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Native Americans in the San Francisco Bay Area: Patterns in Ancient Teeth, Palimpsests of Behavior

Dave Grant
San Jose State University

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NATIVE AMERICANS IN THE SAN FRANCISCO BAY AREA:
PATTERNS IN ANCIENT TEETH,
PALIMPSESTS OF BEHAVIOR

A Thesis

Presented To

The Faculty of the Department of Environmental Studies

San Jose State University

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

by

Dave Grant

December 2010

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SAN JOSE STATE UNIVERSITY

The Designated Thesis Committee Approves the Thesis Titled
NATIVE AMERICANS IN THE SAN FRANCISCO BAY AREA:
PATTERNS IN ANCIENT TEETH; PALIMPSESTS OF BEHAVIOR

by

Dave Grant

APPROVED FOR THE DEPARTMENT OF ENVIRONMENTAL STUDIES

SAN JOSE STATE UNIVERSITY

December 2010

Dr. Rachel O'Malley	Department of Environmental Studies
Dr. Priya Raman	Department of Communication Studies
Alan Leventhal	M.A. San Jose State University

ABSTRACT

NATIVE AMERICANS IN THE SAN FRANCISCO BAY AREA: PATTERNS IN ANCIENT TEETH; PALIMPSESTS OF BEHAVIOR

by Dave Grant

In analyzing burial populations from seven sites in the Santa Clara Valley, patterns on teeth were found that did not conform to the flat normative wear explanation. This study attempts to expand upon the seminal work of Molnar (1968), Hinton (1981), and Keiser (2001a, 2001b) and to propose a definitional refinement of wear patterns found on teeth from populations in Central California. Flat normative wear was present. In addition, four additional distinct wear patterns were found. Wear patterns include slants and scoops on posterior teeth and rounding and grooving on anterior teeth. Statistically significant differences were identified between an older (4,000-2930BP) northern population and younger (2200BP-250BP) populations from the Santa Clara Valley. Analysis of the southern population suggests that these individuals did not utilize their teeth as frequently to produce patterned wear and suggests an elite class that was exempt from normal processing activities. The percentage of slants, rounding, and scoops all increased through time from the older, northern population to the younger, southern populations. Males exhibited more flat wear and more slant wear than females. Southern males had more slant wear than females and were evenly split on the rounding pattern. Scoops, which may be related to arrow shaft processing or peeling, are overwhelmingly found in the southern population after the adoption of the bow and arrow in this area. Further research is called for to further refine and define these processes.

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Palimpsest: (from Latin palimpsestum, scraped again) a manuscript written on a surface from which an earlier text has been partly or wholly erased. Palimpsests were common in the Middle Ages, before paper became available, because of the high cost of parchment and vellum. In a figurative sense, the term is sometimes applied to a literary work that has more than one “layer” or level of meaning.
www.wikipedia.org.

I. INTRODUCTION

Humans are opportunistic omnivores. They are capable, physiologically, of eating anything that will not poison or kill them. Modern hunter gatherers constantly sample as they move across the landscape. They consume a plant here, a larvae or bug there, anything edible is noted, gathered, and consumed or collected and stored for later consumption. Their situational awareness is geared toward optimizing survival at both macro and micro levels.

Very few true hunter-gatherer cultures are left in the world. They have all been pushed into marginalized environments that make their temporal existence harder and more dangerous (Lightfoot, 2009). A few, notably the Hadza in the Great Rift Valley of Tanzania, are in Africa. Several inhabit the more remote areas of Papua New Guinea, some the Amazon, and several the Arctic (Finkel, 2009).

California was a unique hunter-gatherer environment because of its climatic placement. Only five areas in the world have a “Mediterranean” climate. They are the northern rim of the Mediterranean Sea, California, central Chile, the South African Cape and the western and southern areas of Australia (Anderson et al., 1997). California had greater prehistoric population densities than anywhere else north of Mexico. Populations at contact are minimally estimated to have been 330,000 (Cook, 1943; Lightfoot, 2009). By 1860, they had been reduced to 30,000 through social disruption, destruction of food lifeways, and, most importantly, European diseases.

Reconstructing Native Californian prehistoric, protohistoric, and historic lifeways has inherent limitations. Archaeological midden deposits, reports of early explorers, mission records, literate travelers, proto-ethnographers, and academic ethnographers all contribute to our understanding of Native Californian dietary practices at contact. The inherent limitations are that many elements of the diet either do not preserve or are completely digested, leaving no trace in the archaeological record. Dentitions also can contribute valuable information to the knowledge base (Larsen, 1995; Hillson, 1996).

It has been argued by Hillson (1996, 2005), Larsen (1997, 2000), and others that the study of human dentition can provide some of the strongest evidence for prehistoric health, diet, and hygiene. Dentitions are the only part of the skeleton that interfaces with the external environment, and teeth are some of the best preserved elements in archaeological sites. Poor oral and dental health has plagued *Homo sapiens* for thousands of years. In prehistoric populations a primary category of paleopathology includes dental attrition and wear, comprised of caries, abscesses, periodontal disease, hypoplasias, and generalized occlusal wear. If individuals lived long enough and ate a preagricultural diet of meats and plant foods, their teeth usually became worn to the point of producing significant pathology. In some cases, abscesses penetrating into the sinuses or blood system resulted in sepsis and death.

Dental occlusal wear is a well understood process and is separated into three primary mechanisms: 1) attrition, 2) abrasion, and 3) erosion. Attrition is defined as tooth on tooth contact. Abrasion is defined as contact with food or abrasive particles included in food. Erosion is defined as loss of enamel through the medium of acidified

foods and fermentation (Larsen, 1997; Kaidonis, 2008). Dental enamel is only 1000 - 2000 micrometers thick (1-2 mm). As dental enamel is worn away by attrition, abrasion, or erosion, primary dentin, which encases and surrounds the pulp cavity, becomes exposed. Since primary dentin is softer than enamel, the dentin erodes even faster. The body then produces secondary dentin, which layers at the top of the pulp cavity to protect the nerve cavity. In addition, the nerve retreats towards the apical end of the tooth root (Larsen, 1997). As wear progresses further, the pulp cavity becomes compromised. Normal bacteria from the mouth flora can then enter the open nerve canal, which leads to abscesses and infection. Surprisingly, this does not always happen because, as the nerve retreats toward the apical end of the root, it dies and seals off the apical end of the tooth. This prevents infectious agents from reaching the nerve canal in the jaw and the blood supply.

It was not until the latter half of the 20th century that modern dentistry, with its benefits, became commonplace in industrialized nations. Teeth, because of their highly mineralized content, are some of the best preserved of all archaeological skeletal materials and as such can provide useful information about an individual's interaction with his or her environment, foodways, and behaviors. In dealing with prehistoric populations, it is important to consider all elements that affect individuals and their dentitions. Consideration is given to the natural environment, food acquisition, preparation and consumption practices, material culture, and finally, environmental management practices such as pruning and pyromanagement.

The research objectives of the present study are twofold: 1) to determine if there is a statistically significant quantity of patterned wear present, and 2) to determine if there are demographically related differences in patterned dental wear observed in the Central California Prehistoric Native American populations under study. As a byproduct of this research project, a new scoring system for the extreme patterned dental wear observed in San Francisco Bay Area California Prehistoric Native American populations was developed. The primary explanation presented in the literature for dental wear is that grit in the food is the causative agent for the extreme wear seen in Central California populations (Leigh, 1928; Molnar, 1968; Hinton, 1981; Jurmain, 1990; Hillson, 1996; Hillson, 2005).

It is hypothesized that a large quantity of abrasives in the diet is responsible for the extreme degree of (dental) attrition, in fact among the most severe for any population yet described (Jurmain 1990:333).

Although grit in the food, from multiple sources, is a factor in dental wear. Primary causes for the observed wear may well be multifactorial in nature. There has been little research focused on other causation vectors of dental wear. While this research explores and suggests other possible causative factors that may directly affect tooth wear; the main focus of this project remains to document significant patterned wear present, and determine if there are male and female and age-related differences.

II. PROBLEM STATEMENT

California Native Americans are seen by anthropologists and archaeologists as unique among Native Americans cultural groups (Kroeber, 1925; Heizer, 1980). At contact, they had denser populations than any other aboriginal group north of Mexico (Cook, 1940, 1976; Milliken, 1995; Lightfoot, 2009). They had a wider and more diverse array of food sources to choose from than other Native American cultures (Kroeber, 1925; Heizer, 1980). They developed acorns as a storable food resource that freed them from shortages and famines without developing, and becoming dependent upon, agriculture (Anderson, 2005; Lightfoot, 2009). They never adopted pottery as a storage mechanism even though they were aware of that technology (Heizer, 1980; Lightfoot, 2009). They had worse dental attrition than any other known group of hunter-gatherers (Jurmain, 1990). All dental wear seen has primarily been attributed to “grit” from food processing and subsequent consumption.

As dentitions were being recorded and scored for some of the archaeological populations in this study, a greater degree of variation of wear was observed that did not fit this default, horizontal, flat “grit” model. Alternative explanations were sought through a comprehensive literature review and were not found.

In order to systematically document, record, and score these unique patterns, a new scoring system was developed as a central component of this study. Specific wear patterns were grouped into classes. These distinctive groupings are classified with the following attributes: 1) flat wear, 2) slants, 3) rounding, 4) scoops, and 5) grooves. Both macro photography and microscopic analysis (e.g., striations) were used to refine and

distinguish these groupings. Occlusion or lack of contact between upper and lower dentitions was also an important factor as a defining mechanism and variable. If, when placed in occlusion, the upper and lower teeth did not meet, then non-masticatory activities were strongly suggested as a contributory factor.

II. DENTAL LITERATURE REVIEW

Archaeological dental literature is extensive and diverse. However, in many ways, the most informed experts and practitioners are dentists who deal with teeth, tooth pain and malocclusions in living populations on a daily basis. Therefore, by working in consultation with dentists and other facial specialists, having them review, assess, describe, and explain in technical terms, the distinctive wear patterns and other dental anomalies seen in the archaeological record. This would further enhance the complex analyses facing osteologists/skeletal biologists. However, specific modern ethnographic and archaeological studies on dental attrition and other malocclusal anomalies within living and prehistoric populations are reviewed below.

Modern ethnographic dental populations

Most of the relevant literature about dental attrition and malocclusion, deals with modern hunter-gatherer populations which include the Greenlandic and Arctic Eskimos, and Australian Aborigines. Other studies of note such as 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 which he attributed this to their "softer" diet.

