Dave Grant 03/01/2009

LITERATURE REVIEW

Clinical

Archaeological dental literature is extensive and diverse but, in some ways, the most informed experts and practitioners are dentists who deal with teeth, tooth pain and malocclusions in living populations on a daily basis. This would seem like a logical place to start. Most of the relevant literature deals with modern hunter gatherer populations like Greenlandic and Arctic Eskimos and Australian Aborigines. Lavelle (1970) compared gradients of attrition on the M1,M2 and M3's in 19th century British, Anglo-Saxon, Mongoloid, West African and Australian Aboriginal populations and found the British subjects had the least amount of wear of all the studied groups and attributed this to their softer diet. Molnar et. al. (1975) did a study using a group of Australian Aborigine children who had at least four dental casts taken from ages 6 to 18 years of age. They chose 64 out of a possible 1717 individuals to analyze with a roughly equal sex ratio. They found that the males lost considerably more molar cusp height, 2.0mm for males vs. 1.6mm for females, when measured from the top of the cusp to the lowest point in the central groove. They attributed the increased enamel loss to diet, specifically to the males spending more time in the bush and eating "bush tucker" while the females stayed in town and ate a more refined diet of cooked foods. Tomenchuk and

Mayhall (1979) took casts from 85 modern Eskimo individuals and measured the cusp heights to the depth of the central groove to access age. They found that they could accurately predict age 97% of the time. Richards (1985) used two Australian Aboriginal groups that were neighbors but occupied very different ecological zones. One prehistoric group of 74 had a lake and riverine ecological zone with hunting and fishing being the main subsistence activities. The second group of 38 was more traditional with hunting but more plant gathering activities. He found that posterior tooth wear was more dominant in the first group and anterior wear was more prominent tin the second group. The resultant differences in tooth wear and facial morphology was much more complicated and not attributable to a simple cause and effect relationship involving tooth attrition. Young's (1998) essay entreating dentists in Australia to pay more attention to the functional aspects of worn dentition made some interesting points. One was that teeth do not function in a "centric" occlusion, but that wear actually increases the ability of teeth to act as tools because the jaws have a wider range of motion and can function more efficiently as crushing shearing masticatory tools. Second was that siliceous and phytolithic foods cause wear patterns that reveal diet and some behaviors. Kaidonis et. al. (1998) ran an experiment using extracted teeth and devising a machine that calibrated tooth wear as measured in lost weight, using different loads and different lubricants. They found, not surprisingly, that heavier loading caused heavier wear but that lubrication decreased the damage, specifically if saliva at a PH of 7 was used. They also

found that lubricated wear was modest up until a load of 9.95 them increased dramatically under all observed conditions. They also observed that there were two phases to dental wear, A "running in" phase where wear is rapid and the equivalent of about two years of tooth attrition then slows down to a "steady state wear"

Dental Scoring and Aging

Dental researchers have attempted to quantify the occulusal surface wear seen on prehistoric teeth since Broca (1879) devised a four point wear scale. Leigh (1925, 1928) and Campbell (1939) used a modified version of Broca's system. Leigh attached 3 age ranges to the stages of wear, a 2 was 20-30 years old, a 3 was 30-40 years old and a 4 + was 40 and up. He comments in 1928 that the wear seen on the skulls from San Francisco bay was more severe by far than that seen in Santa Barbara or the Central Valley. He attributes the differences to grit in the diet and chewing of tobacco. Of the 104 skulls he observes from San Francisco bay he attributes 76(73%) of them to the 40+ age group and of those 76% have exposed pulp chambers, significantly higher than any other California sample.

Murphy (1959) used a large collection (he does not define the number) of Australian Aborigine skulls to delineate and define occulusal surface wear. He defines graphically 6, 7 or 8 stages of wear for each tooth in the dentition separating maxillary from mandibular as distinctly different wear entities. His precise descriptions lay the

groundwork for all future scoring systems. Brothwell (1963) devised a scoring system with four major age groups, 17-25, 25-35, 35-45 and over 45. Miles (1962) based his system on the ages that molars erupt, which is under strict genetic control. The first molar erupts at about 6 years of age, the second at about 12 years old and the third from 18 to 25. By the time the 2nd molar erupts the first has 6 years of wear, and by the time the third erupts the first molar has 12 years of wear and the second molar has 6 years of wear. Wear stages can be plotted given a reasonably large group of sub adults to establish a baseline. He introduced the term "Functional age of Teeth" based on the wear patterns established on the molars by the age of 20 to 25. He introduced the concept of seriating a population of skulls to establish youngest and oldest and then gradually put the rest into age sequence, based on wear. Molnar (1972) used Murphy's 8 stage wear sequence and added two elements;1) a full front profile of each tooth type showing the volume of the tooth lost by attrition, and 2) introduced an additional component of describing the form of wear. Form being not just attrition which is one element of a three number sequence. One digit describes attrition, one digit describes the slope of wear mesial/distal or buccal/lingual or horizontal and the third digit speaks to the unusual form, rounded, notched, cupped or flat. This was the first attempt to define wear form, not just attrition but the shape of the wear itself. This seems to have been prompted by one of the three populations that he was studying, the one from Stockton California

comprising 39 individuals dating to 2,000 to 3,000 BP. This group had wear patterns that gave him a template for the patterning he proposed with his trinomial system.

Scott (1979) refined the molar section of scoring by dividing the molars into four quadrants, each scored from 1 to10 for attrition and dentine exposure, so each molar could have a possible wear score from 4 to 40. Smith (1984) refined Molnar's system by dropping the tooth profiles, eliminating the form of wear chart and trinomial system for form scoring. She refined Murphy's system by displaying it vertically rather than horizontally. She used an eight level system for occulusal wear. Lovejoy (1985) used a modified ten point scale modified and adapted from Murphy. He had nine wear grades in the maxilla and ten in the mandible. Lovejoy seriated the 332 dentitions using a large population of sub-adults (132) to establish the baseline. He excluded those adults with ante mortem tooth loss, seriated the rest of the adults and then reinserted the ones with AMTL and re-seriated the population. He used three other aging methods pubic symphysis, femoral head cranial sutures to form an aggregate aging conclusion. He used Miles' 6, 6.5, 7 attrition scale to seriate and assumed wear increased with the loss of one molar row and even faster with the loss of both molar rows. He concluded that "wear is regular and symmetrical and reflects increasing chronological age in the population." He used three other aging methods pubic symphysis, femoral head, cranial sutures along with dental wear to form an aggregate aging conclusion. His conclusion is that all the wear seen is the result of mastication with grit in the food and he found no cultural patterned

wear. Walker, Dean and Shapiro (1991) using a Channel Islands population of 97 individuals from a somewhat disturbed context and in some cases were just isolated mandibles. They used as many independent aging criteria as they had available and concluded that aging, using teeth alone, was an acceptable method of aging a population if no other skeletal elements are available and that seriation of a population was extremely important for accuracy. Bedford et. al. (1993) used 55 individuals from a known age at death population from the Grant collection. They used 3 examiners and four skeletal aging methods, auricular surface, pubic symphysis, radiographs of the proximal femur and the clavicle. They concluded that aggregation of the four methods was best and outperformed any individual criteria by itself. They also felt that seriation of each element within the population was important. They used a single year age estimate of, for instance, 33 not implying that that individual actually was 33 but was older than one they aged at 31 or 32 and younger than one they aged at 34 or 35. Drier (1994) performed an interesting aging study on 143 prehistoric Arikara using a method he devised by grinding 20 fresh molar teeth for equal time intervals and precisely record the changes found in the emergence of dentine and the removal of cusps and other features. He scores each quadrant from 1-25 using precise definitions and measurements for a total possible score of 100 for each molar. He is attempting to attain greater precision and better statistical information to analyze. The severe limitation imposed by his methodology is that all tooth wear is presumed to be flat on the occulusal surface. He

independently aged the population using pubis and cranial sutures and found that by using regression analysis his scoring system was at least as accurate. He found no differences between upper and lower quadrants or between right and left arcades.

