1979a) demonstrated that the slope of the principle axis equation, which is an indicator of the relationship between the variables (i.e., the degree of wear on the adjacent molars), could be used as an indicator of the rate of wear. A steep principle axis slope (b) indicates a rapid rate of wear, whereas a gentle principle axis slope indicates a slow rate of wear.

The principle axis analysis test is a type of model II regression analysis, which measures the intensity of association between a pair of variables (Sokal and Rohlf 1981, 2012). Similar to model I regression analysis, the degree of association between the variables can be visually expressed as a trend line (the slope of the principle or major axis). Different than model I regression analysis, this test does not assume a causal relationship between the variables and does not assume that the x-axis is uniformly measured without error (Bernal et al. 2007; Chattah and Smith 2006; Scott 1979a; Scott 1979a; Sokal and Rohlf 1981, 2012). This makes the principle axis method more appropriate than model I regression analyses, as these are based on bivariate correlation measures, which measure to what degree two variables co-vary. This means that high correlation could be produced by both rapid and slow wear, since the correlation coefficient merely represents the whether the two variables vary together, and not whether the differences are great or small. Furthermore, the aim of defining rates of wear based on adjacent molar wear scores is not to predict one variable from the other. In model I regression analysis, where this is the case, assumptions are that that one variable is measured without error and is fixed, while the other varies (Scott 1979a; Sokal and Rohlf 1981, 2012). Both assumptions are not applicable in the case of wear scores of adjacent molars. The principle axis method is a parametric test, meaning that in a normal situation the variables should be continuous, or at least interval in nature for statistical treatment. However, research has shown that this method can be applied to the ordinal variables used in many dental wear scoring methods, since test have shown that the results are similar to those of analyses using continuous or interval data (Benfer and Edwards 1991; Scott 1979a, 1979b). Scott explains that "[f]or the principal axis analysis to perform most satisfactorily, however, the data should be either interval level or the best approximation which an ordinal scale can give" (1979a:213). He compared the use of the principle axis method using his own ordinal dental wear scoring technique (Scott 1979b), and that designed by Molnar (1971). He found that the use of the more elaborate method of dividing the molar occlusal surface into quadrants, which each are assigned a score for the degree of wear (Scott 1979b), produced more satisfactory results than the use of the eight category Molnar method (1971), due to its smaller confidence regions. He argued that the use of the latter method may lead to (greater) overlap in the confidence limits for the different groups in the comparison. Nonetheless, his comparison demonstrated that both methods produce similar and interesting results, and since Molnar's method is more rapid and efficient to use, and also documents other aspects of wear than the degree of occlusal crown loss, this study uses the eight category method devised by Molnar (1971) and applies principle axis analysis to the ordinal data it produces.

To compare wear rates, the principle axis equation was determined by plotting the wear score of M1 on the Y1 (x) axis, and M2 on the Y2 (y) axis (Sokal and Rohlf 1981:594–601). Principle axis equations and 95% confidence limits (CL) were calculated according to Sokal and Rohlf (1981:596–599) using Microsoft Excel. Since this method avoids the effects of age on the degree of dental wear, significant differences between the rate of wear (the principle axis slopes) of different sites can be taken to indicate differences in food consistency or food preparation techniques. Rapid rates of wear are usually associated with tough, abrasive diets (often hunter-gatherer or hunter-fisher diets). Slower rates of wear are more often associated with refined, less abrasive diets (processed agricultural produce) (Smith 1984; Larsen 1997; Lukacs 1996; Watson et al. 2011).

Dental chipping

Dental chipping is related to both alimentary and non-alimentary activities.

Tough, abrasive foods and the inclusion of contaminants such as sand and grit, and stone particles from grinding tools are thought to cause chipping and fracturing of dental enamel and dentine (Bonfiglioli et al. 2004; Budinoff 1991; Molleson and Jones 1991). Non-alimentary causes include cracking nuts (Mickleburgh 2007), cracking crab shells (Budinoff 1991), chewing seal hides and preparing sinew (Merbs 1968; Pedersen 1947), cracking bones (de Poncins 1941), retouching chert artefacts (Gould 1968), and holding objects between the teeth (Bonfiglioli et al. 2004; Merbs 1968; de Poncins 1941; Schour and Sarnat 1942). Both alimentary and non-alimentary dental chipping are, like other types of dental wear, related to age and affect the individual dental elements differently (Molnar 2008). Differences in degree and location of chipping on the dental elements and throughout the dentition between the sexes, or at different sites and occupation periods may also indicate (gender-based) divisions of labour or craft activities or differences in diet composition or food preparation techniques (Molnar 2008).