Molnar and colleagues (1983) conducted a case study employing a group of Australian Aborigine children who had at least four dental casts taken from ages 6 to 18 years of age. These researchers sampled 64 out of a possible 1,717 individuals to analyze. They had a roughly equal sex ratio. They found that the males lost considerably

more molar cusp height, 2.0 mm for males vs. 1.6 mm for females, when measured from the top of the cusp to the lowest point in the central groove. Based upon their study, these authors 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.

In another study Tomenchuk and Mayhall (1979) took casts from 85 modern Eskimo individuals and measured the cusp heights to the depth of the central groove to assess age. They found that they could accurately predict age 97% of the time based upon this metric methodology. Still another study, Richards (1985), analyzed two prehistoric Australian Aboriginal groups that were neighbors but occupying very different ecological zones. One prehistoric group of 74 occupied a lake and riverine ecological zone with hunting and fishing being the main subsistence activities. The second group, numbering 38, was more traditional with hunting, but was heavily oriented toward more plant gathering activities. He found that posterior tooth wear was more dominant in the first group and anterior wear was more prevalent in the second group. The resultant differences in tooth wear and facial morphology were 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 addressed some interesting points. One of these points was that teeth do not function in a “centric” occlusion, but that wear actually increases the ability of teeth to act as tools. The jaws have a wider range of motion and

can function more efficiently as crushing and shearing masticatory tools. Another point noted was that siliceous and phytolithic foods cause wear patterns that can reveal aspects of diet and other behaviors.

In a recent study, Kaidonis and co-workers (1998) ran an experiment using extracted teeth and devising a machine that calibrated tooth wear measured as lost weight of the tooth, using different loads and different lubricants. These researchers determined, not surprisingly, that heavier loading caused heavier wear, but that lubrication decreased the damage, specifically if saliva at a pH value of seven was used. They also found that lubricated wear was modest, up until a load of 9.95, and then increased dramatically under all observed conditions. They also observed that there were two phases to dental wear: 1) a “running in” phase where wear is rapid, and the equivalent of about two years of tooth attrition then slows down to a second phase that they describe as 2) “steady state wear.”

In summary, these clinical dental studies seem to suggest that there is not a simple cause and effect relationship between diet and dental attrition, there are complicating factors involved such as cranial morphology, lubrication, and numerous environmental factors.

Archaeological ethnographic dental literature

The archaeological evidence for foods that were eaten is, necessarily, confined to those materials that resist decay in archaeological depositional environments. Middens, village sites and mortuary site depositional remains are restricted to animal bones, 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 an emphasis towards land mammals. In the Late period, sea mammals predominate including sea otters. Large hoofed animals like elk, deer, and antelope were preferred along with smaller animals and birds and, surprisingly, sea otters. Leventhal (1993) ascribes most or possibly all of these remains to mortuary and anniversary feasting events.

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

Ethnographic analogy models are 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 populations. Their diets do not match, but their lifestyles are similar as hunter-gatherers. Australians tend to range widely, within their tribal areas and subsist on “bush tucker” when away from urbanized settings. In dry desert settings, which most modern Australian aboriginal populations have been forced to live in, dental abrasion has been noted as extreme but not more than 5 or 6 on Molnar’s scale and

usually less (Molnar, 1983). The abrasion and attrition is attributed to sand in the food and ashes clinging to the meat cooked on open fires.

Inuit have been widely documented to use their teeth and mouth as a third hand. All prehistoric Eskimo populations subsisted almost entirely on a diet that was almost totally meat based. Their normal prey base was seals, walrus, caribou, and fish. In certain populations, ocean watercraft and hunting technology was developed to take bowhead and beluga whales, notably on the west and north coasts of Alaska. Early explorers have widely commented upon all of these peoples from diverse environments within the Arctic as having extremely strong teeth (Gilder, 1881; Hayes, 1885; de Pontrains, 1941; Merbs, 1968, 1983). Of course, it is the masticatory apparatus, notably 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 described an Eskimo holding a bow drill in his teeth and when Lyons tried it he described an unpleasant vibration and side to side motion (Lyons, 1824). Murdoch (1892) sketched bow drills bought for the Smithsonian Institution in Barrow, Alaska in 1892. Hayes (1885) described a hunter crushing a bird's head with his teeth. De Poncins (1941, 1949) described Eskimos cracking seal bones with their teeth while three of them consume a fifty pound seal. De Poncins 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, possibly 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 (de Poncins 1941:94).

Women used their teeth just as handily. Nansen (1893), Gilder (1881), de Poncins (1941,1949) and 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 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 (de Poncins 1941:71).

On the North West coast, contact with Europeans came much later than it did in other parts of the country, including California. Extensive contact was not made until traders discovered a market for sea otter skins in China, beginning in 1778 and continuing until the 1840's (Gibson, 1992). The hunger for iron and their ability as “thieves” were noted by every vessel that traded with native populations on Vancouver and the Queen Charlotte Islands. Captain Meares noted in 1786:

The natives (of Prince William Sound) never failed to exert their extraordinary talents in the art of thievery. They would employ such a slight(sic) of hand in getting iron materials of any kind, as is hardly to be conceived. It has often been observed when the head of a nail either in the ship or boats stood a little without the wood, that they would apply their teeth in order to pull it out (Gibson 1992:155).

Ethnographic analogy only goes so far when comparing widely divergent hunter-gather populations to California's Native Americans. An important fact to be mindful of is that they all were adapted to their localized environments, and they all employed teeth as part of their tool kit.

Causation environmental and biocultural context

Modern industrialized cultures have imposed models of what is edible and acceptable within a given societal framework. Most modern cultures do not eat bugs or larva; they also do not eat foods, especially meats that are uncooked. They are selective in what they define as food.

Most Western cultures try to eat three healthy meals a day, spaced evenly. All of these behaviors are societal constructs that do not necessarily apply to prehistoric hunter-gatherer cultures. To look at what might be causing excess dental wear, this study addresses five possible evidence categories: 1) ethnographic accounts from documented hunter gatherer cultures, 2) written diaries, letters and reports from the early explorers observing Californian Native Americans at proto contact and contact, 3) foods eaten as evidenced from midden and archaeological evidence, 4) food remains from coprolite evidence, and 5) other materials that may have abraded the teeth.

The wear observed in Prehistoric California Native Americans is more severe

than any other hunter-gatherer population known. Jurmain states that “the extreme degree of attrition, in fact, among the most severe for any population yet described” (Jurmain 1990:333). He was describing CA-ALA-329, one of the sites included in this study. No other site reports or research studies published have presented data to contradict this statement. What is the potential causality for this wear?

Grit in the food is attributed as a major component for the attrition seen in these populations. Except for the far southeastern corner of California, Native Americans did not have corn, as part of their food palate but they did have acorns. In the literature, Kroeber (1925) states acorns are indicated as the baseline dietary caloric component. They were 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 evidence for the widespread usage of acorns is represented by 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 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. Heizer and Elsasser (1980) 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, or 33%, based on a 3,000 per day caloric need; with the yield of 75 white oaks or 61 coast oaks. This is based on a normal acorn yield per tree.

The presumed grit that came with acorn processing (Kroeber, 1925; Leigh, 1928; Jurmain, 1990) is assumed to cause the dental wear. This hypothetical relationship

between acorns being processed in stone mortars and dental attrition has become firmly embedded in the archaeological literature. This explanation may be too simplistic.

Based upon the above, an important question must be raised. How could 200 grams of acorn meal a day, cooked as mush or eaten as bread, which would need little or no mastication, cause such devastating wear? The assumed grit in the acorn meal would require mastication to produce dental attrition. The grit could potentially come from one primary source, the pounding of acorns into flour in stone bedrock or portable mortars. Grit would be produced as tiny spalls created from the stone on stone contact and the grit would become incorporated into the acorn meal. Acorn mush would require little mastication to form a food bolus before swallowing which might limit the damage caused by grit.

Other potential causal factors should be investigated. Leigh (1928) noted in a California Channel Islands population that small mammals were eaten whole, either raw or roasted. He mentions that older, edentulous individuals had their own personal small mortars and used them to crush whole small mammals that younger individuals supplied to them. Other potentially abrasive elements Leigh noted, that were pounded and ground, included salmon bones, rabbit vertebrae, deer bones and dried meat.

Coprolites provide a unique source of environmental and dietary information. A coprolite is dried and fossilized feces that represents from one to six feeding events. Hartnady and Rose (1991), from coprolite evidence, notes the whole bones of small mammals were frequently found in coprolites from residents of the Lower Pecos region of Texas. Australian ethnographers note that chunks of rabbit are eaten whole, bones,

viscera and fur all together (Molnar, 1972). Reinhardt et. al. (2007) analyzed coprolites from dry caves in Colorado and Texas sites. These researchers found that small mammal bones were found in 58 out of 100 (58%) coprolites from Colorado sites and a startling 97 out of 100 (97%) 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 three of 96 (3 %) elements were charred, possibly indicating either light cooking or no cooking. That finding 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 Reinhardt (1998), researching a population from the Lower Pecos region in Texas, found from ten to twenty percent of the weight of a dry coprolite were phytoliths from Yucca and Agave plants that were roasted in earth ovens. Interestingly, they found no dietary grit present in the coprolites.

Phytoliths are small grains of silica that are found in almost all plants. Plants draw water as part of their metabolic processes. Monosilicic acid is dissolved in that water but the plant cannot utilize that compound. Plants produce phytoliths by extruding dissolved silica into the intracellular structures where the water containing the silica evaporates leaving a sharp silica particle (Piperno, 2006). It is thought that phytoliths also help the plant by making the leaves less palatable and more abrasive to discourage grazing animals and to provide rigidity. Some plants, like rice, would not be able to stand erect without phytoliths in their leaves and stalk. Phytoliths come in a wide variety of shapes and sizes but typically are from 5-15 microns in size and are all harder than

dental enamel (Piperno 2006). Dental enamel is 4.5 to 5 on a MOH hardness scale and silica is a 7. As the plant is eaten, chewed, and ingested, the phytoliths abrade the occlusal surface of the teeth, eventually wearing through the surface enamel and exposing the dentin.

California dental wear

There are only two articles and four archaeological excavation reports that report on patterned wear in California populations (Molnar, 1968; Schultz, 1977; Basin Research, 1985; Brock, 1985; Sutton, 1988; Fong and Brittan, 1994). Molnar's (1968) seminal study made a point of stating that the wear observed in California was more severe than that seen in the two other comparative populations from Arizona and Mexico. This prompted him to devise a trinomial system to describe the form of observed wear seen. Schultz (1977) describes ten individuals from Stone Lake, CA-SAC-145, in a fishing economy with occlusal grooves on the anterior teeth.