Miles revisited his scoring system in (2001) with the intent of fine tuning his criteria. He postulated that every population would have a small population of truly old people. He maintains that the upper age limits are set by preconceived ideas that prehistoric populations never had people live beyond 50, 60 or 65 depending upon the preconceived ideas of the researcher. He revisits the same population he seriated and aged back in 1963 with an upper age limit of 60-65 with the idea of expanding the age categories. He added 35 individuals that had been excavated recently from that same population. He states that in most populations the group under 40, age is over estimated and the population 50 and over it is underestimated. His teaching collection was 16 individuals from the Spitalfields collection, of known sex and age, aged between 80 and 92. He suggests that 1) there are most likely always going to be a few individuals who live to truly old ages, 2) “Those that have lost over half of their dentition are likely to be over 60 years of age.” 3) Criteria for advanced age are resorbation of the alveolar process leading to a thin horseshoe shaped mandible, and similar changes in the palate, 4) Seriation is critical and population specific. He ends up by adding 22 individuals to the over 70 category and 4 of those over 75.

All of these scoring systems operate under the assumptions that wear is constant, progressive and age related. That as people age occulusal wear increases and that the wear seen in sub adults reliably continues at roughly the same rate throughout life. Using a dental wear scoring system in conjunction with as many other skeletal age indicators as are available is preferable to any one system by itself but two researchers, Lovejoy (1985) and Miles (2001) at least, suggest that tooth wear, properly seriated and with a large group of sub adults can provide the most reliable single indicator of age. Given the fact that teeth, sometimes, are the tissues with the highest survival rate in burial context, a reliable age related dental wear scoring system could prove very useful.

Form and Shape of Dental Wear

Grooves. All scoring systems are occulusal oriented; the view is from above the tooth looking down. Molnar (1972) was the only researcher who attempted to quantify the form of wear as well as the shape of the wear. His form and shape of wear system is a trinomial approach with one digit denoting wear, one denoting the angle of wear and the last one describing the shape of the wear. It was reprinted in Hillson (1996) but has not been it used by any other researchers to date. It is notably lacking in Buikstra and Ubelaker's Standards (1994) whose forms or derivatives thereof are used widely by osteological researchers. Non-masticatory behaviors using the teeth as tools or as a third hand are widely reported in research journals and ethnographic accounts but presently, no

widely accepted scoring system is used to record them. . Forms of patterned wear are roughly broken down into four forms, grooves, rounding, cupping and/or scoops and slants. The literature for each is reviewed as a distinct category.

Grooves are found in the teeth of both fossil humans and modern humans. Fossil humans display occulusal wear and interproximal grooves. No occulusal grooves have been reported in fossil humans. Frayer and Russell (1987) report that fourteen teeth in ten individuals from Krapina Neanderthals (10/39 individuals) display interproximal grooves. There was one groove on a lower I2, the rest were on premolars and molars both maxillary and mandibular. They had a trough like appearance with striations although no SEM micrographs were taken. There were 14/176 teeth involved. They attribute the grooving to toothpicking to either remove impacted food or as a palliative measure to relieve irritation or inflammation of the gum tissue. They also mention other Neanderthal sites with grooved teeth. The Vlasic site had 3/37 individuals with interproximal grooves, Ofnet had 1/15 and Skateholm had 1/49. Fox and Frayer (1997) used the same population of Neanderthals found non-dietary scratches on the labial surface of the anterior teeth and offered two possible scenarios, one was pulling/holding abrasive materials between the clenched teeth and the other was holding meat in the teeth and cutting off a chunk with a flake tool which occasionally missed, cut too deep and left labial scratches on the anterior teeth. Of the teeth examined 50% of the deciduous teeth showed labial scratches and 85% of the permanent teeth also displayed them.

Lozano (2008) uses a population of 20 Homo Heidelbergensis individuals and examined their teeth by SEM for non-masticatory wear. He found dietary striations, vestibular striations on the labial surface of the anterior teeth, enamel flakes from pressure crushing, vestibular-lingual striations across the dentin surface and enamel rims that suggest back and forth movement across the surface of the tooth. They conclude that 15/20 were right handed, that the vestibular-striations and enamel flakes indicate that they were either cutting meat, pulling leather or vegetable fibers across the occulusal surfaces of the anterior teeth and using their teeth as tools.

Modern humans also exhibit interproximal grooving. Lukas and Pastor (1988) found 8/52 individuals with interproximal grooves and anterior tooth abrasion. The 8 individuals had 17 interproximal grooves and one of the eight had 6 grooves alone. They ascribed the grooves to two etiologies, 10 of the grooves were due to habitual probing and 7 grooves were attributed to therapeutic probing. They suggest that the individuals ascribed to habitual probing were possibly doing it for compulsive and/or cultural reasons. The other explanation is that 3 individuals with 7 grooves were doing it for therapeutic reasons, to relieve gingival inflammation. One individual with 6 grooves was probably occupationally induced with all grooves on premolar or molar teeth. Lessa and Guidon (2002) describe one very ancient burial from a small rock shelter in Brazil dating to 11,060 BP with an interproximal groove on the distal side of the left first maxillary molar. The groove is 4mm in width and 3.5mm tall and situated on the neck just below

the CEJ. This individual was female and aged 35-45 years old with extensive dental wear and a cupped pattern on the three remaining molars. They also mention two other burials from Brazil with similar grooves, one dating to 4200 BP and the other to 1330BP. They suggest the instrument of causation may have been a cactus thorn or a wooden probe but the groove could have been palliative in nature but the adjacent second molar was lost antemortem.

Occulusal grooves have been reported in many populations worldwide. Cybulski (1974) found thin linear grooves on the occulusal surfaces of mandibular anterior teeth on 5/154 individuals. These five individuals were all female and the wear was concentrated on the canines. The population was coastal British Columbian natives from the Prince Rupert region dating from 4,000 BP to 250 BP. He attributed the thin grooves to basket making and weaving. For two neighboring tribes, the Eyak and the Tlingit there is ethnographic notations of women holding and splitting spruce roots with their teeth for basketry. He also found 12 individuals with flattened and polished wear on the labial side of the mandibular anterior teeth which he attributed to labret wear, which was ethnographically documented. Schultz (1977) found ten individuals, both male and female, from Stone Lake, near Stockton in the Central Valley of California with grooves. He does not state how large the original population was. He describes the ten individuals with occulusal and interproximal grooves and attributes the grooving to fiber processing to make nets and lines to support a fishing economy. There were five males and five