In this study, the presence and severity of dental chipping was documented according to a grading system developed by Bonfiglioli et al. (2004). They define a dental chip as "an ante mortem irregular crack, involving enamel or enamel and dentine, situated on the buccal, lingual or interproximal edge or crest of the tooth" (Bonfiglioli et al. 2004:449). Their grading system defines three categories of dental chipping, based on size and depth of the lesion in the enamel surface. Grade 1 comprises a "slight crack or fracture (0.5 mm), or larger but superficial enamel flake loss". Grade 2 is characterized as a "square irregular lesion (1 mm) with the enamel more deeply involved". Grade 3 is a "crack bigger than 1 mm involving enamel and dentine of a large, very irregular fracture that could destroy the tooth" (Bonfiglioli et al. 2004:449).

The location of the chip(s) on the tooth was also recorded, using the following categories defined by the author: buccal, lingual, interproximal mesial, interproximal distal, occlusal, occlusal buccal, occlusal lingual, occlusal interproximal mesial, occlusal interproximal distal.

Ante mortem dental chipping is distinguished from post mortem dental chipping based on the smoothing of the sharp edges of the break area as the tooth continues to wear after damage, and the lack of the characteristic colour difference between the crown surface and a freshly broken area (which is generally lighter in appearance) (Belcastro et al. 2007; Milner and Larsen 1991). Smoothing and colouration of the chip area were assessed both macroscopically and microscopically.

Dental notching

Occlusal surface and interproximal grooves or notches are caused by the repeated action of drawing an object across the surface of a tooth or teeth. Notching may be intentionally created, in which case the anterior teeth are usually affected and the overall appearance of the modification is symmetrical. Non-alimentary activities which cause notching/grooving of the teeth are crafting activities, such as basketry and cordage manufacture, but also habitual activities such as tooth picking or the clamping of an object (such as a needle, nail, pen, of pipe stem) between the teeth. The location, size, shape, direction, and microwear patterns of a notch or groove may indicate its cause (Alt and Pichler 1998; Brown and Molnar 1990; Larsen 1985; Milner and Larsen 1991; Pedersen 1949; Schulz 1977; Ubelaker et al. 1969; Wallace 1974).

Dental notching/grooving is assessed and documented in this study according to guidelines set out by Bonfiglioli et al. (2004). Although the presence of a dental notch is recorded in Molnar's scoring system, the severity of the notch is not. To distinguish between large and small notches, any notches observed were graded according to Bonfiglioli et al.'s system. They define a notch as "an indentation involving the tooth's incisal/occlusal edge, sometimes extending across all the surface. The depression is broader than it is deep and both the enamel and dentine are smooth and polished; it runs in a vestibulo-lingual direction and the orientation may be perpendicular or transverse to the mesial/distal axis of the tooth" (Bonfiglioli et al. 2004:449). Like dental chipping, notches are categorized according to a three-grade system. Grade 1 comprises a "slight superficial indentation affecting only the enamel". Grade 2 is characterized by a "wider and deeper indentation with polished dentine". Grade 3 is a "very deep and equally wide depression with heavily polished dentine" (Bonfiglioli et al. 2004:449).

The orientation of the notch(es) on the tooth is also recorded, using the following categories defined by the author: occlusal traversal, occlusal parallel, occlusal other, interproximal.

LSAMAT

Lingual surface attrition of the maxillary anterior teeth (LSAMAT), is a pattern of wear which exclusively affects the lingual surfaces of the upper front teeth (without corresponding wear on the lower front teeth), and has variably been described as the result of alimentary or non-alimentary activities (Comuzzie and Steele 1988; Hartnady and Rose 1991; Irish and Turner 1987, 1997; Larsen et al. 2002; Liu et al. 2010; Pechenkina et al. 2002; Robb et al. 1991; Turner and Machado 1983). Turner and Machado first documented the pattern in 1983. They describe LSAMAT as "the occurrence of progressive wearing with age of upper anterior lingual tooth surfaces without corresponding lingual or labial surface wear on any lower teeth. It is not the result of any manner of occlusal overbite, overjet, malocclusion, or other normal or abnormal anatomical consideration" (Turner and Machado 1983:126). LSAMAT was found to be correlated with a high rate of caries. Since the precise aetiology of this pattern of wear is currently unknown, it is posited here that in-depth analysis of the affected teeth, affected individuals, macrowear and microwear patterns, and association with other patterns of wear or dental pathology will benefit our understanding of LSAMAT.

The presence of LSAMAT (lingual surface attrition of the maxillary anterior teeth) was recorded but not evaluated for its severity. This type of dental wear involves the loss of enamel on the lingual surfaces of the maxillary anterior teeth. According to previous studies, teeth affected by LSAMAT have enamel that is worn away on the lingual surface, often leaving the dentine exposed, and the remaining structure tends to have a polished appearance. No corresponding wear is found on the mandibular teeth. These criteria were used here to assess the presence or absence of LSAMAT (Irish and Turner 1997; Robb et al. 1991; Turner and Machado 1983; Turner et al. 1991).