Fong and Brittan (1994) describe six out of 45 (13%) individuals recovered from a Pleasanton California site dating from 1100 BP to 700 BP. They report both interproximal and occlusal grooves in six individuals, four females and two males. No quantification was given as to the number and location of the grooves. This was an archaeological site excavation report, not a research paper.

Basin Research (1985) records a single burial from CA-SCL-68 in San Jose California with "wear patterns not produced through mastication, non-occlusal facets and a notched upper canine" (Basin Research 1985:3). Brock (1985) also notes a burial from CA-SCL-450, San Jose California, with a notched upper right second premolar

which may have been used as a tool. Sutton (1988) recovered a single indeterminate burial CA-KER-2225 from Kern County with a pronounced occlusal groove running from a mesial distal direction across the mandibular left second incisor.

Review of previous dental scoring and aging criteria

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

Murphy (1959a, 1959b) used a large collection (he does not define the number of specimens) of Australian Aborigine skulls to delineate and define occlusal surface wear. He defined graphically 6, 7 or 8 stages of wear for each tooth in the dentition separating maxillary from mandibular as distinctly different wear entities. Murphy's precise descriptions laid the groundwork for all future scoring systems, such as Brothwell (1963), Molnar (1968), Scott (1979), Smith (1984), Drier (1994) and others.

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 which predicts that the first molar erupts at about six years of age, the second at about twelve years old, and the third from 18 to 25 years of age. By the time the second molar erupts the first has approximately six years of wear and by the time the third erupts the first molar has approximately twelve years of wear and the second molar has six years of wear. These wear stages can be plotted, given a reasonably large population of sub-adults to establish a baseline database. Miles coined the term “Functional Age of Teeth” based on the wear patterns present on the molars by the age of 20 to 25. Miles introduced the concept of seriating a population of skulls to establish youngest to oldest and then gradually put the rest into a defined age sequence, based on wear (Miles, 1962).

Molnar (1968) employed Murphy’s eight stage wear sequence and also added two elements 1) a full frontal profile of each tooth type showing the volume of the tooth loss by attrition and 2) an additional component for describing the form of wear. “Form” being not just attrition, which is just one element of a three number sequence. One digit scores attrition, another digit describes the slope of wear mesial/distal, buccal/lingual or horizontal and the third digit also describes the unusual form, as in, rounded, notched, cupped or flat.

This was the first attempt to define wear form, not just attrition, but the shape of the wear itself. Furthermore, this study seems to have been prompted by one of the three populations that he was studying at the time. This was the one from Stockton California

comprising 39 individuals dating to 2,000BP to 3,000BP. His other two populations were Pueblo farmers and Meso-American farmers. The Stockton population exhibited wear patterns that provided him with a template for the patterning he proposed with his trinomial system described above.

Scott (1979) further refined the molar section of dental scoring by dividing each molar into four quadrants. Each quadrant was scored using a scale of 1 to 10 for attrition and dentine exposure. Each molar could have a possible wear score ranging from 4 to 40. Smith (1984) refined Molnar's system by dropping the tooth profiles, eliminating the form of wear chart and the trinomial system for form scoring. She also refined Murphy's system by displaying it vertically rather than horizontally. Smith employed an eight level system for occlusal wear. Smith's scoring system has been widely adopted and is used in Standards (Bailstra and Ubelaker, 1994).

Lovejoy (1985) employed a ten point scale which was modified and adapted from Murphy. He developed nine wear grades for the maxilla and ten grades for the mandible. Lovejoy seriated the 332 dentitions using a large population of sub-adults (132) to establish the baseline from the Libben Ohio site. The methodology excluded those adults with ante mortem tooth loss (AMTL), seriated the rest of the adults and then reinserted the ones with AMTL. Based upon these results, he then re-seriated the entire population. Lovejoy also used three other aging methods: pubic symphysis, femoral head, and cranial sutures to form an aggregate aging determination. Additionally, Lovejoy used Miles' 6, 6.5, 7 attrition scale to seriate and made the assumption that wear increased with the loss of one molar row and even faster with the loss of both molar rows. Lovejoy then

concluded that “wear is regular and symmetrical and reflects increasing chronological age in the population” (Lovejoy, 1985:54). Lovejoy also stated 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) used a Channel Islands population of 97 individuals derived from disturbed archaeological contexts and isolated mandibles found without any accompanying skeletal material. These researchers used as many independent aging criteria as they had available. These criteria were the pubic symphysis and auricular surface. They concluded that using teeth alone was an acceptable method of aging a population, especially if no other skeletal elements were 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, University of Toronto, Canada. These investigators used three 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 worked best and outperformed any individual method alone. Bedford felt that seriation of each aging element, auricular surface, pubic symphysis, proximal femur, and clavicle, within the population, was important. These researchers used a single year age estimate as a methodology. For instance, by stating that an individual was 33, they were 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 (Bedford, 1993). Drier (1994) performed an aging study on 143 prehistoric Arikara using a method he devised. Drier ground 20 freshly extracted molar teeth for precise and equal time

intervals and recorded the changes found in the emergence of dentine and the removal of cusps and other features. He then scored each quadrant from 1-25 using exacting definitions and measurements. The scoring range for each molar was from 4 to 100. This researcher was attempting to gain greater precision and have better statistical information to analyze. One severe research limitation imposed by this methodology is that all tooth wear is presumed to be level on the occlusal surface. Another is that only molar teeth were utilized. This study independently aged the population using pubic symphysis and cranial sutures and concluded that, by using regression analysis, his scoring system was at least as accurate as the more conventional methods. He found no differences between upper and lower quadrants or between right and left arcades (Drier, 1994).

Miles in 2001, revisited his scoring system devised in 1962, with the intent of fine tuning the criteria. Miles postulated that every population would have a small number of truly old people. He suggested that the upper age limits are set by preconceived ideas of prehistoric populations never having individuals that lived beyond 50, 60 or 65 years of age. He felt that these age limits were set by the preconceived ideas of the researcher. He revisited the same population he seriated and aged in 1962 with an upper age limit, at that time, of 60-65. He added 35 individuals that had been excavated recently from that same population. He stated that in most populations the group that is aged under 40 is overestimated, and the population that is 50 and over is underestimated. Miles' teaching collection included 16 individuals from the Spitalfields collection, of known sex and age, which were accurately aged from 80 to 92. He concluded 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” (Miles, 2001: 976), 3) criteria for advanced age are resorption of the alveolar process leading to a thin horseshoe shaped mandible, and similar changes in the palate, and 4) seriation is critical and population specific. Miles concludes by adding 22 individuals to the over 70 age category with four of those being over 75 (Miles, 2001).

Deter’s study, used three age groups, 18-30, 31-45 and 45+, a population of 306 hunter gatherers, as well as 87 agriculturists. She found that hunter-gatherers had consistently greater wear than agriculturists. She also found that anterior teeth had a greater wear on anterior teeth than on posterior teeth. These findings are contrary to other studies by Smith (1984) (Deter, 2008).

All of these scoring systems operate under the assumptions that dental wear is constant, progressive, and age related. As people age, occlusal 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. Two researchers, Lovejoy (1985) and Miles (2001) suggest that tooth wear, properly seriated, and with a large group of sub-adults, can provide the most reliable single indicator of age.

Summary

The literature demonstrates that prehistoric peoples worldwide had been using their teeth not just for crushing and chewing foods. They also left 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 (Molnar, 1972). Prehistoric Central California Native Americans exhibit advanced wear and attrition, as well as what is inferred as culturally induced patterning, similar to other hunter-gatherer cultures like Australian Aborigines and Eskimos. Both groups are well documented to have made extensive use of their teeth for processing foods, hides and as tools (Molnar, 1968; Schultz, 1977; Hinton, 1981; Merbs, 1968, 1983).

Prehistoric Californians are unique in the sense that they never adopted 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. While processing the large amount of plant material that this entailed also involved using teeth as anvils to hold, process, remove bark and soften fibers. Most of this work is believed to have been done by women. However, men were heavily involved 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 wear and attrition (Piperno, 2006; Mathewson, 1985). Coprolite evidence demonstrates that their menu was wider and more diverse than previously believed, to the degree that small mammals were possibly more heavily exploited and eaten with bones intact (DuBois, 1935; Powers, 1877; Steward, 1941; Stewart, 1941). Ethnographic evidence from other hunter-gatherer cultures supports the contention that the definition of available edible resources needs to be expanded. What is considered edible also needs to be reexamined as evidenced by crushing bones with the teeth to

extract nutrients and marrow, as well as consuming viscera as part of the consumable package (Powers, 1877; DuBois, 1935; Gifford and Klimek, 1936).

Early explorers also provide important information regarding foods and resource acquisition processes that suggest a wider, more diverse diet than can be inferred from the archaeological record. They also provide first hand accounts of their acquisition of baskets to take back to Spain as an art form from California (Fages, 1937; Shanks and Shanks, 2006). All of this, directly and indirectly, demonstrates the use of the dentition for inferring behaviors that have remained notably obscure.

There has been no question that grit in the food is one of the causation factors responsible for the extreme dental wear seen in Northern Central 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 identified and 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.

IV. RESEARCH DESIGN

The present study employs and then refines and builds upon Molnar's (1968) seminal work defining, not just attrition, but also the form of dental wear. Existing dental attrition models attribute the wear exhibited in Central Californian Native American populations to grit from various food sources. The main causative abrasive agents usually discussed include stone grit particles retained in the flour made from grinding seeds on manos and milling stones and from acorns pounded in bedrock or portable stone mortars (Kroeber, 1925; Leigh, 1928; Molnar, 1968; Jurmain 1990). Some researchers have also suggested sand particles found in sun and wind dried fish and meat as a potential causative agent in Arctic populations of Eskimos (Leigh, 1928; Butler, 1970; Walker, 1978; Hinton, 1981; Littleton and Frohlich, 1993; El-Zaatari, 2008). Ashes from foods cooked in fires which became incorporated into the food are also suggested (Dixon, 1905; Walker, 1978). All of these environmental factors can potentially contribute causative abrasive agents involved in dental attrition.

Dental scoring has always been recorded from an overhead occlusal view with wear being scored as an ordinal or interval scale typically in increments from 1-8. A one score referring to little or no wear and an eight score being a complete loss of crown enamel (Murphy, 1959; Miles, 1963, 2001; Brothwell, 1963; Molnar, 1968; Smith, 1984; Lovejoy, 1985; Littleton and Frohlich, 1993; Drier, 1994).