females aged from 18 to 50 years old and dated from 2100 BP to 800 BP. There were 26 grooves found involving 32/187 teeth. All teeth affected by grooves were anterior canines or incisors. The direction of all grooves was buccal/lingual except for one occulusal groove that ran across both canines and one incisor. Three individuals had grooves across the occulusal surface of the incisors; the other seven had interproximal grooves. Owsley and Bellande (1982) describe 3/120 individuals from a Cherokee population situated in Georgia. Two individuals have interproximal grooves which they attribute to chemical or acid erosion and one individual, aged 15-19 years old, had matching notches on an upper and lower central incisors which they attribute to an unknown cultural activity. Larsen (1985) found 5 of 171 individuals with occulusal grooves from a population inhabiting the Great Basin of the Western United States. His study population comprised individuals from 38 different sites ranging from 1 to 36individuals. Only 3 of the 38 sites had more than 10 individuals, the rest were either single or small burial populations. A total of 16 teeth from 5 individuals displayed grooved occulusal surfaces and all were male. Direction of the grooves was mesial/distal and varied in width from 0.4 to 2.0mm. He ascribes the grooved dentitions to fiber processing in the making of nets, fowling bags and other hunting gear and possibly sinew preparation as noted in Greenlandic Eskimos. Littleton and Frohlich (1993) analyzed 12 different skeletal samples from 4 different subsistence patterns in the Arabian Gulf. They mention that the two earliest populations from Bahrain dating from 4300BP to 3800BP in

one sample with 69 adults and 2750 BP to 2500 BP in a second sample with 98 adults showed “distinct grooving” on the anterior teeth due to use of the teeth as tools and possible fiber cordage processing to manufacture baskets and rope. They also mention that ALL adults are affected from both sexes. Unfortunately they do no include any concrete data, numbers, measurements or pictures. Fong and Brittan (1994) in a site report from Pleasanton Ca report 6/45 individuals with interproximal and occulusal grooves. One individual is ascribed to toothpicking because the groove is on the molar afflicted with caries and an abscess. The other 5 individuals had grooves on the anterior teeth. There is no description or numbers given but from the two pictures shown they appear to be interproximal and located above the CEJ. Macchiarelli (1989) working with a population from Oman dating to 7,000-6,000 BP numbering 49 individuals, noted that the wear was extreme in all teeth present and at a very young age. The average age at death was in the mid 20’s. They also noted that the upper incisors were rounded, and that the premolars in both upper and lower positions were also rounded. There were no grooves seen but mentioned that there were interproximal grooves “ episodically observed on the buccal aspect of lower molars” Unfortunately there is no quantification of any of these observations. Minozzi et. al. (2003) writes about a single adult male burial from Libia that dates to 7800 BP. The skeleton was in poor condition and the 7 teeth present were loose. All teeth were premolars, canines and incisors. All teeth showed grooves ranging from 1.6 to 3.3mm and ran in a buccal/lingual direction. They

attribute the grooves to fiber processing in the manufacture of baskets, nets and mats. They ran an experimental study using a medieval tooth abraded with *Typfa latifola* plant leaves which were used in local basketry construction. They found that the machine they constructed produced "microscopically appreciable modifications of the tooth surface" (p 226). It took 245 hours of abrasion to produce that effect. They suggest two possible causation scenarios for the grooves found 1) dragging thin fibers or sinews across the teeth or holding the materials like pincers and 2) using teeth as a third hand to hold material while manipulating fibers or stings. The pictures shown do not seem to exhibit the depth of the grooves on the surface of the teeth but rather on the enamel rim surrounding the exposed dentin. The occulusal wear appears essentially flat with elevated enamel rims which are cut by the grooves. Turner and Anderson (2003) recorded one individual from a burial population of 70 individuals from medieval Kent. The anterior dentition looks like it was carved with an Exacto- knife with sharp concave abrasions on the occulusal and interproximal surfaces of the anterior dentition. The individual was male and aged 30-40 years old. They attribute the extremely unusual abrasion pattern to a carpenter's occupational habit of holding nails in his teeth. Erdal (2007) found 5 of 36 individuals from a tenth century population in Turkey with mesiodistal grooves in the dentitions. The 5 women had 9 incisors affected with grooves. The grooves were thin, from .9mm to 1.7mm in width. Grooves were distributed with 6/9 maxillary and 3/9 on the mandibular incisors. He found that in that same region of Turkey wool is being spun

by hand and run across the teeth to soften the fibers by wetting them with saliva. He suggests that this is the causation of the grooves seen in the archaeological specimens. Since grooves were only found in females he suggests that this is a sex based division of labor.

Anterior Rounding. Rounding of the anterior teeth, especially on the mandibular arch has not been recorded heavily in archaeological populations. Brace (1967) explores the size of teeth in fossil and modern humans and mentions, however briefly, that Neanderthals have heavily rounded incisors that were being used as extra hands and non masticatory activities. Hinton (1981) is the only other researcher, besides Molnar who has mentioned rounded anterior incisors. He surveys two hunter-gatherer populations, Australian Aborigines and Eskimos, and compares them to two agricultural populations, Ohio farmers and South Western Pueblo peoples for forms of dental wear. He uses a modified Molnar wear scale and uses a number coding to designate flat, cupped and rounded wear. He has two grades in cupped wear and only one in rounded wear. His populations are substantial, Eskimos number 195, Australians 151, Ohio farmers 129 and South Western Pueblo farmers 248. He found both rounding and cupping in all populations but substantially different. Eskimos and Australians had rounded anterior teeth 30% of the time when wear levels reached 5-8 on a modified Molnar wear scale. Cupped wear was present but, depending on the tooth only from 2-10%. Pueblo farmers

had cupped wear in 20-50% of the anterior teeth with minor percentages of rounded wear. The Ohio farmers were a mixed subsistence group, with both hunting and fishing but also relying on Maize cultivation. They fell in between but still had up to 40% cupped wear with a very minor incidence of rounded wear. He uses histograms and graphs but no statistical analysis stating that his sample and scoring method made for double ordinal scoring. He could not assume that the steps from 1-8 were equal in grade, and also could not assume that the wear between different tooth classes was comparable so decided not to do statistics.

Scoops/Cupping. Cupping as defined by Hinton (1981) is as a rim of enamel surrounding a deep trough in the dentin. Causation is not explored but since dentin is softer than enamel it is logical that whatever abrasive forces are operating on the dental surface will wear away the dentin faster than the enamel resulting in a pit or trough in the dentin. As he explains above, Southwestern Pueblo farmers exhibit up to 50% of their teeth with cupped forms on the upper canine and 30% on the lower canine. Scooping as seen in Northern California populations differs from cupping in that, normally, the mesial and distal enamel rims are worn away to form a deep scoop with rims on the buccal and lingual sides of the tooth. This form is seen most often on the lower molars.