Other

In a relatively small number of cases, patterns of dental macrowear were observed which in the opinion of the author could not be adequately documented using only the dental wear scoring method (Molnar 1971), and the methods for documenting other categories of wear described above. An example is a small number of cases in which individuals showed wear on the lingual surfaces of the mandibular anterior teeth, which in all aspects apart from its location appeared identical to patterns of wear identified here as LSAMAT. Another example is a small number of individuals in which odd buccal wear facets were found on the anterior teeth, perhaps indicating the use of labrets or other facial jewellery around the mouth, or non-alimentary uses of the teeth.

In all such cases the patterns of wear on each individual tooth were described at length in the remarks section on the standard form, and were photographed from a number of different angles.

4.2.3 Dental pathology

Dental pathology was assessed both macroscopically and microscopically using a BMS 143 Trino Zoom stereo microscope with attached digital camera and a digital Dino Lite 413TZ polarizing microscope.

Caries

High caries rates have been attributed to a carbohydrate rich diet. The global increase in caries rates over time has been attributed to sociopolitical and cultural developments associated with the adoption of agriculture (Cohen and Armelagos 1984; Klatsky and Klatell 1943; Larsen 1997; Larsen et al. 1991; Littleton and Fröhlich 1993; Meiklejohn et al. 1984; Milner 1984; Turner 1979). The rate of caries in any population is related to the type of diet consumed. Dental anthropological research has shown that the 'hunter-gatherer/forager' diet is associated with a very low caries percentage, while 'mixed economies' and 'agricultural economies' have much higher caries rates (Koca et al. 2006; Larsen et al. 1991; Powell 1985; Scott and Turner 1988; Turner 1979; see Figure 2.1). Furthermore, the location of caries on the individual dental elements and throughout the dentition is known to be related to diet composition and food preparation techniques (Caglar et al. 2007; Larsen 1988; Lingström et al. 2000; Powell 1985; Vodanovic et al. 2005).

However, caries rates are also known to be related to age, with rates increasing as people grow older. This means that comparison of caries prevalence rates between populations of differing age profiles is problematic: differences in caries rates derived from the simple tooth count and individual count methods could (at least in part) result from differing age profiles. For this reason, this potential source of variation must be controlled for in order to assess foodways based on caries prevalence. Furthermore, the individual dental elements are differentially susceptible to caries, with molars more frequently affected than incisors and canines and premolars, and premolars in turn more frequently affected than incisors and canines (Hillson 2001, 2008b; Wasterlain et al. 2009). For this reason, differential preservation of individual dental elements between populations may render them incomparable with regards to simple caries prevalence. Both AMTL and PMTL affect the separate tooth classes differently. In order to assess differences in caries rates as a result of the consumption of cariogenic foods, age, differential susceptibility, and differential preservation must be taken into account. Comparisons must be made between the same age groups and tooth classes in each population (Hillson 2001, 2008b; Wasterlain et al. 2009).

In this study, dental caries were evaluated macroscopically, and were diagnosed only when a distinct cavity had formed with evidence of demineralization (as opposed to for example fracturing or intentional modification), affecting at least the enamel, and often also the dentine, and in the case of cement-enamel junction caries or root surface clearly affecting the cement (Hillson 1996:269). The location and type of carious lesion was also documented according to Hillson (2001, 2008b). He distinguishes between pit and fissure caries, smooth surface caries, and root surface caries. Here, this distinction is followed in the following categories defined by the author: occlusal (pit/fissure), buccal (smooth surface), lingual (smooth surface), interproximal mesial (smooth surface), interproximal distal (smooth surface), cervix buccal (root surface), cervix lingual (root surface), cervix interproximal mesial (root surface), cervix interproximal distal (root surface).

Caries prevalence was calculated using both the tooth count method [(total number of carious teeth / total number of teeth] x 100 and the individual count method [(number of individuals affected by caries / total number of individuals) x 100] (Lukacs and Thompson 2008). Furthermore, population caries rates were assessed and compared by age group, tooth class, and sex.

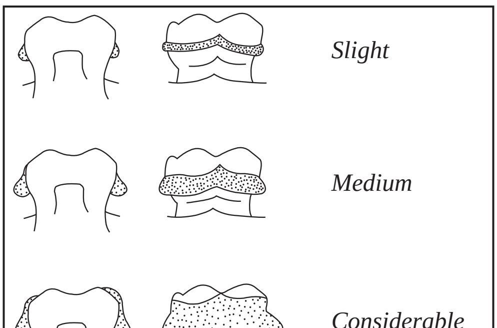

Figure 4.1 Degree of calculus formation. After Brothwell (1981).