Normative wear is therefore presumed to be flat and essentially level because the process of mastication from incorporated grit in the food bolus abrades the dentition. As the food bolus is chewed and moved across the teeth, grit abrades the enamel and exposes

dentine. This causation model has become firmly embedded in the bioarchaeological dental literature, and will be referred to as the “Grit Model”. Some researchers have noted various significant aberrations from this flat or horizontal pattern, which are best described as grooves (Schultz, 1977; Larsen, 1985; Fong, 1990; Littleton and Frohlich, 1993; Monozzi et al., 2003; Esched, 2006; Erdal, 2008). With the exception of Molnar (1968), Hinton (1981), and Keiser (2001a, 2001b) who worked with Molnar’s system, no one has proposed a more comprehensive system to record and quantify unique dental wear. Unfortunately, Molnar’s proposed trinomial system was not widely adopted. His proposed system was not incorporated into the Standards recording system (Buikstra and Ubelaker, 1994). It was reproduced once in Hillson (1996) and used by Keiser (2001) in two studies working with a population of Maoris.

Research questions

1) Are patterns present in the dentitions of Central California Native Americans that are different from the flat normative wear model?

2 Are there differences in the patterns present between:

- a) posterior and anterior teeth?
- b) young and old?
- c) Northern and Southern populations?
- d) males and females?

V. ENVIRONMENTAL CONTEXT

Pyromanagement

The Native Californians were not simply in California, they were California. They were an integral and essential agent in the creation of the balance of land, vegetation and animal life (Anderson 1997:16).

Early explores and travelers constantly comment on the “neatness” of the landscape in California. Following are a sampling of the comments in chronological order:

The inland we found to farre different from the shore, a goodly country, and fruitfull soyle, stored with many blessings fit for the use of man: infinite was the of very large and fat Deere which there we sawe by the thousands, as we supposed in a heard (Burrage, 1906:171). Written by Frances Fletcher describing the area inland seen by Sir Francis Drake.

The forest trees are the stone pine, the cypress, the evergreen oak and the occidental plane tree. They stand apart from each other without underwood, and a verdant carpet, over which it is pleasant to walk, covers the ground. There are clearings several leagues in extent, forming vast plains that abound in all sorts of game (La Perouse, 1989:68).

The road they pursued was plain and level as a bowling green without even a stone to impede their progress, as they advanced they passed through forests of fine oaks, the greatest part of which they left on their right hand, these oaks were scattered so far apart, that instead of incommoding or obstructing their way, they contributed much to render it more delightful... (Menzies, 1924:277).

For about twenty miles it could only be compared to a park, which had originally been planted with the true old English Oak. The underwood that had probably attended its early growth had the appearance of being cleared away and had left the stately lords of the forest in complete possession of the soil, which was covered with luxuriant herbage and beautifully diversified with pleasant eminences and valleys (Vancouver, 1953:86).

The hills and plains are verdant with a carpet of fresh grass, and the scatter of live oaks on all sides appearing like orchards of fruit trees, give to the country an old and cultivated aspect (Bryant, 1985:377).

Placerville “gradually ascending...we came upon a comparatively level country, which had all the beauty of an English park ...the oaks of various kinds, which were here the only tree, were of immense size, but not so numerous as to confine the view; and the only underwood was the manzanita, a very beautiful and graceful shrub, generally growing in single plants to the height of six or eight feet. There was no appearance of ruggedness or disorder; we might have imagined ourselves in a well kept domain (Brothwick, 1948:114).

stand more or less apart in groves, or in small irregular groups, enabling one to find a way nearly everywhere, along sunny colonnades and through openings that have a smooth park like surface (John Muir, 1988:141-142).

All of these quotes were talking about the appearance, the cultured park-like appearance, of the landscape throughout California. What none of them realized is that this was a partially man-made landscape, influenced by thousands of years of Native management. On the journey north in 1769, Portola, Fages, Constanano, and Crespi all independently comment on the fires and burned over areas they encounter which irritated them because their horses needed forage. The Native Americans were burning fields of seed producing plants after they had been harvested. The burning was to promote new growth, attract game and fertilize the ground. One of the first laws that the Spanish passed in California in the 1790s was to forbid the Indians from setting fires. This fire suppression attitude has persisted until the present day and intensified in the 1950s with the advent of the Smokey the Bear campaign. Omer Stewart (1951) put forth the idea of indigenous burning as a constructive force, but was not well received. It was not until Kat Anderson and other researchers in the 1990s began serious inquiry into the anthropogenic landscapes that opinions started to change.

Pyromanagement was a basic subsistence activity that promoted new growth of important plants, cleared out old acorn duff, controlled insects, and prevented highly destructive crown fires. Fire suppression inadvertently promotes the growth of huge fuel reserves of low growing trees and shrubs that led to destructive crown fires. The consequences have longer lasting damaging effects that would be prevented if small preventive controlled fires are utilized.

Native Americans did not use pyromanagement to promote just food production, although it was effective for that, specifically seed bearing grasses, but rather they utilized this technique more for production of medicinal plants, tobacco, basket and cordage making materials.

California Indians did employ various cultivation methods in the management of the regional landscape. But they reserved the most labor intensive methods per unit primarily to tend non food resources—growing tobacco and cultivating specific plants for basketry and cordage materials (Lightfoot, 2009:128).

As populations increased and territories shrunk, most tribal groups were evenly spread across the landscape but had limited territories (Milliken, 1995). They used sustainable harvesting techniques to ensure continuous production of critical materials. The production of the amounts of cordage and basketry materials they utilized was not possible with natural regimes of plant production. Straight, unblemished shoots with no lateral branching scars simply do not occur without disturbance from fire, flooding, or pruning (Anderson, 1993, 1997, 1999, 2005). Native Americans must have observed this difference and sought to mimic the disturbance regime to procure materials that were essential to their material culture. Looking at museum collections of plant materials

gathered for basket making, as well as pictures, native basket makers show huge quantities of materials that appear almost artificial in their straightness with consistent lengths and thicknesses (Merrill, 1973; Anderson, 1993, 1995, 2005; Shanks and Shanks, 2006).

California Native Americans were viewed as simple people with marginal cultural accomplishments (Bean and Vane, 1990). Classing them as hunter-gatherers over simplifies the conception. Normally the designation in the literature is either hunter-gatherer or agriculturist, with agriculturists being thought of as a more advanced level of culture.

There is a spectrum, and different peoples fall on different spots on that spectrum. The spectrum encompasses five distinct markers; gathering, protection, encouragement, cultivation, and agriculture (Doolittle, 2000). Pure hunter-gatherers like the Hazda of Tanzania and the Inupiat of the north slope of Alaska contrast starkly with agriculturists of the Southwest and the Southeastern United States who were maize dependent cultures. These are polar opposites. In between these two poles there is protection, with humans enhancing some natural characteristic of the plant. Encouragement is manipulation of plants that occur in the wild using techniques like pruning, coppicing and burning. Cultivation is the propagation of wild species such as tobacco in California near village areas (Shaler, 1808; Kroeber, 1925; Harrington, 1942; Doolittle, 2000). At the extreme agricultural end of that spectrum is corn, which without human intervention, cannot reproduce.

California Natives fell along the gathering, protection, encouragement, and cultivation elements of this spectrum. Except in the southeastern corner they did not practice agriculture. They gathered wild species; they protected acorn groves from fire by burning the underbrush before it became dangerous. They encouraged many, many kinds of basketry materials like deergrass, hazel, and sourberry thickets to produce far beyond their natural reproductive capacities. Finally they cultivated by storing and sowing tobacco seeds in plots near their villages (Shaler, 1808; Anderson, 2005).

There is a pendulum that has swung between the California Natives being described as “simple” hunter-gatherers on the one hand, and being conscientious stewards of the landscape along the idealistic lines of modern restoration environmentalists. The reality is that they were at different points along the spectrum at different times during their resource gathering tour of the landscape. They did some cultivation, like tobacco. They certainly gathered, stored and processed storable resources like acorns, seeds, and anything else that could be dried and stored. Excessive growth was encouraged and structured using strategies such as burning and pruning to maximize any and all raw basketry and cordage materials that they needed to support their material universe (Anderson, 1993, 1995, 1997, 2005; Lightfoot, 2009).

They protected their resources from other tribes, as well as faunal and avian competitors. They used fire as a baseline tool to manage and control their environment. They were not stewards, they were intelligent manipulators of the environment for their own ends and invoked, “Two general rules, do not waste resources and do not hoard

resources; greed, wastefulness or disrespect for other life forms causes the worlds to go out of balance” (Anderson, 1997:33). California Native groups were described as:

There were examples of the highest socio cultural development known among the so called hunting and gathering peoples. Peoples of widely disparate cultural backgrounds, language and religion lived side by side, sharing much, while keeping autonomy and identity quite distinct. California Indians have for a very long time been viewed as simple peoples. Nothing could be further from the truth. (Bean and Vane, 1990:265).

Foods and other things people put in their mouths

The native foods most noted by Portola, Fages, Costanso and Crespi included seeds as a form of sage gruel, fish, (Chumash and Bay area), deer, elk geese, and other waterfowl (Brown, 2001). The cross cultural definition of what was acceptable as food is illustrated by the incidents the expedition suffered on the first Spanish expedition into California in 1769. Scurvy was so epidemic and diarrhea (a symptom of scurvy) that Portola’s expedition had to halt north of Monterey, near Half Moon Bay. They stayed for three days because the company was heavily impacted by scurvy and hunger and could not make further progress. Brown (2001) and Browning (1992) attribute their recovery to the blackberries and rose hips, containing vitamin C, that were found there. They carried their own flour with them to make tortillas and ended up rationing the flour to the weakest individuals “daily ration of five tortillas made of flour and bran; we had neither grain nor meat” (Costanso, 1911:111). Within 50 miles of their location, 17,000 Native Americans were flourishing on a unique to California hunter-

gatherer diet of seeds, acorns, roots, culms, fish as well as large and small game (Milliken, 1995).

**Native Californians had a very different relationship with their food, than
industrial, agricultural societies**

Technomic, sociotechnic and ideotechnic are classifications of artifacts and material culture that include aspects of food acquisition, procurement, processing and consuming within all cultures (Binford, 1962). Almost all cultures have evolved societal structured rules for the foods they acquire process and consume and also for what is socially defined as food. The foundation for Judeo-Christian society is the Bible:

1 Then God blessed Noah and his sons, saying to them, "Be fruitful and increase in number and fill the earth. 2 The fear and dread of you will fall upon all the beasts of the earth and all the birds of the air, upon every creature that moves along the ground, and upon all the fish of the sea; they are given into your hands. 3 Everything that lives and moves will be food for you. Just as I gave you the green plants, I now give you everything (Genesis 9:1-4).