Slants. Slants are created on mandibular molars as the lingual cusp of the maxillary molar engages with the buccal cusp of the mandibular molar in normal masticatory behavior creating an abrasion zone which wears away the lingual side of the maxillary molar and the buccal side of the mandibular molar. As the wear plane progresses the slope of the mandibular molar becomes steeper towards the buccal side and its complimentary maxillary molar becomes steeper towards the lingual side. The slopes can become extreme depending upon the abrasiveness of the diet and the grit that may be included in the food as well as being caused by non masticatory activities involving the teeth. Many investigators have described the wear seen on the molar array of M1, M2 and M3 as helicoidal meaning the mandibular M1 shows a slight buccal angle, the M2 is approximate flat or slightly buccal and the M3 is tilted slightly lingually forming a three tooth arcade shaped some what like a helix, therefore the term Helicoidal. Campbell (1925) first described it as a "compound plane" and Ackerman (1953) described it as a helix and from that the term helicoidal has evolved. It is used more of a descriptive term than implying causation although Smith (1986) states that it increases with attrition. She used a sample of 667 adult dentitions and found that almost 50% of the dentitions had a maxilla wider than the mandible; the other 50% had a mandible wider than the maxilla at the M3. This last finding was unexpected; she had suggested that almost all of the sample would have a maxilla wider than the mandible for a "normal" helicoidal curve. In a previous study Smith (1984) compared a hunter gatherer

population of 298 individuals with an agricultural population of 365 individuals. She found that the slope of wear on the M1's for the agriculturalists had a steeper wear plane by about 10 degrees than the hunter gatherer population. She suggested that grit added in the grinding process of the crops was responsible. Roydhouse and Simonsen (1975) disagree, they feel that helicoidal occlusion is not caused by food abrasion but by tooth-to-tooth contact. They used a population of 300 skulls from British Columbia and compared their occlusion and the subsequent wear with other populations of Maoris, Australian Aborigines, Huron Indians and Egyptians. They do not state how many dentitions from each site were examined in comparison. They attribute the wear seen in the contrasting populations to grit ingested with the food in the Australian, Maori and Egyptians with detailed food analysis but feel that since the wear seen is similar to that seen in the B.C. there must be another explanation available. They cite ethnographic accounts that the B.C. natives were very careful to wash the grit off of and out of their food and they always had plenty of water available; that grit in the food could not be the causative agent in the B.C. population. They feel that the side to side movement of the jaws is the prime determining factor in creating the form of wear seen in their population. Whether the slanted wear is created or just accelerated by grit in the food the undeniable fact is that slanted wear on mandibular and maxillary molars does exist in substantial numbers and is nor being adequately reported and recorded.

California Dental Wear. There were only three articles found that report patterned wear in California populations. Molnar's (1972) seminal study made a major point of stating that the wear seen was more severe that that seen in the other two populations from Arizona and Mexico and prompted him to devise a trinomial system to describe the form of wear seen. Schultz (1977) describes 10 individuals from Stone Lake in a fishing economy with occulusal grooves on the anterior teeth. Fong and Brittan (1994) describe 6/45 individuals recovered from a Pleasanton Ca. site dated form 1100 BP to 700 BP. He reports both interproximal and occulusal grooves in the 6 individuals, 4 females and 2 males. One male had definite interproximal grooves on molars associated with caries and an abscess. The other 5 individuals had primarily interproximal grooves on the anterior mandibular incisors but no quantification was given as to the number and location of the grooves. This was a site report and not a research paper.

Causation and Biocultural Context: Opportunistic Omnivores

Humans are opportunistic consumers; we are capable, physiologically, of eating anything that won't poison us or kill us first. Modern hunter gatherers are observed to be constantly sampling as they move across the landscape, a leaf here, a larva or bug there, anything edible is looked upon favorably. Modern cultures have imposed models of what is edible and acceptable within a societal framework. We do not eat bugs or larva, we do

not eat foods, especially meats, that are uncooked. We try to eat three healthy meals a day, spaced adequately. All of these are societal constructs that did not apply to prehistoric hunter gatherer cultures. In order to look at what might be causing this excess dental wear we will look at four categories, 1) food remains from the coprolite evidence, 2) other materials that may have abraded the teeth, 3) foods they ate from the archaeological evidence, 4) ethnographic accounts from other hunter gatherer cultures, 5) written diaries, letters and reports from the early explorers observing Californian Native Americans at contact

The wear seen in California Native Americans is more severe than any other known.

Jurmain (1990) states that

> "the extreme degree of attrition, in fact, among the most severe for any population yet described."

in describing ALA329, one of the major sites for this study. No other site reports or research

paper have presented data to contradict this statement. So what is causing this wear?

There is no doubt that grit in the food is a major component for the attrition seen in these populations. Teaford and Lytle (1996) demonstrated, using SEM technology, quite clearly that eating just one corn muffin with each meal for a week produced measurable wear 30 times more severe than a normal modern diet. The key factor is that the corn used to make the muffin was ground on a sandstone mortar. Except for the far

southwestern corner of California they did not have corn as part of the food palate but they did have acorns. Typically, in the literature, Kroeber (1925), acorns are indicated as the baseline caloric component supplemented by seasonal gatherings of seeds, berries, greens, birds, fish, shellfish sea mammals as well as large and small land mammals. Acorns do not survive archaeologically but the evidence for the usage of acorns is the plethora of bedrock and portable mortars that are found throughout California. Acorns are very high in calories and healthy fats. Bainbridge (1986) states that each 100 grams of acorns, whether raw, dried or as flour has about 500 calories. The fat content is 38-50%, carbohydrates are 13-18% and there are 16 essential amino acids present. Grant (2004, unpublished) demonstrated that given the typical yield of a white oak or a coast oak in an average year, a village of 30 individuals could supply 1,000 calories per day per individual with the yield of 75 white oaks or 61 coast oaks. This is based on an assumed dietary need for 3,000 calories per day. If the grit that came with acorn processing is presumed to cause the dental wear seen, is it logical to assume that the 200 grams of acorn meal a day, cooked as mush which would need little or no mastication could cause such devastating wear? If there was grit in the acorn meal it would require mastication to produce attrition. If the acorn meal cakes were cooked in the ashes of a fire that would supply additional grit, but again, would need little mastication.

Other potential causations factors have to be looked at. Leigh (1928) noted in a California population that small mammals are eaten whole, either raw or roasted. He also

mentions that older edentulous individuals had their own personal small mortars and used them to crush whole small mammals that younger individuals supplied for them. Other potentially abrasive elements that were pounded and ground were salmon bones, rabbit vertebrae, deer bones and dried meat. Coprolites are a unique source of information. A coprolite is dried and fossilized feces that represents from 1 to 6 feeding events. Hartnardy and Rose (1991) from coprolite evidence, note the whole bones of small mammals were frequently found. Australian ethnographers note that chunks of rabbit are eaten whole, bones, viscera and fur all together. Reinhard et. al. (2007) analyzed coprolites from dry caves in Colorado and Texas. They found that small mammal bones were found in 58/100 coprolites from Colorado and a startling 97/100 in the coprolites from Texas. They found that all parts of the animals were consumed including the viscera which were evidenced by the spores of fungal organisms harbored in the intestines of the animal. In the Colorado sample only 3/96 elements were charred possibly indicating either light cooking or no cooking which was reinforced by the presence of rabbit fur in the coprolites. This suggests that small mammals were heavily exploited as a fundamental resource in prehistoric populations. Danielson and Reinhard (1998) researching a population from the Lower Pecos region in Texas found from 10 to 20% of the weight of a dry coprolite was phytoliths from Yucca and Agave plants that were roasted in earth ovens. Interestingly enough they found no dietary grit in the coprolites.

So what exactly are phytoliths? Phytoliths are small grains of silica that are found in almost all plants. The plants produce phytoliths by extruding dissolved silica into the intracellular structures where the water containing the silica evaporates leaving a sharp silica particle. It is thought that phytoliths also help the plant by making the leaves less palatable to discourage grazing animals and provide rigidity to some plants like rice, which would not be able to stand erect without the phytoliths in its leaves and stalk. Phytoliths come in a wide variety of shapes and sizes and they are all harder than dental enamel. As the plant is eaten, chewed and ingested the phytoliths abrade the occulusal surface of the teeth.