Dental calculus

The formation of calculus is heavily influenced by oral hygiene and diet composition. Nonetheless, its formation is a complicated process, involving numerous biological and environmental factors, such as age, sex, fertility, hormonal imbalances, hereditary predisposition, salivary constitution, mineral composition of drinking water, and fluid intake (Hillson 1996; Lieverse 1999).

In this study, the presence and degree of dental calculus formation was documented per individual tooth according to the three basic categories (slight, medium, considerable) as distinguished by Brothwell (1981:155; Figure 4.1).

Periapical abscesses

Periapical abscesses tend to be associated with exposure of the pulp chamber, allowing bacteria and the toxins they produce to enter and travel through the pulp chamber and cause infections once trapped in the chamber or at the root apex. Exposure of the pulp chamber is caused either by a carious lesion, severe dental wear, or trauma. This can trigger an inflammatory response within the tooth, leaving a void in the bone filled with pus. As pressure continues to build the pus breaks through the thin layer of outer alveolar bone (usually on the buccal surface). In archaeological specimens, in which periapical abscesses are commonly found, this results in a clearly exposed cavity in the alveolar bone, with signs of periapical inflammation and bone resorption (Hillson 1996, 2008b).

Care was taken to distinguish signs of periapical bone inflammation and resorption when a periapical cavity was observed. Furthermore, the edges of the cavity area were assessed macroscopically, and where possible, microscopically, for the presence of sharp fracture edges to establish whether the cavity could have been the result of post mortem damage to the material and breakage of the thin cortical bone surface (Hillson 1996, 2008b).

Periapical lesions were recorded on a presence absence basis. The location of each individual periapical lesion was recorded using the dental notation of the associated tooth and whether the lesion was positioned on the buccal or lingual side of the alveolar bone (Buikstra and Ubelaker 1994).

AMTL

Ante mortem tooth loss (AMTL) is often treated as a dental disease, although in actual fact it may result from disease processes such as caries and periodontal disease, or from infections related to pulp exposure due to extreme dental wear or traumatic injury. Dental anthropological research has shown that, while various conditions may cause AMTL, and all human populations suffer from AMTL, there is a marked tendency for higher AMTL rates in populations that consume refined, carbohydrate rich diets (Larsen 1995; Larsen 1997; Scott and Turner 1988). As such, high rates of AMTL may be related to the consumption of a refined, carbohydrate rich diet. However, AMTL is also very strongly related to age, with rates increasing as people grow older. Similar to the case of dental caries, when comparing AMTL rates between groups, the effects of age, differential preservation of individual dental elements, and differential susceptibility of individual dental elements to ante mortem loss must be taken into account (Hillson 2001, 2008b; Wasterlain et

al. 2009). Differences observed between populations could (at least in part) result from differing age profiles and differentially preserved/affected dental elements. For this reason, these potential sources of variation must be controlled for.
AMTL was assessed firstly on the basis of the presence or absence of each individual dental element, and subsequently recorded when the alveolar bone showed clear signs of resorption at the location of a particular dental element (Hillson 1996). AMTL was only recorded when resorption was so extensive that the alveolus could no longer accommodate a tooth at that location. Caution was applied when recording AMTL of the third molars, since congenital absence may give the appearance of AMTL if there appears to be enough space in the alveolar arch to accommodate the third molars. The rate of AMTL is calculated as follows: number of AMTL / total number of observed tooth positions (= observed teeth + unerupted teeth + AMTL + PMTL) = AMTL rate. Furthermore, population AMTL rates were assessed and compared by age group, tooth class, and sex.

Hypercementosis

Hypercementosis is the accumulation of excessive cementum on the roots of the teeth, due to heavy dental wear, malocclusion, periodontal inflammation, Paget's disease, or trauma (Corruccini et al. 1987; Hillson 1996, 2008b). The tooth root becomes enlarged as layers of cementum are deposited, and hypercementosis can be recognized by the bulbous appearance of the roots, particularly the apices. Hypercementosis may be associated with periapical granulomas, since the increasing thickness of cementum may cause pressure and inflammation of the periodontal tissues. Loss of bone around the root apices may also result from hypercementosis, without inflammatory response (Hillson 2008b). Hypercementosis was recorded on a presence/absence basis, and potentially associated dental pathology (e.g., periapical lesions) or excessive dental wear were noted.