Hunter-gatherer cultures treated their food resources quite differently. There are very few true hunter-gatherer cultures left in the world and they have all been pushed into marginalized environments that make their temporal existence harder and more dangerous (Lightfoot, 2009). Their food acquisition and procurement rituals involved an ongoing level of respect for the living creatures they designated as prey. All beings, plants, animals and men, had spirits that were equal. Proper treatment and respect kept the universe orderly, and allowed people to survive and the animals they needed to keep allowing themselves to be taken.

California was a unique cultural environment which supported the largest populations of Native Americans in North America, north of Mexico, at contact. California prehistoric population estimates varied but a generally accepted minimum is 330,000 to 350,000 at contact in 1769 (Cook, 1942). Powers (1877) fought with his editors over the population issue. He felt, after visiting most of the remaining tribes in California in 1871 and 1872, that an accurate prehistoric population estimate was 1,520,000 at contact. J. W. Powell, his editor, insisted that was too high and Powers reluctantly reduced it to 705,000. In the local San Francisco Bay area, the best estimate for the local population at contact is 17,000 calculated by Milliken upon exhaustive review of Spanish mission baptismal, birth, and death records (Milliken, 2004).

The key to supporting these dense populations was the storage and availability of high quality, nutrient and calorie dense food materials. Kroeber called it “The Food Problem in California” (Kroeber, 1925).

The California Indians are perhaps the most omnivorous group of tribes on the continent. Further, the food resources of California were bountiful in their variety rather than in their overwhelming abundance along special lines (Kroeber, 1925:523).

This statement reflects the contrast between the bison dependent cultures of the central plains, the salmon dependent cultures of the northwest coast and the wide multi line harvesting system of the Californians. If one resource failed another was exploited.

The best definitional approach of what constitutes food for Native Californians is to start from a zero based perspective. Everything in their environment, animal or vegetable could be considered food. It took millennia of trial and error to refine and define what constituted acceptable foodstuffs. Native Californians were the only Native

American culture to convert acorns into a nutritious storable commodity that formed the economic foundation baseline everywhere within the state that oaks were available (Mayer, 1976).

Other Indian populations, such as the Iroquois, added lye and alkali compounds when boiling acorns to detoxify them (Mayer, 1976). The Indian cultures in the Southeast boiled acorns to extract the oils they contained (Mayer, 1976; Gifford, 1936). In Arizona and New Mexico, Indian cultures only utilized “sweet” acorns, with little or no tannic acid, and then only to a very limited degree. They treated them almost as famine food (Gifford 1936). Mesoamerican cultures, in northern Mexico with stands of oak trees available, never utilized acorns directly as food, but historically found them acceptable only as hog food (Gifford 1936).

Making acorns edible was a five step, labor intensive process involving 1) gathering, 2) shelling, 3) grinding, 4) leaching, and 5) cooking. California tribes were the only Native American cultures to systematically analyze and develop methods to remove the tannic acids that made acorns bitter and unpalatable (Mayer, 1976; Gifford, 1936). This involved developing a method for leaching tannins out of the acorn meal. It is thought that the immersion method probably came first in which quantities of acorn were buried in a stream bank and the tannins were allowed to leach out naturally over a several month period, then removed and processed into meal and cooked (Mayer, 1976). This leaching process later evolved into two time-shortened constrained methods, the sand basin and the twined basket method. By pouring either hot or cold water over the acorn meal the tannic acid could be leached from the acorn meal. The sand basin method was

used primarily in the north and the basket method primarily in the south, with the central area using both methods. There were positive and negative elements to this process. Hot water worked faster and with less time consumed but also leached out some of the valuable oils that acorn meal contained. Cold water took longer, with as many as ten pours, but fewer oils were leached out. Both methods required greenery laid over the acorn meal to avoid disturbing the meal and to prevent the acorn meal from being washed away. The meal was then boiled to make acorn soup or a thicker compound labeled acorn mush. A still heavier compound sometimes was made into bricks and baked as bread. Two quarts of dried acorn meal produced ten to twelve quarts of acorn soup, a couple of quarts less if it was made into a thicker mush and 6-8 quarts if the mixture was molded and made into bread (Grinnell, 1893; Mayer, 1976). The finished product, as soup or mush, was sometimes mixed with clover or meat and consumed immediately. When it was made into acorn bread it could be kept for three weeks (Grinnell, 1893).

Grit. The mechanics of pounding and grinding acorns in a stone mortar with a stone pestle to make acorn flour, causes tiny particles of rock to spall off from the surface of the mortar and the pestle. These particles or “grit” become incorporated into the acorn flour, which when consumed are hypothesized to be causing the extreme wear seen in Californian Native American teeth (Leigh, 1925, 1928; Molnar, 1968; Jurmain, 1990). This theory is the widely accepted, established standard explanation for the extreme dental wear seen in California Indian populations. This causative explanation may have started with Leigh in 1928 who was a dentist, which added credibility to the suggestion. “The technique of preparing the flour and subsequently cooking it, through the

introduction of extraneous abrasives, apparently has deleteriously affected the teeth of aboriginal California” (Leigh, 1928:411). Over the ensuing eighty years, various other causation factors have been considered but only as supplemental add-ons, never as primary causative agents. The hypothesis that other factors have contributed to the amount of wear found in California Native populations has been introduced by several researchers. Molnar (1968) suggested basketry materials as a contributor to dental wear, Larsen (1985) also strongly implied basketry for a Nevada population. Schultz’s study (1977) suggested fishing cordage and lines for CA-SAC-145 at Stone Lake, California site. Jurmain (1990) noted basketry materials as a possible causation factor for the CA-ALA-329 population’s extreme wear.

There has been one experimental study conducted to look for evidence of this process. Teaford and Lytle (1996) ran a replication study in which one individual, Lytle, ate one corn meal muffin with every meal for a week. The corn for the muffins was ground on stone metates of two types, one made of sandstone and one of igneous rock, a much more resistant material. The results showed that, over and above the normal wear baseline of scratches and pits, the corn meal ground on the igneous surface showed 13 times more wear features and the sandstone ground cornmeal showed 30 times more wear features. Since dental enamel is only 1-2 mm thick, they estimated that it would take ten to fifteen years of this type of wear to remove the enamel (Teaford and Lytle, 1996). To date, this is the only experimental study utilizing traditional grinding methods, and isolating the consequent contaminated meal as the cause of the replicated wear.

Ethnographers and archaeologists have made the distinction between metates being used for hard seeds and mortars being used for acorns. Both processing instruments are made of stone. There is evidence that Californian Native Americans did create and use wooden mortars. The first mention of a wooden mortar is de Unamuno in 1587 at a village inland from Morro Bay. They were looking through a deserted village “and a trough made out of a tree trunk, in which we infer, they ground roots or tree bark for some dish or drink of theirs”(Wagner, 1923:154). Menzies, Vancouver’s naturalist, states:

We have already remarked that the Natives were at this time busily occupied in collecting Acorns and storing them up for food, these they shell toast and dry as we do coffee and afterwards pound them in a Mortar to coarse flower which they make into bread and eat with their fish; The Mortars used for this purpose are generally of wood though we saw some made of Stone and pretty well finished (Menzies, 1924:325).

Wooden mortars and pestles are mentioned in several ethnographies, most notably by Harrington (1942) in the Costanoan region. The wooden mortars are described as hollowed out in the side of a log. In 1792, Caderno describing seed processing: “Then they grind them in wooden mortars, very well made by them” (Cutter, 1990:140). Leonard (1839) traveling with Captain Walker’s expedition in California along the Merced River stated:

They go to a large log and build a fire upon it and burn it half or two-thirds of the way through, which is done by keeping the log wet except about a foot in diameter, where the fire is kept up until the hole is deep enough and the proper shape. After the hole is burnt deep enough they extinguish the fire, scrape out the coals and ashes and have a tolerable well shaped hopper. When this is done they get a long stone which is rounded at one end, and put the acorns in and commence mashing them fine, which is easily done as they are always previously dried by fire or the sun. The meal thus made is taken out and mixed with water in a

basket made almost water-tight—which they broil by making stones red hot and throwing them into the basket. By this process they make a kind of mush with which any hungry man would be glad to satiate his appetite. In the summer they subsist principally upon acorns, at least a person would so judge to see the number of holes that were burnt into the logs for the purpose of mashing them (Leonard, 1839:104).

Wooden mortars and pestles may have been important processing tools in archaeological populations but would not have preserved archaeologically in midden or burial context. They would have had one major theoretical advantage, no spalled grit in the acorn meal to impact dentitions in a negative manner.

It is beyond the scope of this study, but valid experimental research questions can be posited for addressing this issue, 1) While pounding acorns with a rock pestle impacting on soft acorns and acorn meal in a stone mortar, how much spalled rock is there? 2) During the leaching process do the heavier rock particles separate from the acorn meal and wash out? 3) During the cooking process, do the heavier rock spalls settle to the bottom of the cooking basket? 4) During consumption of acorn soup, mush or bread how much hard mastication is required? 5) And lastly, acorns and their processed products are very soft materials with no hard or rigid components, by what mechanism are the theorized spalled particles abrading the teeth?

Acorns. California ethnographic reports, both informal (1825-1900) and academically formalized (1900-1950) abound with reports of the processing of acorn meal. More than a few of them make a point of mentioning how carefully the sand (Northern method) is removed from the meal, and how important that was to the women doing the processing. Grinnell (1893), visiting the Yosemite Valley, records the acorn leaching and cooking process:

Then began the separating of the inferior from superior flour. There were three grades—the coarser, which was on the surface of the reservoir; the bottom or leavings which were next to the sand filter; and between these two, the clean, fine sort. With the edges of the two hands, the top of the meal was scraped off into a basket, into which hot water was poured and rapidly stirred. The agitation caused the meal to separate from the sand, and it was turned off, leaving the residue of debris in the bottom. This operation, repeated three times, left a clean coarse material for “mush”. Now the first layer of material in the filtering reservoir had been disposed of and we hasten to the next or middle portion. This was scooped out by the hooked fingers placed in a basket and set to one side. There was now nothing left in the basin but the lining coat of flour. This was peeled off with its adhering sand, and treated to several generous washings and drainings, similar to the first batch. When it was ready for the porridge pot, there was supposed to be no trace of grit in the whole basket. “(Grinnell 1893:43)

The middle flour, “the clean, fine sort,” is made into acorn bread, the heaviest of the acorn mixtures. Each loaf was the size of a rubber ball, heavy and dense. They would cool and harden in the stream for two to three hours. Then they were stored for up to three weeks, when the next baking day would occur (Grinnell, 1893).