Other plants that have extensive phytoliths are basketry materials. California Native Americans did not manufacture pottery. They had a better technology. They made baskets, dozens and dozens of different kinds and forms of baskets. Baskets are lightweight, portable, do not break and can be made watertight and waterproof. They can be made into different forms to perform different tasks, from seedbeaters to winnowing trays to storage baskets. Native Californians made baskets for every conceivable storage event, with or without lids. Seeds, acorns, dried roots and tubers, dried fish, fried meat and dried berries were all stored. They made baskets that were so tight they were used for cooking hot, boiling liquids. They used pitch and ashpaltum to waterproof water jugs made from baskets. They made water bottles the same way. They made baskets to winnow, gather, and store seeds. They made seedbeaters out of basketry materials.

Cradles and cradleboards were made from basketry materials. They also made hunting and fishing equipment, fishing lines, fishing nets, fowling nets, rabbit nets, and decoys. Tules were woven into skirts for the women, and used for housing and Tule boats. Choris' drawings made in 1816, show headgear that had woven components as well as tule boats and woven skirts and belts for the women. Basket making and the use of basket materials pervaded their culture, where other cultures used and can be dated from sequences of pottery; here there is no pottery. California Native Americans began life in a basketry cradle and cradleboard and ended life by having their favorite baskets ceremonially burned at their funeral. Shanks and Shanks (2006) state that baskets have been made in California for thousands of years and when they are found archaeologically they are nearly identical to those being made today. Unfortunately, baskets do not survive often in an archaeological context. Baskets are a recognized art form world wide and California baskets are the apex of the basket pyramid. Shanks and Shanks (2006) relate that Kroeber, at the beginning of the last class he taught at Berkeley, brought in a large Pomo basket, placed it in front of the class, filled it with water, covered it with a piece of glass and left it there for the rest of the semester. On the last day of class he lifted off the piece of glass and all of the water was still there. This is a statement and a testament to the skill of the basket makers in California. The earliest Spanish explorers recognized the craftsmanship seen in baskets from the native Californian weavers. The

Anza expedition of 1775-1776 brought so many baskets that entire villages were sold out (Dawson and Deetz, 1965)

In order to understand the relationship that baskets had with native California Indians a passing understanding of their land management practices is required. California Native Americans managed the land and its resources in a very active, hands on fashion. They were not prototypical hunter gatherers wandering across the landscape eating resources as they went and moving rapidly from place to place. They were semi-sedentary and moved in seasonal rounds of gathering and hunting. They had a rich diverse environment to choose from but they had limited territories. In the last 1,000 years before contact they had fairly strict territorial boundaries with extensive trade networks that brought in critical raw materials like obsidian. Increased population densities forced them to become creative with the resources available to them. Their main sources of food came from within ten to fifty miles of their central location. Being somewhat restricted in territory they made maximal use of the resources available to them. As such, they made use of fire as a primary land management technique. Fire removed the underbrush from the oak savannahs, destroyed the duff under the oak trees and killed the acorn insects that lived in the duff and litter under the trees. It promoted new growth in grasses and low growing plants that attracted grazing animals like deer and antelope in greater densities. Fire burned off the older growth in hazel and alder thickets and forced the plants to grow long straight new shoots which were harvested the

next year for basket materials and arrow shafts. Merrill (1923, 1973) states that there were 78 different species of plants were used in California basketry. She derived her information by analyzing the basketry collection housed at the University of California in Berkeley. Certain basketry materials were used more often than others, willow (*Salix sp*.), beargrass (Xerophyllum *tenax*), deergrass (*Muhlenbergia rigens*), hazel (*Corylus cornuta*), redbud (*Ceris orbiculata*) and buckbrush (*Ceanothus cuneatus*) are the primary plants used in baskets. Part of the basket making process is harvesting and splitting the material into usable lengths. Anderson (2005 p. 44) shows the mouth and the teeth being used in this process, as a third hand, to hold the root in the teeth while the hands are used to split and process the root into basketry material for twining baskets. Many other basketry materials utilize the teeth as either direct processing equipment to soften the shoot or strand of milkweed with saliva as the fluid and teeth as the hammer and anvil, or to use the teeth to grip and hold while the hands do the splitting.

The archaeological evidence for foods that were eaten is, necessarily, confined to those materials that resist decay in archaeological depositional environments. Most middens, village sites and mortuary sites are restricted to animal and fish bones and shellfish. Hylkema (2002) details the progression of resource intensification as evidenced from cemetery excavation sites from the middle to late periods in the Santa Clara Valley and San Francisco Peninsula archaeological sites. There is a generalized hunting focus that includes both land and sea mammals, but with a slant towards the land

mammals, in the late period sea animals predominate including sea otters. As expected, large hoofed animals like elk and deer are preferred along with smaller animals and birds and surprisingly, sea otters. Leventhal (1993) ascribes most or possibly all of these remains to mortuary feasting and anniversary feasting events.

In looking at dental abrasion, meat in and by itself will not cause occulusal abrasion, possible grit included in the cooking process would, as would gnawing and crushing of bones to extract marrow. Shellfish, or rather the grit incorporated in shellfish, has the possibility of causing dental abrasion also. It would seem sensible and logical that shellfish would be washed before chewing and ingestion so the incidence of abrasion would be minimal.

Ethnographic analogy is a widely used technique to tease out and infer behaviors from archaeological populations that have similar food ways and lifestyles. The two most widely used with regard to California Native Americans are Australian Aborigines and Eskimo peoples. Their diets do not match, but their lifestyles are similar. Australians tend to range widely, within their tribal ranges and subsist on ‘bush tucker” when away from urbanized settings. In dry desert settings which most modern aboriginal populations have been forced to live in, the dental abrasion has been noted as extreme but not more than 5 or 6 on Molnar’s scale and usually less. The abrasion and attrition is attributed to sand in the food and ashes clinging to the meat cooked on open fires.

Eskimos have been widely documented to use their teeth as a third hand. All Eskimo populations subsist almost entirely on a purely meat diet. Their normal prey base is seals, walrus, caribou and fish. In certain populations, technology was developed to take bowhead and beluga whales, notable on the west coast of Alaska. Early explorers have widely commented upon all of these peoples from diverse environments within the Arctic as having extremely strong teeth. Of course, it is the masticatory apparatus, notable the masseter and temporalis muscles that have become highly developed and as a consequence have resulted in a broad mandibular ramus. Lyon (1824) noted that men they used their teeth to tie and untie lines, the females were observed to use their teeth to soften skins and masticate sinew for sewing. He also describes an Eskimo holding a bow drill in their teeth and when he tried it he describes an unpleasant vibration and side to side motion. Murdoch (1892) has sketches of bow drills bought for the Smithsonian in Barrow Alaska in1892. Hayes (1885) describes a hunter crushing a birds head with his teeth. de Poncins (1941, 1949) describes Eskimos cracking seal bones with their teeth while 3 of them consume a 50 pound seal. He lived with a Canadian Eskimo population for two years, and observed them closely. He also noted them holding a fish in their teeth while pursuing another with a fish spear and, possible the most famous quote regarding Eskimos and teeth.

"What those teeth could do I already knew. When the cover of a gasoline drum could not be pried off with the fingers, an Eskimo would take it between his teeth and it would come easily away. When a strap made of sealskin—and I know of nothing tougher than sealskin—an Eskimo will put it in his mouth and chew it soft again. And those teeth

were hardly to be called teeth. Worn down to the gums, they were sunken and unbreakable stumps of bone."