4.2.4 Dental defects

Enamel hypoplasia

Enamel hypoplasia are disruptions in the formation of the dental enamel. Hypoplasia are known to be related to a wide range of physiological and psychological conditions, although they are most often attributed to systemic disorders and physiological stress including particularly metabolic disorders and nutritional deficiency (but also infectious disease, and physical and emotional trauma), occurring during the formation of the tooth. Research has shown that (linear) enamel hypoplasia are useful indicators of changes in nutritional status over extended periods of time, such as the transition from hunter-gatherer subsistence to agriculture. As such, the rate of (linear) enamel hypoplasia in a population is used to indicate physiological condition, and extremely specialized or monotonous diets or infectious disease is often inferred. Depending on the location of the enamel defect in the dentition and on the tooth crown(s), the age at which the defect oc-

curred may be estimated. The dental elements most frequently affected by LEH are the upper canines (Goodman and Rose 1991; Hillson 1996, 2008b; King et al. 2005; Smith et al. 1984).
Enamel hypoplasia were recorded on a presence/absence basis per dental element. Affected elements were photographed. A distinction was made between furrow-type defects, pit-type defects, and plane-type defects as defined by Hillson (1996:166–167). In this classification, furrow-type defects are defined as furrow-shaped defects in the enamel which follow the perikymata, and are generally arranged in a linear formation around the tooth crown (also Linear Enamel Hypoplasia or LEH). Pit-type defects are pits in the enamel surface of varying size and shape. Pits may be distributed across the surface of the crown or arranged in bands around the crown sides, sometimes following LEH. Plane-type defects are large exposed areas of damaged enamel marked with brown striae.

Discolouration and Opacities

Discolouration of the enamel may result from intrinsic or extrinsic factors, such as deficiencies during mineralization (Hillson 1996) or smoking (Davies 1963).
Discolouration and opacities were recorded on a presence/absence basis per individual dentition. If extrinsic staining was present, the colour was noted and photographs were taken. When the coloured or opaque area appeared mottled white or yellow/brown, and pitting was present, a tentative diagnosis of dental fluorosis was made (Hillson 1996).

4.3 Methods of Documenting

4.3.1 Dental notation

There are numerous labelling systems, also known as dental notations, which have been used in the past and remain in use today to identify the individual teeth in the human dentition. The system used here was introduced by the Fédération Dentaire Internationale (FDI) or World Dental Federation in 1971. This system is used for reasons of its widespread international recognition and its convenient numerical notation which is well suited to use in databases (FDI 1971). The FDI system divides the dentition into quadrants and numbers the teeth in each quadrant in mesial-distal direction (for both the adult and deciduous dentition). However, the FDI system also numbers the quadrants in clockwise direction (as seen from a frontal perspective) from 1 to 4, starting with the upper right quadrant. The combination of both numbers produces a unique two-digit code for each individual tooth. To distinguish between the adult and the deciduous dentition the quadrants in the deciduous dentition are numbered from 5 to 8. The FDI two-digit system is depicted in Figure 4.2.

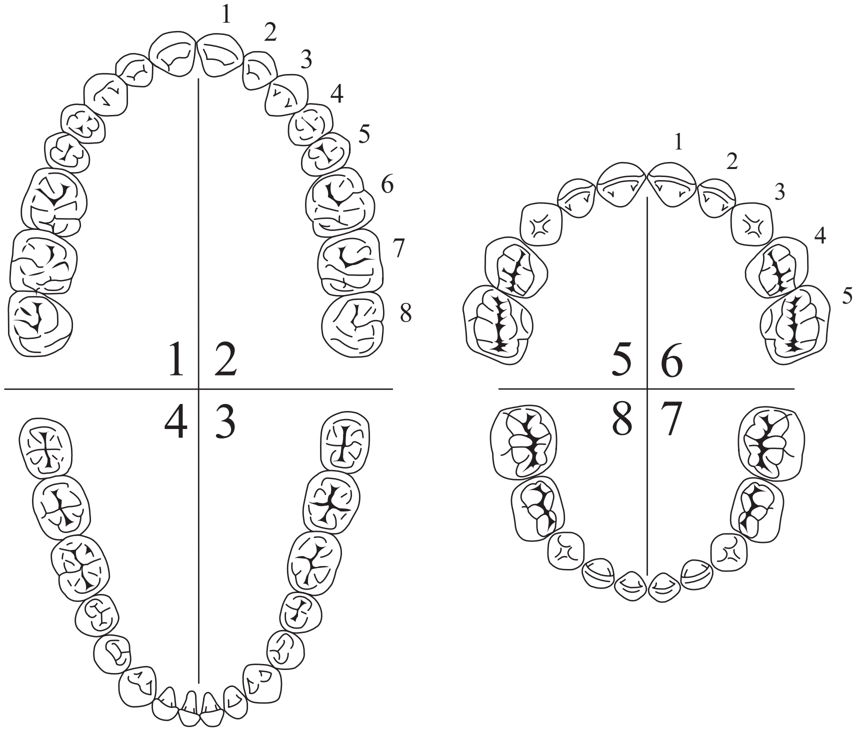

Figure 4.2 FDI notation.