“Native Californians are now widely regarded, by anthropologists and the general public as acorn eaters” (Jacknis, 2004:12). This attitude does not reflect the depth and breath of actual subsistence commodities utilized. Not only were California Native Americans omnivorous in terms of diet breadth but are estimated to have used over 500 plants and animals as food (Kroeber, 1925; Heizer and Elsasser, 1980). Several ethnographies record teeth being used to assist in processing acorns. Ethnographers observing tribal groups have noted many incidences of acorns being shelled with teeth (Grinnell, 1893; Dixon, 1904; Merriam, 1918; DuBois, 1935; Mayer, 1976). Lucy Thompson (1916), a Yurok tells how, after the evening meal, the family, men, women, and children would sit around the fire and remove the hulls off the acorns with their teeth:

and commence taking the hulls off so as to get the meat of kernel out. This is done by the teeth, and it is wonderful how expert we become at it; and it is seldom a kernel is mashed or bruised (Thompson, 1916:280).

They used an amazing variety of resources for food but they had only one processing tool, the mortar/pestle, and its one alternative ground stone tool, the metate/mano. Since mortar and pestle processing is thought to have heavily contributed to contaminating the acorn meal with “grit,” it is important to look at this processing technology.

Plant materials. There are two remaining food groups pertaining to tooth wear. Berries, while an important food resource, do not appear to be implicated in occlusal wear, having no internal or external abrasive elements. However, berries, such as raspberries, gooseberries, madrone berries, barberries, blackberries, manzanita berries, skunk berries, juniper, and boxthorn berries have all been documented as being ground in mortars and therefore may have absorbed spalled particles from the mortars (Schultz, 1981). Thus, it is possible that grit due to berry processing may have affected tooth wear.

The other food group important to dental attrition is greens. Greens are an underappreciated, underreported, resource category. At first glance, edible plants would not seem to be overtly involved in dental wear. However, a great percentage of leafy plants structures contain phytoliths (Piperno, 2006). Plants draw water up through their roots along with dissolved minerals during normal respiration and chlorophyll producing activities. The water gets metabolized by the plant or it is removed through transpiration from the surface of the leaves. Available minerals, if they can be used by the plant, are incorporated into the plant tissues, and the remaining ones, like silica, magnesium, and

aluminum are extruded into spaces between the cells and there form crystals called phytoliths.

Phytoliths are sometimes species specific, but in a significant number of cases, are amorphous, typically appearing in the microscope field as long flat plates of irregular shapes. Silica phytoliths are, essentially, small pieces of silica which when chewed upon or drawn across the occlusal surfaces of teeth produce microwear and/or scratches. Two studies, by Reinhard et. al. (2007), and Reinhard and Danielson (2005), proposed the causation of the extreme dental wear found in a Pecos, Texas population solely to phytoliths from agave and yucca consumption. The evidence for this determination came from coprolites they investigated that had 20% of their dry weight categorized as phytoliths. After cooking the agave and yucca leaves, intense mastication is required to release the carbohydrates imbedded in the fibers of the plants. This process of intense mastication would cause the phytoliths in the leaves to abrade the teeth, leaving microwear patterns. The physical evidence, besides the teeth, is the residue fiber bundles that are spat out and preserved in dry caves as quids and are found by the thousands.

Hartnady and Rose (1991) found the same extreme wear, and the coprolite evidence showed the same plant materials, agave, yucca, and prickly pear phytoliths; along with small mammals eaten whole, as the primarily proposed causation elements. Danielson and Reinhard (1998) dissected and analyzed 14 coprolites for phytoliths and found no dietary grit in any of them. This may support a counterargument to the grit in the diet hypothesis as causation for the dental wear seen in California.

Plant resources were numerous and plentiful but seasonal. High on the list were the clovers. There were clovers growing early in the spring and eagerly sought by Native Americans.

In the clover season, when the meadows were bright with pink and white blossoms, whole rancherias went out literally to graze, and the Indians, might be seen lying prone in the herbage, masticating the clover tops like so many cattle (Mooney, 1890:255).

After a long winter and early spring of eating acorn mush, dried meats and game, a huge helping of fresh greens must have been welcome and would also help prevent scurvy. There were over 37 green plant species consumed by the Miwok. Most were stone boiled or steamed in an earth oven (Barrett and Gifford, 1933). An equal and possibly larger number of exploited green plant species is recorded by Chestnut (1902) for Mendocino County, and Timbrook (2007) records a multitude of plants used by the Chumash and the Ohlone.

The vegetation in the Contra Costa County and Santa Clara County areas certainly differed in mixture but probably not in plant inventories. Most of the plant resources found and used in other areas were likely exploited by the local populations in Contra Costa, Alameda, and Santa Clara counties. In one dental microwear study, it was found that one individual, whose main diet during the study consisted of salads, had the worst micro wear damage of all the subjects in the study (Teaford and Tylanda, 1991). Plant remains found at CA- SCL 732 and CA-SCL 690 consisted of ten edible greens, sixteen plant species with edible seeds, and an additional three species with recovered but uncarbonized seeds. All were recovered in a midden context from CA-SCL-732 and CA-SCL-690 (Milsicek, 1993).

Basketry Materials. Another group of plants rich in phytoliths are basketry materials. Though exposed to pottery by trading and contact with the Colorado River tribes in the southeastern portion of the state, they never adopted the technology. Instead, they made baskets, dozens and dozens of different kinds and forms of baskets. Baskets were lightweight, portable, did not break and were made watertight and waterproof. They were 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, tubers, dried fish, dried meats, and dried berries were all stored in baskets. Baskets that were made so tight they were used for cooking with hot, boiling liquids. They used pitch and asphaltum to waterproof water jugs made from baskets. Native women made baskets to winnow, gather, and store seeds. From the same basketry materials they made seedbeaters, cradles, and cradleboards. Men also manufactured 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 boats.

Choris' drawings made in 1816, show headgear that had woven components as well as tule boats, woven skirts, and belts for the women. One painting that is seldom reproduced shows baskets and hunting gear. Basket making and the use of basket materials pervaded their material culture. California Native Americans began life in a basketry cradle and cradleboard and ended life by having their favorite baskets ceremonially burned at their funerals. Shanks and Shanks (2006), in their seminal book on Northern California basketry, 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 often survive in an archaeological context. Today baskets are a recognized art form worldwide and California baskets are the apex of the basket pyramid (Shanks and Shanks, 2006). Menzies, traveling with Vancouver in 1793, recorded:

But the most curious article we observed amongst these Natives were their Baskets which are of various shapes and sizes and so closely worked as to hold water, but by means of dying the Materials of various colors they work in them figures and ornaments of the most complicated kind; We have seen representations of different animals, the Arms of Spain, and long inscriptions worked in these Baskets by these illiterate people with a degree of exactness that was really astonishing and this we believe is chiefly performed by the Women (Menzies, 1924:326).

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 (Shanks and Shanks, 2006).

In order to understand the relationship that baskets had for California Native Americans an understanding of their land management practices is useful. California Native Americans managed the land and its resources in a very proactive fashion. They were not prototypical hunter-gatherers wandering across the landscape, eating resources as they went, and moving rapidly from place to place. Many were semi-sedentary and moved in seasonal rounds of gathering and hunting (Lightfoot, 2009). They had a rich diverse environment to choose from, but they also had limited territories (Milliken, 1995).

In the last 1,000 years before contact, Native Californians had fairly strict territorial boundaries with extensive trade networks. These trade routes brought in critical raw materials, like obsidian and scarce basketry materials, which were lacking in their own territories (Davis, 1961; Lightfoot, 1993; Milliken, 1995, 2008). Increased population densities forced them to become creative with their resources. Their main sources of food came from within ten to fifty miles of their central location. Being restricted in territory dictated maximal usage of the resources available to them. As such, they used pyromanagement as a primary land management technique (Anderson, 1993, 1996, 2005; Blackburn and Anderson, 1994; Lightfoot, 2009). Fire removed the underbrush from the oak savannahs. Fire 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 new long straight shoots which were harvested the next year for basket materials and arrow shafts.

Merrill stated that there were 78 different species of plants used in California basketry (Merrill, 1913). The information was derived by analyzing the basketry collection housed at the University of California in Berkeley. Shanks and Shanks noted that most tribes used ten or less species of plant materials when making basketry (Shanks and Shanks, 2006). Specifically for the Costanoan/Ohlone linguistic region at least 14 plant species that were associated with or identified on Ohlone baskets.

Materials: Coiled Ohlone baskets had foundations of peeled shoots, probably willow and hazel (Mathewson 1998:148). Wefts were made of sedge root (*Carex*). Black designs were of dyed bulrush root (*Scripus*)

and occasionally bracken fern root (*Pteridium*) (Bocek 1984, 247; Dawson p.c.). ... (Ibid:30)

Ohlone Twining Materials: Sedge root was the most important Ohlone basketry weft material (Merriam 1967, 381). For warps, the preferred materials were willow and hazel (Mathewson 1998, 148, 167, 179). Dogwood (*Corylus*) and chamise (*Adenostoma fasciculatum*) were also said to have been used as warp materials (Bocek 1984, 252, 249). As mentioned, horsetail and Indian scouring rush (*Equisetum*) were apparently used for black designs in twined baskets. Juncus rush (*Juncus*) was used on one winnowing basket for designs. (Ibid:33)

Berry Basket: It was made of tule and lined with sycamore leaves (*Platanus racemosa*) to prevent the berries from falling between the warps. (ibid:34)

Acorn Storage Baskets: These were made of peeled willow warps and were coarse utilitarian baskets wrapped with willow bark. The bottom was covered with cattail (*Typha*) leaves and the top with madrone (*Arbutus menziesii*) leaves. (Ibid 35) Of these 14 species of plants the following could be harvested in (meadows and wetland environments) riparian and fresh water Tule Marsh communities: 1) bulrush (*Scripus californicus*), 2) cattail (probably *Typha latifolia*), 3) tule (*Scirpus acutus*), 4) sedge (*Carex densa*), 5) Juncus [common rush] (*Juncus patens*) 6) horsetail rush (*Equisetum laevigatum*), 7) Indian Scouring 'Horsetail' Rush (*Equisetum hyemale*), 8) willow (probably *Salix lasiolepis* or *Salix scouleriana*) and 9) Sycamore (*Platanus racemosa*.)