Women used their teeth just as handily Nansen (1893), Gilder (1881), de Poncins (1941,1949) Lyon (1824) all describe women using their teeth to soften frozen skins, pull off frozen boots, and hold skins in their teeth while sewing. de Poncins (1941) states"

> "the old woman sat all day long scraping skins—a task that never ends in the life of the Eskimo, for weather, snow, and water are constantly soaking and hardening the clothes he wears and the skins he sleeps on…when a skin is finished she flings it against the igloo wall …she has two or three different scrapers to work with, but the real softening is done with her teeth. I have said before, I believe, that the Eskimo's teeth serve him as a third hand, and though I had demonstrations of this again and again, yet each time it was as marvelous in my eye as a turn at the circus. The miracle was that when Niakognaluk had finished a skin it was really white and as supple as a glove."

Ethnographic analogy only goes so far when comparing widely divergent hunter gather populations to California Native Americans. The important thing to credit them is that they all were just as intelligent as we are, they just did not have the technology that we have, but they were creative, intelligent and used what tools they had to take care of themselves and the people they cared about and if that meant using their teeth, so be it.

The early explorers in California, fortunately, kept diaries wrote letters and reports of their travels, activities and encounters with California Native Americans. They were decidedly Eurocentric but once that bias is discounted there is valuable information disclosed. The principal ones are Crespi translated by Brown (2001) from 1769. Palou translated by Bolton (1926), they were both on the same expedition in 1769 led by

Portola and Fages. Fages' second journey diary from the 1772 expedition. There are the Friar Santa Maria diaries, who sailed with the *San Carlos* and was the first ship to enter San Francisco Bay. Anza and Font from 1776 who traveled up the east side of San Francisco bay. There are also letters from the various Fathers who ran the missions from 1770 till 1826 when they were all secularized.

They note foods presented to them, game seen, hunted and consumed, dress, mannerisms, domestic and hunting equipment. Crespi (2001) makes note of every village that they encounter, foods given and traded for and attitudes of the "wretched heathens". Brown (2001) translates Crespi's original field notes and also his edited account for potential publication side by side. They both contain the same basic information but some significant details are lost between the two editions. Crespi records that at almost every village a large bowl of "sage gruel" is proffered and/or given to them. Sage gruel was Chia (*Salvia columbariae*), one of the forgotten crops of the Americas. It grew wild from California through into Central America. Ayerza and Coates (2005) record that in Mesoamerica it was a domesticated crop and the fourth largest tribute crop demanded by the Aztecs behind maize, beans and amaranth as recorded in the Codex Mendoza housed at Oxford University. Crespi's attitude towards the sage gruel is casual, but the reason it was offered consistently is that it was an elite food and only offered to important guests (Leventhal pers. comm.2009). Nowhere does Crespi complain or even mention the

foods as being gritty or abrasive, if fact he welcomes and looks forward to it. He mentions in the April 17th 1770 entry that they are passing through…

> "We found the country all very grass grown with green grass in seed, from which the heathens are now plucking their seed crops, and in many spots along the way we came upon a great many heaps of them….Some heathens came over from the village and gave us to understand that since they were plucking their seeds at present and we had stopped in the hollow at a place where they had not yet plucked,
> we should move onward and the attempt was made to keep our mounts away so as
> not to do them damage , because they gave it to be understood that they were unhappy with their eating the seeds."

It is a leap, but it could be interpreted that this was a group of farmers trying to protect their crop from careless invaders. It could also be argued that these were proto agriculturists who carefully managed a resource and protected it from predators and competition from other grazers.

Tobacco being smoked in pipes was mentioned frequently in the Crespi diaries and is supported by the archaeological findings of pipes dating to the late period in grave associations. Two species of tobacco grow wild in California, *Nicotiana quadrivalis* and *Nicotiana attenuaya.* Anderson (2005) records a dozen or so tribes sowing tobacco seeds over cleared ground that had been burned to produce fertilizer and two or three times during the growing season, pinching off new and stunted growth to encourage the leaves to grow larger and at the end of the season to collect and save seeds. There is also ethnographic evidence of tobacco being chewed after being mixed with burnt lime from clamshells.

Summary

The literature shows us that worldwide, prehistoric peoples have been using their teeth not just for crushing and chewing foods but also leaving behavioral imprints on the hard surfaces of their teeth from using them as a third hand and as tools as far back as Neanderthals and possibly even earlier. Prehistoric central California Native Americans evidence more advanced wear and attrition as well as culturally induced patterning, than even cultures like Australian Aborigines and Eskimos who are well documented to have made extensive use of their teeth in processing foods, hides and as tools to improve subsistence acquisition of resources. Prehistoric Californians are unique in the sense that they never developed pottery, except in the far southeastern corner along the Colorado River, but rather exercised creative abilities in utilizing basketry as a primary food acquisition, processing and storage medium. Processing the large amount of material that this entailed involved using teeth as anvils to hold and process, remove bark and soften fibers. Most of this work is believed to have been done by women, but the men were heavily involved also in preparing cordage, ropes, string, fishing nets, fishing lines, fowling nets, rabbit nets, fishing weirs and acorn storage bins. Phytoliths as well as grit, found in basketry materials, are some of the causative agents in dental scoring and attrition. Coprolite evidence shows that their menu was much wider and diverse than previously believed in the sense that small mammals possibly were more heavily exploited and eaten with bones intact. Ethnographic evidence from other hunter gatherer

cultures supports the idea that the definition of edible resources needs to be expanded, and that what is considered edible also needs to be reexamined as evidenced by crushing seal bones with the teeth to extract nutrients and consuming viscera as part of the consumable package. The early explorers also provide important information regarding foods and resource acquisition processes that suggest a wider, more diverse diet than can be suggested from the archaeological record alone. They also provide first hand accounts of their acquisition of baskets to take back to Spain as an art form from California. All of the above, directly and indirectly involve the use of the dentition to infer behaviors that have remained obscure.

There is no question that grit in the food is part of the causation responsible for the extreme dental wear seen in Northern California prehistoric populations. It is also possible that there are other sources contributing to the patterned dental wear seen that may reveal behaviors that have not been previously addressed. The dental wear seen may well be multifactorial in nature and not just a simple cause and effect relationship derived from consuming food resources.

LITERATURE CITED

Anderson, DL & Popovich, F. 1998. Dental reductions and dental caries. American Journal of Physical Anthropology 47:381-386.

Anderson, M. Kat. 2005. Tending the Wild, Native American knowledge and the management of California's natural resources. University of California Press, Berkeley, Ca.

Arcini, Caroline. 2005. The vikings bare their filed teeth. American Journal of Physical Anthropology 128:737-733.

Arnold, W.H., Naumova, E.A., Koloda,V.V., Gaengler, P. 2007 Tooth wear in two ancient populations of the Khazar Kaganat Region in the Ukraine. International Journal of Osteology 17:52-62.

Ayerza, Ricardo Jr. and Coates, Wayne. 2005. Chia: rediscovering a forgptten crop of the Aztecs. University of Arizona Press, Tuscon AZ. 85721.

Bedford, Russell, Lovejoy, Meindl. Et. al. 1993. Test of the multifactorial aging method using skeletons with known age at death from the Grant Collection. American Journal of Physical Anthropology 91:287-297

Bernal, Valeria, Novellino, Paula, Gonzalez, Paula, Perez, Ivan. 2007 Role of wild plant foods among late holocene hunter-gatherers from central and north Patagonia (South America): an approach from dental evidence. American Journal of Physical Anthropology 133:1047-1059

Bonfiglioli, B., Mariotti, V., Facchini, F., Belcastro, MG., Condemi, S. 2004 Masticatory and non-masticatory dental modifications in the Paleolithic necropolis of Tafororalt (Morocco). International Journal of Osteoarchaeology 14: 448-456.