4.3.2 Standard documentation forms

Dental wear and pathology were documented on a standard form, developed by the author. The form consists of depictions of the complete set of dental elements in buccal, occlusal, and lingual view. These depictions can be coloured in according to the presence or absence of (parts of) the dental elements as a result of dental wear or ante mortem tooth loss. In the same manner dental chipping, dental notching, LSAMAT, and caries are drawn in the figures.

The individual dental elements are numbered according to the Fédération Dentaire Internationale (FDI) or World Dental Federation (1971).

The three-digit dental wear scores (Molnar 1971), and both chipping and notching grades for each individual tooth (Bonfiglioli et al. 2004) are scored in a table at the bottom of the sheet. The age and sex of the individual (where known), along with total number of teeth, number of caries, number of chipped teeth, number of notched teeth, the presence of alveolar bone resorption and hypercementosis, are recorded above the table. Above the table on the right hand side of the sheet, there is room for remarks and additional observations.

4.3.3 Photography

Due to time constraints, high quality photographs for illustration purposes were taken only of certain dental elements chosen for their typical or exceptional dental wear. General overview photographs were taken of each dentition for later reference. The photographs were taken using a BMS 143 stereo microscope with a BMS tCam 1,3 Mpixel USB 2.0 CMOS digital camera attached, with a digital Dino Lite 413TZ polarizing microscope, and with an Olympus Pen E-PL1 with macro lens. In some cases the digital photos were altered using Adobe Photoshop, in order to make the image clearer. In all cases the alterations concerned increasing/decreasing the contrast or the brightness of the pictures.

4.3.4 Scanning Electron Microscopy (SEM)

For the purpose of this study, ten teeth have been subjected to SEM analysis, in order investigate patterns of wear indicating non-alimentary use of the teeth, for example for crafting activities. Here, only qualitative analysis was used, as the results of the analyses are further contextualized using information on dental macrowear and the vegetable component of the diet based on ancient starch grain analysis.
The individuals were selected for SEM analysis on the basis of a number of different characteristics. Firstly, six teeth from two individuals from the Site of Punta Macao present either exceptional or anomalous patterns of anterior dental wear, warranting further investigation as to the cause(s) of the patterns of dental wear. Secondly, two individuals from the site of Anse à la Gourde were selected for the LSAMAT present in their upper anterior teeth. A further juvenile individual from Spring Bay 1c was selected on the basis of lingual wear of the central incisors that resembles LSAMAT. As discussed in more detail in Chapter 6 and Chapter 7, this pattern of wear is enigmatic, in the sense that its precise cause is debatable, and as there appears to be a great deal of variety present in the cases identified as LSAMAT worldwide. Samples were selected here based on the author's distinction two types of LSAMAT, which the author proposes may have different aetiologies. Of the two main types of LSAMAT distinguished by the author, two teeth for each type were selected for SEM analysis.

4.3.5 Database

A database was developed using Microsoft Access to assess and organize the data, alongside the standard form. The database essentially records the same information as the dental wear form, while allowing statistical analysis of the data.
The database consists of two linked tables, each containing a different level of information about the individual feature numbers. The first table Teeth Feature contains the general information per feature number (individual person): sex, age, presence of LSAMAT, presence of dental chipping, presence of dental notching, presence of caries, remarks, and the site name.
The second table Teeth Element is linked to each individual feature in Teeth Feature, and contains the data on each separate dental element belonging to that individual. Starting with the element number, this table lists the element's status (present, deciduous present, not

present, not gradable, cast, un-erupted), degree of wear, direction of wear, occlusal surface shape, presence of LSAMAT, degree of chipping, location of the chip, whether the chip area is worn smooth, presence of caries, location of caries, presence of notching, location of notching, and remarks. By using two linked tables in such a way, different 'layers' of information are created, which can then be analyzed in a straightforward manner. This means that statistical analysis of inter- and intra-individual dentitions can be performed separately or combined with ease.

4.4 Methods of Analysis

4.4.1 Sampling and representativeness

In working with archaeological remains we must be aware of the great variety in types of data, issues of preservation, and differing excavation strategies, which affect the composition of the dataset we have at hand. Firstly, archaeological remains recovered at a single site, area, or region can always be said to be merely a selection of the entire material culture remains of a past population, as perishable materials will be absent or underrepresented, and human activities such as construction work, and natural processes of erosion will affect the amount and type of materials recovered at any location. Excavation strategy and research questions will likewise affect the size and composition of the dataset, as archaeological sites are rarely entirely excavated, and depending on the size and location of excavation units, certain materials and sociocultural contexts will be overrepresented and others will be underrepresented. This can bring up certain issues regarding the use of statistical methods to analyze data, as many statistical methods, used for example to compare different categories and results, rely on the assumption that the sample was randomly selected. In this context, random selection refers specifically to the fact that each individual case in the population has an equal chance of being selected for the sample. It is generally accepted that in this way the chances of the sample accurately reflecting the character of the population are as great as possible. But of course, random selection, just as any other method of selection, never guarantees that the sample accurately reflects the population from which it is derived. Even working from the assumption that a randomly selected sample accurately reflects the population (which is what we must inevitably do), an archaeologist rarely has this kind of control over his dataset and sampling strategies. Nonetheless, statistical tests are an important tool in the analysis of (bio)archaeological data, and although they must be used with due caution and regard for the underlying assumptions of each method, their importance in a field with rapidly increasing datasets and sample sizes is paramount (Drennan 2010; Madrigal 2012; Sokal and Rohlf 1981, 2012).