Plants found within the California Prairie/Oak Savanna communities include: 10) bracken fern (*Pteridium aquilinum pubescens*), Plants found within the Chaparral/Mixed Hard Wood Forest communities include: 11) Chamise (*Adenostoma fasciculatum*), 12) Pacific Madrone (*Arbutus menziesii*), 13) California Hazel (*Corylus californica*) and 14) Pacific or Western Dogwood (*Cornus nuttallii*) (Shanks and Shanks, 2006:33-35).

Certain basketry materials were used more often than others, willow (*Salix sp.*), beargrass (*Xerophyllum tenax*), deergrass (*Muhlenbergia rigens*), hazel (*Corylus cornuta*), redbud (*Ceris orbiculata*) buckbrush, (*Ceanothus cuneatus*), bulrush root (*Scripus*), cattail (*Typha*), Juncus (*Juncus*), sedge root (*Carex*) and Scouring rush (*Equisetum hyemale*) are the primary plants used in baskets (Merriam, 1967).

Overall a massive quantity of materials were needed to manufacture everyday necessities, such as baskets, and any kind of hunting and fishing gear that required cordage. Individual tribal territories were relatively small, as little as 81 to 225 square kilometers (Milliken, 1995). Given the large amounts of materials needed for basketry, active pyromanagement was imperative to maximize the plant communities' productive capabilities. Blackburn and Anderson (1993) state that a single cradleboard took 500-675 straight sourberry sticks from at least six burned patches, a medium cooking basket would require 3,750 deergrass stalks from at least 75 healthy plants that had been previously burned (Blackburn and Anderson, 1994). This required an understanding and appreciation for land and botanical plant management:

Deergrass were used in bread molds, eating dishes, burial baskets, cooking baskets, acorn flour sifting trays, flat plaques, gift baskets, storage baskets, coiled burden baskets, basket hoppers and loosely woven bread baskets [Bates, 1982; Harrington, 1942; Zigmond, 1978] Native Americans had to manage and maintain abundant populations of certain plants at what was virtually an industrial level (Anderson 1996:413).

Part of the basket making process is harvesting and splitting the material into usable lengths. Anderson (2005:44), in a picture, shows the mouth and teeth being used in this process, as a third hand, to hold the root in the teeth while both hands are used to split and process the root into material for twining baskets. Curtin (1949) notes "the end of the split cattail is held between the teeth while the work continues" (Curtin, 1949:117). Many other basketry materials utilize the teeth as direct processing equipment. Teeth were used to soften the shoot or stalk of milkweed, with saliva as the fluid and teeth as the hammer and anvil. The teeth were used to grip the materials while the hands did the splitting. Wheat (1967; Powers, 1877) in working with the Paiutes, shows a series of

eight pictures of a female Paiute using her teeth to strip and hold basketry materials and noted:

Most importantly, every woman carried bundles of long, slender willows which had been scraped white, and coils of willow sapwood that she had gathered and prepared during the winter months when the leaves were gone. These willows were the raw material necessary for the manufacture of nearly all of the family's household goods. From them she wove the tough little water jugs that she carried in her hand against thirst in the desert. From them she made cradles for the newborn infant, the hat that protected her head, the vessel in which they cooked, the bowl into which she served, and the tray in which she parched seeds, harvested berries, dried meats, cleaned nuts and roots and with which she seined fish. From the willows she wove the beater with which she gleaned the seeds from the grasses, and the baskets on which the seeds were collected. And finally, with these willows she made the basket in which she carried all the other baskets (Wheat, 1967:92).

Then, gauging with her tongue and teeth, she split the willow lengthwise into three equal parts.....she took a new grip with her teeth and continued splitting. Taking the woody center again in her teeth... (Wheat, 1967:93-94).

They gather these sticks by the thousands and take them home, where the women, children and men all join in peeling the bark off the sticks. They take up a handful in the right hand, then place the butt end on one of them in their mouth, taking hold of it with their teeth and the left hand, giving it a twist so as to peel the bark around the end; and as they get the bark started they give the stick one quick jerk and the bark peels off at one effort (Thompson, 1916:31).

Research by Larsen examining the grooves he found in anterior teeth of prehistoric Indian dentitions in Nevada, corresponded exactly to the angles which were demonstrated in Wheat's photographs (Larsen, 1985). Barrows (1900) working among the Coahuilla witnessed them using their teeth to split rushes into three equal portions. Several other researchers, working with tribal groups, have also documented watching them using their teeth when processing plants into basketry materials (Coville, 1892;

Gifford and Klimek, 1936). In some cases, the type of plant material used can be very abusive to the teeth, specifically *Juncus* stems that were recorded being used by a Kumeyaay woman (Campbell, 1999). This particular plant is very heavy in phytoliths. This plant, also called horsetail and/or scouring rush, was used by the Costanoan as a basketry material to produce black designs (Shanks and Shanks 2006). Scouring rush is so rich in phytoliths and so abrasive that it was used by the Chumash to sand down wooden bowls and to smooth arrow shafts (Timbrook, 2007). Pictures of Scouring Rush (*Equisetum hyemale*) show phytoliths glistening along its stems and leaves. If, as stated above by Shanks (2006), it was being used as basketry material in Costanoan territory and if it is assumed that teeth are used in the preparation of this material, its extreme abrasiveness could be viewed as a prime contributor to occlusal dental wear and the creation of wear patterns.

Cordage. Ethnographically, basket making and basketry in general, from the procurement and harvesting of the raw materials, to the processing, storage and the eventual utilization of these materials into finished products was gender certified as being women's work (Willoughby, 1963). All of the Spanish contact diarists, (Brown [for Crespi] 2001, Fages 1937, Guerrero [for Anza] 2006, Browning [for Costanso] 1992), and later ethnographic accounts from foreign visitors, are resplendant with notations of the basket work of Native Californians, and that women are the ones that made the baskets.

Crespi states that:

“on their heads a great many fathoms of a sort of cord of theirs that they make their nets with, and many fathoms more of strings of their shell

beads so that their heads all made up they look as though they were wearing a large turban.” (Brown, 2001:385)

String and artifacts made of string are mentioned or implied, many times by Crespi as he traveled north with Portola. Along with baskets, cordage was one of the primary foundations of their material culture.

If women made the baskets, men made hunting equipment and, most importantly, cordage (Wheat, 1967; Hoover, 1974; Mathewson, 1985). It is difficult to overstate the importance that cordage had to the material culture of California Native Americans. Cordage was the foundation material that was the origin of their hunting equipment, nets, snares, and thong belts for carrying essentials and anything that needed to be strung or sown together from women’s skirts to rabbit skin blankets.

Cordage was made from just a few plants that produced long bast fibers that run the length of the stem (Hoover, 1974; Mathewson, 1985; Gottlieb, 1999; Timbrook, 2007). Bast fibers are long fibers that are just under the skin of certain plants and detach from the woody core easily. The principal plants utilized were dogbane or Indian hemp (*Apocynum cannabinum*), milkweed (*Asclepias sp.*), iris (*Iris macrosiphon*), yucca (*Yucca sp.*), agave (*Agave sp.*), and nettles (Hoover, 1974; Mathewson, 1985; Timbrook, 2007). All California tribes made and utilized cordage from the plants available in their territories, but not all tribes had enough of certain types of preferred plants, such as dogbane. If the favored plants were not available, they traded with neighboring tribes to procure the desired materials (Davis, 1961; Hoover, 1974). Plots of land that produced quantities of certain desirable plants were guarded and protected. “The owner would jealously guard his plot until the plants ripened and hurriedly harvest them for fear others

might get to them first” (Garth, 1953:33). To remove the long bast fibers from the dogbane or milkweed stems, either a pair of stones was used to crush the outer woody stem to more easily remove the inner fibers or teeth were used to achieve the same result (Powers, 1877; Wheat, 1967; Edholm, 1999; Gottlieb, 1999).

In the Central area of California the principal plants used for cordage were dogbane and milkweeds (Mathewson, 1985; Timbrook, 2007). There is no ethnographic notation of Iris being used in Central California even though the plant does grow as far south as Santa Cruz. It is quite possible it was used and not observed or recorded. Hoover (1974) notes that a special tool was used to strip Iris fibers, a mussel shell thumb guard. He stated that if the thumb guard is present, Iris was being processed. Thumb guards are found in the Costanoan area in burial context so it is logical to add Iris fibers to the list of Costanoan cordage materials (Hoover, 1974).

The northwestern tribes used Iris to the virtual exclusion of other fibers and were skilled at forming this fiber into snares, ropes, and netting that was used as an exchange mechanism (Mathewson, 1985). Iris ropes were a standard fifteen feet in length and when lent out to snare deer and elk, the owner got a share of the kill just as if he had been part of the hunting party (Goddard, 1903; DuBois, 1935; Nomland, 1935). Iris ropes also had a “magical” element to them. A hunter would gather the raw materials himself which took three or four days, and a week to actually make the rope and it would be constructed in the forest away from the influence of women (DuBois, 1935). The Chumash used milkweed to lash their plank canoes together as water made the fibers harden and it did

not rot. They also used milkweed for all of their fishing lines and nets for the same reason (Timbrook, 2007).

Quantities of the raw materials needed to make nets, snares and basic string are difficult to comprehend:

Craig Bates of the Yosemite Museum has estimated that approximately five stalks of Indian Hemp (*Apocynum sp*) or milkweed (*Asclepias spp.*) would have been required to manufacture one foot of cordage (Craig Bates, personal communication 1992); a Sierra Miwok feather skirt or cape containing about 100 feet of cordage made from approximately 500 plant stalks, while a deer net 40 feet in length (Barrett and Gifford 1933) contained some 7,000 feet of cordage, which would have required the harvesting of a staggering 35,000 plant stalks (Blackburn and Anderson, 1993:23).

Although the deer net described above required 35,000 plant stalks to manufacture, ethnographic evidence of much larger fishing and rabbit nets, up to 100 meters (300 feet) long, would have utilized an even larger quantity of plant materials (Stewart, 1941; Wilson, 1972; Swezey, 1975).

In several ethnographies, teeth are mentioned as being used to assist in the manufacture of arrow shafts. Barrows (1900) describes the Coahuilla using teeth to peel, notch and straighten wormwood arrow shafts. Coville (1892) reports on the Paramint straightening reed arrow shafts with the teeth. Nomland (1935) working among the Sinkoyne mentions elderwood arrow shafts being straightened by holding them in the teeth while whittling the shafts with a flint knife.