Brown, Alan K. 2001. A Description of Distant Roads: Original Journals of the First Expedition into California, 1769-1770 by Juan Crespi. San Diego State University Press, San Diego Ca. 92182.

Choi, Inui 1986 Dental wear in determining the age at death from the Santa Catalina de Guale population: Methodology. Senior Honors Thesis Northern Illinois Univ.

Cybulski, Jerome S. 1974. Tooth wear and material culture: precontact patterns in the Tsimshian area, British Columbia. Syesis Vol. 7.

Danielson, Dennis and Reinhard, Karl. 1998, Human dental microwear caused by calcium oxalate phytoliths in prehistoric diet of the Lower Pecos Region, Texas. American Journal of Physical Anthropology 107:297-304.

Deter, Christine A. 2008. Gradients of occlusal wear in hunter-gatherers and agriculturalists. American Journal of Physical Anthropology 00:111-000.

Drier, Frederick. 1994. Age at death estimates for the protohistoric Arikara using molar attrition rates: A new quantification method.
International Journal of Osteoarchaeology 4:137-147

El-Zaatari S. 2008. Occlusal microwear texture analysis and the diets of historical prehistoric hunter-gatherers. International Journal of Osteology. 00:000-000

Erdal, Y.S. 2008. Occlusal grooves in anterior dentition among Kovuklukaya inhabitants (Sinop,Northern Anatolia, 10th Century AD) International Journal of Osteology, 18:152-166
Ermenc, Branko. 1997. Metamorphosis of root dentin and age. International Journal of Osteoarchaeology 7: 230-234.

Eshed, Vered, Gopher, Avi, Hershkovitz, Israel. 2006. Tooth wear and dental pathology at the advent of agriculture: New evidence from the Levant. American Journal of Physical Anthropology. 130:145-159

Fong, Michael R. and Brittan, David G. 1994. Skeletal and dental abnormalities at a prehistoric central California site.Proceedings of the Society for California Archaeology 7:117-134.

Formicola, Vincenzo. 1988. Interproximal grooving of teeth: Additional evidence and interpretation. International Journal of Osteoarchaeology. 29(4):663-669.

Fox, Lalueza C. 1992. Information obtained from the microscopic examination of cultural striations in human dentition. International Journal of Osteoarchaeology 2:155-169.

Fox, Carles Lalueza and Frayer, David W. 1997. Non-dietary marks in the anterior dentition of the Krapina Neanderthals. International Journal of Osteoarchaeology 7:133-149.

Fox, Carles Lalueza, Juan, Jordi, Albert, Rosa M. 1996. Phytolith analysis on dental calculus, enamel surface, and the burial soil: Information about diet and Paleoenvironment. American Journal of Physical Anthropology 101:101-113.

Frayer, David W., Russell, Mary D., 1987. Artificial grooves on the Krapina Neanderthal teeth. American Journal of Physical Anthropology 74:393-405.

Froughton, Jack, 1994. Late Holocene Resource Intensification in the Sacramento Valley Calif.: The Vertebrate Evidence. Journal of Archaeological Science 21:501-514.

Gilder, William H. 1881. Schwatka's Search. Charles Scribners's Sons. New York.

Hall, Roberta, Morrow, Robert, And Clarke, Henry J., 1986. Dental pathology of prehistoric residents of Oregon. American Journal of Physical Anthropology 69:325-334.

Hall, Roberta, And German, Thomas. 1975. Dental pathology, attrition, and occulusal surface form in a prehistoric sample from British Columbia. Syesis 8:275-389.

Hartnardy, Philip, and Rose, Jerome C., 1991. Abnormal tooth loss patterns among Archaic-Period inhabitants of the Lower Pecos Region, Texas. In: Kelly, MA, Larsen CS, editors. Advances in Dental Anthropology, pgs 267-278. New York Wiley-Liss Inc. p267-278.

Hillson, Simon. 1996. Dental Antropology. Cambridge University Press,.Cambridge, United Kingdom. CB2 2RU.

Hillson, Simon. 2005. Teeth. Cambridge University Press, Cambridge United Kingdon CB2 2RU.

Hinton, Robert J., 1981. Form and patterning of anterior tooth wear among aboriginal human groups. American Journal of Physical Anthropology 54:555-564.

Hylkema, Mark G. 2002. Tidal marsh, oak woodlands, and the cultural florescence in the Southern San Francisco Bay Region. In: Erlandsdon, Jon M. and Jones, Terry L. editors, Catalysts to Complexity: Late Holocene societies of the California coast Cotsen Institute od Archaeology, Los Angeles Ca.

Jurmain, Robert. 1990. Paleoepidemiology of a Central California prehistoric population from ALA-329: Dental disease. American Journal of Physical Anthropology 81:333-342

Kaidonis, JA., Richards, LC. Townsend, GC. and Tansey, GD., 1998 Wear of human enamel: A quantitative in vitro assessment. Journal of Dental Research 77(12):1283-1990.

King, Tania, Andrews, Peter and Boz, Basak. 1999. Effect of taphonomic processes on dental microwear. American Journal of Physical Anthropology 108:359-373. AJPA 108:359-373.

Kroeber, A. L. 1976. Handbok of the Indians of California. Dover Publications, Inc. New York.

Larsen, Clark Spencer. 1985. Dental modifications and tool use in the western great basin. American Journal of Physical Anthropology 67:393-402.

Lavelle, CLB. 1970. Analysis of attrition in adult human molars. Journal of dental Research 49(4):822-828.

Leigh, R. W. 1928. Dental Pathology of Aboriginal California. University of California Publications in American Archaeology and Ethnology 23 (10):399-440..

Lessa, Andrea and Guidon, Niede. 2002. Lavelle, CLB. 1970. Analysis of attrition in adult human molars. Journal of dental Research 49(4):822-828. American Journal of Physical Anthropology 118:99-110.

Leventhal, Alan. 1993. A reinterpretation of some bay area shellmounds sites: A view from the Mortuary comples from CA-ALA-329, the Ryan mound. M.A. Thesis, San Jose State University.

Littleton, Judith and Frohlich, Bruno. 1993. Fish eaters and farmers: Dental pathology in the Arabian gulf. American Journal of Physical Anthropology 92:427-447.

La Perouse, Jean Francois, 1786 (1989) The Journals of Jean Francois De La Perouse, Life in a California Mission. Heyday Books, Santa Clara University, Santa Clara, Ca 95054.

Lovejoy, C. Owen. 1985. Dental wear in the Libben population: Its functional pattern and role in the determination of adult skeletal age at death. American Journal of Physical Anthropology 68:47-56.

Lozano. Marina. 2008 Non-Masticatory uses of anterior teeth of Sima de los Huesos individuals (Sierra de Atapuerca Spain). Journal of Human Evolution 1-16.

Lukacs, John R., and Pastor, Robert F. 1988. Activity–Induced patterns of dental abrasion in prehistoric Pakistan: Evidence from Mehrgarh and Harappa. American Journal of Physical Anthropology 76:377-398.

Maat, JGR. and Van der Velde, EA. The caries-attrition competition. International Journal of Anthropology 2(4):281-292

Macchiarelli, Roberto.1989. Prehistoric "Fish-Eaters" along the eastern Arabian coasts: Dental variation, morphology, and oral health in the Ra's al-Hamra community (Qurum, Sultanate of Oman, 5^{th}-4^{th} Millennia BC). American Journal of Physical Anthropology 78:575-594.