The skeletal assemblages used in this study are often referred to as a 'population', where in actual fact of course they are samples of the prehistoric living population which were not randomly selected. A large number of factors influence the

composition and size of an assemblage, including mortuary practices, (differential) preservation, and excavation techniques and strategy (e.g., which parts of the burial area(s) were excavated). Treatment of the dead naturally affects the composition of the skeletal assemblage, especially in cases were certain individuals are excluded from burial (i.e., the remains are disposed of in another way), or are buried at a different location. This may affect the ratio of the sexes and different age groups, in which case it may be very clear that burial practices have affected the composition of the skeletal assemblage. Alternatively, burial or other forms of disposal of the corpse may not be related to biological sex or age, but to social status or rank, sometimes making it more difficult to determine whether burial practices have affected the composition of the assemblage. The composition of a skeletal assemblage may also be affected after excavation of the material, as over the years parts of the skeletons are sent for (destructive) analyses. In this study, earlier and simultaneous isotope studies dealing with the geographical origins of individual persons, and in a few cases radiocarbon and AMS dating, meant that dental elements were sampled for most individuals (Booden et al. 2008; Laffoon 2012; Laffoon and De Vos 2011; Laffoon and Hoogland 2010, 2011; Laffoon et al. 2012). Where possible, these dental samples were studied prior to these analyses.
To reiterate, the relation between a skeletal assemblage and the living population at a site at any given time is highly complex, and is influenced by a large number of factors which cannot be compensated for in the statistical methods used to organize and interpret the dataset. In this study, a large amount of comparative analyses are done (e.g., independent and dependant samples t-test, Mann-Whitney U test, and Kruskal-Wallis test), in order to define potential differences between groups of individuals of different ages and sex, and of course between individuals from different sites and periods. In comparing the male and female adult population at a particular site, for example, ideally the numbers of individuals in each group would be similar. This makes the application of certain statistical methods simpler and more appropriate, as many statistical tests rely on similar sizes of the groups to be compared (along with other characteristics such as similar variances and normal distribution) in order to produce reliable results. In practice this is often not the case, for example at the site of Tutu, St. Thomas, USVI, where the adult population consists of six males and fourteen females. Let's assume that the living adult population during the period of occupation at Tutu most likely consisted of approximately 50% males and 50% females, or thereabout. At Tutu, the excavated burial population consisted of over twice as many females than males. The cause of this apparent disparity is hard to determine. Perhaps only a portion of the burial population was excavated? In actual fact Tutu represents one of the most completely excavated sites in the Caribbean, as the construction of a shopping mall at the location of the site meant that large scale open excavation was necessary to salvage the cultural remains at the site (Righter 2002). Burial practices could of course have entailed the interment of most males at a different location on or near the site, or perhaps most males were disposed of in a different manner upon

death. Alternatively, males could have partaken in far riskier activities (i.e., hunting or warfare), which meant they more frequently died away from the settlement and were disposed of elsewhere. Yet another possibility is that the methods used to determine biological sex at the site were inappropriate for this particular population, i.e., that sexual dimorphism was not strongly (or differently) expressed in the skeletal frame, or that based on the criteria used the female sex was favoured. We can continue along these lines, exploring the possible reasons for the disparity in numbers of males and females at Tutu, however, no definitive answer can be obtained, and consequently we have no way of correcting for the cause of this disparity in our choice of statistical methods to analyse potential sex based differences. So it appears we are stuck with a male population which is represented by only six individuals, as opposed to a female population which is represented by fourteen individuals. This brings us to the subjects of representativeness and bias. In this context, representativeness refers to the accuracy with which the sample reflects the population from which it is derived, or in other words, how representative the sample is for the population as a whole. As mentioned above, even when there is control over the sampling procedure, a sample may or may not accurately represent the population. A stringent sampling procedure, particularly when random sampling is used, increases the chances of the sample accurately reflecting the population, but does not guarantee it (Drennan 2010). When the sampling procedure is beyond the researcher's control, as is the case at Tutu, where both sexes are not equally represented, there is simply no way of knowing how representative the sample may be of the whole population. This is equally true for the six males, and the fourteen females. Both groups may or may not accurately represent the population they are derived from (i.e., the males population versus the females population), regardless of the number of individuals in each sample.[5]

4.4.2 Statistical methods

The data produced in this study are both parametric and non-parametric, meaning that both parametric statistical tests and non-parametric tests are used. The statistics computer package IBM SPSS (Statistical Package for the Social Sciences) Statistics 20.0.0 was used to run all statistical analyses. The level of significance for all tests used here is $p \leq 0.05$.