Merbs, Charles F. 1968. Anterior tooth loss in Arctic populations. Southwestern Journal of Archaeology 24:20-32.

Merrill, Ruth Earl. 1973. Plants used in basketry by the California Indians. Ballena Press Ramona Ca. 92065.

Miles, AEW. 2001. The Miles method of assessing age from tooth wear revisited. Journal of Archaeological Science 28:973-982.

Milner, George R. And Larsen, Clark Spencer. 1991. Teeth as artifacts of human beharior: Intentional mutilation and accidental modification.In: Kelly, MA, Larsen CS, editors. Advances in Dental Anthropology, pgs357-378. New York Wiley-Liss Inc.

Minozzi, Simona, Manzi, Giorgio, Ricci, Francesca, di Lernia, Savino and Tarli, Borgognoini, Silvana M. 2003. Non alimentary tooth use in prehistory: An example from early Holocene in central Sahara(Uan Muhuggiag, Tadrart Acacus, Libia. American Journal of Physical Anthropology 120:225-232.

Molnar, Stephen. 1968. Experimental studies in human tooth wear: II. American Journal of Physical anthropology 28:361-368.

Molnar, Stephen.1968. Human tooth wear, tooth function and cultural variability. American Journal of Physical Anthropology 34:175-190.

Molnar, Stephen. 1972. Tooth wear and culture: A survey of tooth functions among some prehistoric populations. Current Anthropology 13(5):511-526.

Molnar, S., McKee, JK., Molnar, IM., and Przybeck, TR.. 1983. Tooth wear among contemporary Australian Aborigines. Journal of Dental Research 62(5):562-565

Molnar, Stephen and Molnar, Iva.1985. Observations of dental diseases among prehistoric populations of Hungary. American Journal of Physical Anthropology 67:51-63.

Molnar, S. and Molnar, I. 1990. Dental arch shape and tooth wear variability. American Journal of Physical Anthropology 82:385-395.

Molnar, Petra. 2008. Dental wear and oral pathology: possible evidence and consequence of habitual use of teeth in a Swedish Neolithic sample. American Journal of Physical Anthropology 00:111-111.

Murphy, Thomas. 1959. The changing pattern of dentine exposure in human tooth attrition. American Journal of Physical Anthropology 17:167-178

Oliveira, R.N., Silva, S.F.S.M., Kawano, A.,and Anyunes, J.F.L. 2006. Estimated age by tooth wear of prehistoric human remains in Brazilian archaeological sites. International Journal of Osteoarchaeology 16:407-414.

Owsley, Douglas W., and Bellande, David T. 1982. Culturally induced dental alterations in a historic Cherokee skeletal sample. Journal of Cherokee Studies 3:82-84.

de Poncins, Gontran. 1941. Kabloona. Reynal and Hitchcock Inc., New York.

Reinhard, KJ, Ambler, JR, and Szuter, CR. 2007 Hunter-Gatherer use of small animal food resources: Coprolite evidence. International Journal of Osteoarchaeology 17:416-428.

Reinhardt, Gregory A. 1983. Relationships between attrition and lingual tilting in human teeth. American Journal of Physical Anthropology 61:227-237

Richards, L.C. 1985. Dental attrition and craniofacial morphology in two Australian aboriginal populations. Journal of Dental Research 64(11):1311-1315

Roydhouse, Richard and Simonsen, Bjorn.1975.Attrition of teeth. Syesis Vol 8 263-273 1975.

.Schmidt, Christopher W. 2001 Dental microwear evidence for a dietary shift between two nonmaize-reliant prehistoric human populations from Indiana. American Journal of Physical Anthropology 114:139-145

Schultz, Peter D. 1977. Task activity and anterior tooth grooving in prehistoric California Indians. American Journal of Physical Anthropology 46:87-92

Scott, Richard G. And Turner, Christy G. 1988. Dental Anthropology. Annual Review of Anthropology 17:99-126.

Seidel, John C. Colten, Roger H., Thibodeau, Edward A., and Aghajanian, John G. 2005 Iatrogenic molar borings in the 18th and early 19th century Native American dentitions. American Journal of Physical Anthropology 127:7-12.

Shanks, Ralph and Shanks, Lisa Woo. 2006. Indian Baskets of Central California. Constano books, Novato Ca 94948.

Smith, Holly B., 1984. Patterns of molar wear in hunter-gatherers and agriculturists. American Journal of Physical anthropology 63:39-56

Smith, Holly B. 1986. Development and evolution of the Helicoidal plane of dental occlusion. American Journal of Physical Anthropology 69:21-35.

Smith, Patricia. 1972. Diet and attrition in the Natufians American Journal of Physical Anthropology 37:233-238.

ST. Hoyme, LE, Koritzer, RT. 1974. Ecology of dental disease. American Journal of Physical Anthropology 45:673-686.

Storey, Rebecca. 2007. An elusive paleodemography? A comparision of two methods for estimating the adult age distribution of deaths at late classic Copan, Honduras. American Journal of Physical Anthropology 132:40-47.

Tal, Haim. and Tau, Shemuel. 1984. Tooth loss and tooth retention in a multitribal group of Bantu-speaking South African Blacks: A study of 500 dry Mandibles. Amrtican Journal of Physical Anthropology 64:75-82.

Teaford,M A, and Tylenda, C A. 1991 A new approach to the study of tooth wear. Journal of Dental Research 70(3):204-207

Teaford, Mark F., and Lytle, James D. 1996 Brief Communication: Diet induced changes in rates of human tooth microwear: A case study involving stone ground maize. American Journal of Physical anthropology 100:143-147

Tomenchuk, John and Mayhall, John. 1979. A correlation of tooth wear and age among modern Igoolik Eskimos. American Journal of Physical Anthropology 51: 67-78

Turner, Christy G. II and Cadien, James D. 1969. Dental Chipping in Aluets, Eskimos and Indians. American Journal of Physical Anthropology 31: 303-310.

Turner, Graham and Anderson, Trevor. 2003. Marked occupational dental abrasion from medieval Kent International Journal of Osteoarchaeology 13:168-172.

Turner, Christy G II. 2004. A second drilled tooth from prehistoric western North America. American Antiquity 69(2)356-360.

Ungar, Peter S., and Spencer, Mark A. 1999. Incisor microwear, diet, and tooth use in three Amerindian populations. American Journal of Physical Anthropology 109:387-396.

Walker, Phillip L. and Erlandson, Jon M. 1986. Dental evidence for prehistoric dietary change on the northern Channel Islands, California. American Antiquity 51(2):375-383.

Walker, Philip L. 1978 A quantative analysis of dental attrition rates in the Santa Barbara channel area. American Journal of Physical anthropology 48:101-106.

Walker, Phillip L., Dean, Gregory, and Shapiro, Perry. 1991. Estimating age from tooth wear in archaeological populations. In: : Kelly, MA, Larsen CS, editors. Advances in Dental Anthropology, pgs 169-178. New York Wiley-Liss Inc.

Watson James T. 2008 Changes in food processing and occulusal dental wear during the early agricultural period in northwest Mexico. American Journal of Physical Anthropology 135:92-99

Young,William George. 1998. Anthropology, tooth wear, and occlusion ab origine. Journal of Dental Research 77(11)1860-1863.