Parametric tests

Parametric tests are used when the data to be analysed is assumed to be normally distributed, or distributed according to another common distribution such as the t distribution (t-tests), and when the variables are continuous or interval. Parametric tests used here consist of basic descriptive statistics, independent samples t-tests, and analyses of variance (Drennan 2010; Madrigal 2012; Sokal and Rohlf 1981, 2012).

5 Generally speaking, as the sample size increases, the chance of accurate representation of the population increases, although again this depends heavily on the sampling strategy.

Independent samples t-test (a.k.a. unpaired samples t-test)
The independent samples t-test tests the hypothesis that two groups are derived from the same population. The t-test assumes that the data are normally distributed, and compares the means of both groups in order to test the hypothesis. The more similar the means are, the greater the chance that the null hypothesis (no significant difference) is accepted. Other assumptions of the t-test are that the samples were collected using random sampling (meaning each individual in the population has an equal chance of being selected), and that there is independence of variates (meaning that all samples are independent from each other, and that sampling of one does not affect the others) (Drennan 2010; Madrigal 2012; Sokal and Rohlf 1981, 2012).

Dependent samples t-test (a.k.a. paired samples t-test)
The dependent samples t-test tests the hypothesis that matched pairs show no significant difference in their means. In other words, it compares the means of two variables for a single group. The more similar the means are, the greater the chance that the null hypothesis is accepted. The t-test assumes that the data are normally distributed. Other assumptions of the t-test are that observations for each pair should be made under the same conditions (Drennan 2010; Madrigal 2012; Sokal and Rohlf 1981, 2012).

Non-parametric tests
Non-parametric tests are used when the data are not normally distributed and/or include ordinal variables. They may also be more appropriate when sample sizes are small (under 20) regardless of the normal distribution of the data. In this study, the Mann-Whitney U test is used to test whether one of two independent samples differ significantly with regards to an ordinal variable. The Kruskal-Wallis non-parametric test for independent samples is used to determine whether two or more groups differ significantly with regards to a particular ordinal variable. The chi-square test, which is based on the $\chi 2$ distribution, is used to test the independence of two variables represented by frequencies (Drennan 2010; Madrigal 2012; Sokal and Rohlf, 1981, 2012).

Mann-Whitney U test
The Mann-Whitney U test is the non-parametric alternative to the independent samples t-test. It assesses whether one of two samples of independent observations tends to have larger values than the other. This test's assumptions are that the observations in both groups are independent of each other, the distributions are equal in both groups, and the observed variables are ordinal. The data need not be normally distributed. This test can also be used for continuous variables when the requirement of normal distribution for the independent samples t-test is not met (Drennan 2010; Madrigal 2012; Sokal and Rohlf, 1981, 2012).

Kruskal-Wallis test
The Kruskal-Wallis test is similar to the parametric one-way ANOVA test, in the sense that it tests the hypothesis that two or more groups were obtained from the same population, however as the Kruskal-Wallis test is designed to analyze non-parametric data, it does so by ranking the data and comparing ranks as opposed to parameters (such as the mean). The Kruskal-Wallis test does not assume the data are normally distributed, making it appropriate for the analysis of ordinal data. Where it is possible to use parametric analyses, a one-way ANOVA is preferred over the Kruskal-Wallis test, as parametric tests are more powerful than non-parametric tests and can detect more subtle differences between samples (Drennan 2010; Madrigal 2012; Sokal and Rohlf, 1981, 2012).

Chi-square tests
The chi-square test for goodness of fit tests whether observed frequencies differ significantly from expected frequencies as defined for the null hypothesis. The chi-square test for goodness of fit assumes that the samples were randomly selected, and the observed frequencies must be at least five. If this is not the case, a Fisher's exact test is more appropriate (Drennan 2010; Madrigal 2012; Sokal and Rohlf, 1981, 2012).
The chi-square test for independence of variables tests whether the observed frequencies differ significantly from expected frequencies as defined for the null hypothesis. As such, it is the same as the chi-square test for goodness of fit in its null hypothesis and in its computation. Essentially, the null hypothesis is reversed from stating the two variables are not significantly different, to the two variables are independent. In practice this means the test, which makes use of the $\chi 2$ distribution, now focusses on the $\chi 2$ value for $p= 0.95$ as opposed to $p= 0.05$ (Drennan 2010; Madrigal 2012; Sokal and Rohlf, 1981, 2012).