Small mammals. Other impacts to the teeth and dental wear are seen with the introduction of small mammals to the diet that were processed in mortars. Specifically, in 1928, Leigh mentions younger tribal members catching small rodents for edentulous

older individuals who pulverized them in their own small personal mortars. Barrett and Gifford (1933) record “For old people with few or bad teeth dried meat and fish were pulverized in a mortar” (Barrett and Gifford, 1933:209), while Gifford and Klimek (1936) document small mammals being cooked, pulverized, and shared out.

Small mammals are underreported, under-researched and underappreciated as a critical part of the California diet. Large mammal bones are the most recognized and best preserved of animal bones in an archaeological context. Smaller mammals tend to be either ignored or assigned to a depositional or bioturbation context rather than being included as prey animals. Broughton’s (1994) article looking at foraging efficiency specifically excludes insectivores, lagomorphs, and rodents, because of their questionable depositional origin. He was looking at foraging efficiency in 18 of the major San Francisco Bay area shell mound sites, and found that large game, specifically artiodactyls, had decreased in size over time. This finding echoes many similar studies in foraging efficiency throughout California (Gerow, 1982; Greenspan, 1986; Hildebrandt and Jones, 1992; Simon, 1992; Hylkema, 2002).

McClure (2004), dealing with early midden sites in south Central California and specifically looking at rabbits, found that the smallest mammals, fewer than 140 grams, were not consistently represented due partially to poor recovery techniques. Slightly larger mammals, 71-340 grams were inconsistently found. Only the largest of the small mammals, 340-3100 grams (mainly rabbits), were adequately represented (McClure, 2004).

McGuire and Hildebrandt (1994) found the same decrease in small game importance through time. Large game, deer and elk, became more important. Submerged in that conclusion, the graph presented shows small game reductions from 85% to 50% of the faunal population in the seven sites surveyed. Fifty percent of the faunal assemblage, specifically lagomorphs, is an appreciably significant percentage, as it also excludes smaller mammals and insectivores but still supplies a significant portion of the animal protein. Small game can be procured easily around the base camp area with snares, deadfalls, slings, thrown sticks, clubs, and small nets by women, children, and adolescents while performing other duties and activities. In most tribal areas these were eaten, with minimal processing and cooking. They were consumed either whole or semi-processed with just the removal of intestines.

Largely ignored are the observations of early literate travelers and later more academic ethnographers, delineating the importance of small mammals in the diet (Delano, 1854; Steward, 1933; DuBois, 1935; Gifford and Klimek, 1936; Stewart, 1941; Heizer, 1974; Mayfield, 1993; McGuire and Hildebrandt, 1994; Morin, 2002). Wheat (1967), working with the Paiute of Nevada, mentions that “the most desirable husband was the man who came home at night with a dozen or more rats hanging from the thong around his waist” (Wheat 1967:117). This is indicating a reliance on smaller mammals as a food source. In their terminology, rat was an all inclusive term encompassing kangaroo rats, mice, wood rats, gophers, ground squirrels, and chipmunks (Wheat, 1967).

Wheat (1967) also notes the Paiutes processed squirrels by stripping entrails and then tucking them back in to roast. She also notes that children liked to suck the brains

out of the roasted skulls. She lists rabbits as being boiled whole then pounded into a powder for soup. She also notes that the rabbit bones from rabbits that were eaten, were later ground and boiled.

DuBois working among the Wintu observed that:

Rabbits that were caught were singed, entrails removed with the larger bones, pounded on a flat rock and then roasted. Sometimes the meat was pounded in a mortar into a doughy mass, rolled into balls and eaten (Jacknis, 1935:245).

Excess quantities of small mammals were roasted after removing the heads, tails, and paws and then “pounded until it was fine and crumbly”(Jacknis 2004:246). Salmon heads, guts, tails and bones were dried and pounded into flour which was then stored for winter usage (Du Bois, 1935). Among the Yana, ground squirrels and other small animals were cooked, gutted, skinned, pulverized, and then shared with other members of the tribe (Gifford and Klimek, 1936). Mayfield (1993), while living among the Yokuts, noted that ground squirrels were a staple item and that all manner of small game were utilized. Nomland (1935) lists the Sinkyone as capturing rats and mice, which were skinned, gutted, and roasted.

In a study focused on small mammals, twenty two years of snap trapping at Hastings Reserve in the Monterey area (Costanoan territory) covered three ecozones; oak woodland, grassland, and chaparral. They concentrated on nine species of small mammals. That included two species of rats, Kangaroo Rat (*Dipodomys venustus*) and the Dusky-footed woodrat (*Neotoma fuscipes*). Six species of mouse, California Mouse (*Peromyscus californicus*), Pinyon Mouse (*Peromyscus truei*), California Pocket Mouse (*Chaetodipus californicus*), Brush Mouse (*Peromyscus boulii*), Western Harvest Mouse

(*Reithodontomys megalotis*), and the Deer Mouse (*Peromyscus Maniculatus*), and one vole, California Vole (*Microtus californicus*). The Kangaroo rat and Dusky-footed Woodrat were only found in the Chaparral zone. The California mouse was found in two zones, Chaparral and Oak woodland, the California Vole was found in two zones, oak woodland and grassland environment. The five remaining species of mice (Pinyon, California, Pocket Brush, Western Harvest, and Deer Mouse) were found in all three ecozones: oak woodland, chaparral and grasslands. All three ecological zones, and therefore all available mammals, were found throughout this project's study area of Contra Costa, Alameda and Santa Clara counties (Heske, 1997).

The list of small mammals that were utilized by the California Native Americans as food sources also includes the several species of ground squirrels, arboreal squirrels, chipmunks, gophers, pocket gophers, and several species of lagomorphs. The list of available species is extensive and the populations of these individuals are numerous.

Within the proper context, small mammals are acceptable prey. Autecological processes dictate that people are the top level predators of small mammals. During the consumption and mastication process, small bones, and some larger bones, were not removed and were consumed along with the meat protein. Cracking of small and medium sized mammal bones, with or without skin or fur covering, could easily cause tooth enamel to fracture, or more likely chip, and leave parallel striations in enamel or dentine on the teeth of the consumer's.

Insects. Another food category is insects, which provided a major protein source. The protein content of grasshoppers, depending upon the species, is between 61% and

76% (Schultz, 1981). Harrington (1942) lists yellow jacket larvae, grasshoppers, and caterpillars as resources for the Central Coast. Barrett and Gifford (1933) list grasshoppers along with caterpillars of Army Worms, Yellow Jacket larvae, and chrysalis of the Pandora Moth (Barrett and Gifford, 1933; Barrett, 1936). These were esteemed as food and after processing could be stored for winter usage. There are several ethnographic accounts of the methods of capture:

They burn a circle in the trees around several acres of ground, set a fire in the middle, shoot the small mammals that emerge and the women walk behind the flames collecting the singed grasshoppers. The fire burns off the wings and the women remove the head and legs before tossing them into the carry basket (Mooney 1890:260).

And in another account:

One windy day while we were at Butte Creek we saw fire rushing down from the mountainside on the other side of a Tulare Slough, and had the curiosity to view it. It was coming down rapidly. Millions of Grasshoppers darkened the air in advance of it, followed by myriads of Crows and other birds that caught them as they flew. The Grasshoppers could fly but a short distance before they had to fall again, and thus they went on ever rising and falling before the fire, until the air was darkened with them for a line of several miles. When the fire had passed us with its streaming tongues, we noticed a number of Indians in a trench at no great distance, and making our way to them over burned ground, we found them busily engaged in bagging the Grasshoppers that had fallen by the millions in the ditch. They gathered perhaps a hundred bushels or more. The Indian method was to dig a trench about ten feet wide, five hundred feet long and three feet deep. This trench they kept free of grass; then, selecting a windy day in the Fall, when the Grasshoppers had reached their fullest development. They set fire to the grass far up the valley. The Grasshoppers would fall into the trench and the Indians were prepared with bags and baskets to scoop them in. They then divested them of their heads, wings, and the hard portions of their leg, and pounded them into a pulp, or Molly, which they made into cakes and dried in the sun, cooking it as they wanted it during the Winter. This habit of the Indians has, to my mind, much to do with the existence of the vast Plains and Prairies, which would never have remained devoid of Woodland but for the annual fires that visited them (Pancoast, 1930:351).

The commitment in time, energy, labor, and planning by the village or sometimes several villages, to procure insects as a resource must have been viewed by tribal members as a worthwhile expenditure of group energy. The episode recounted above by Pancoast (1930) involved enormous tribal resources. If the dimensions given for the trench are accurate, 500 feet by 10 feet by 3 feet deep, this necessitated the removal of over 500 cubic yards of material. The storability of the resource would also have been deemed important as winter food supplies. Bunnell (1903) mentions that when they were destroying the storage granaries of the Yosemite Indians, they destroyed “dried worms, scorched grasshoppers and what proved to be the dried larvae of insects...gathered from lakes east of the Sierra Nevada”(Bunnell, 1903:75). Leonard on his journey with Captain Walker noted that these fly larvae were gathered from Humboldt Lake, Nevada, situated about 60 miles east of Reno by local Indians for trading (Leonard, 1839):

I was one day sauntering along through the village, when I discovered a new dish, which appeared to be some kind of nut, nicely browned. I took one in my fingers, and was about conveying it to my mouth, when I recognized it as the chrysalis of a caterpillar. I dropped it with some signs of disgust, when an Indian exclaimed “To-pe, tope.” And to convince me that it was good, he ate a handful before my face (Delano, 1854:305).

Coprolites. Besides the ethnographies demonstrating that Native Americans were consuming small mammals is the direct physical evidence consisting of recovered bones of small mammals from coprolites. Researchers have found that a coprolite is the remains of one to six eating episodes (Reinhard et al., 2007). The area that is covered by this study, Contra Costa, Alameda and Santa Clara counties in Northern California does not have dry caves that would preserve coprolites, so currently, none have been found in

archaeological context. Other cultural areas have strong evidence for small mammal exploitation through coprolite analysis.

In two sites, Dust Devil Cave in Colorado and Hind's Cave in Texas, showed small mammal evidence from coprolites. In 58 of 100 coprolites from Dust Devil Cave and 97 of 100 coprolites from Hind's Cave showed bones of small mammals (Reinhardt et. al., 2007). In these studies, an additional finding was that all parts of the animals were eaten including the viscera, fur, and bones, with either minimal or no cooking. They also found that up to 20% of the dry weight of the coprolites consisted of phytoliths from various plants. Some of the phytoliths that were found were grasses that are not eaten by humans. They considered these grass phytoliths as evidence of small mammal consumption.

Small animal bones occur in all Archaic and Pueblos sites from this report. They suspect that the grass phytoliths may be evidence of meat not plant consumption (Reinhardt and Danielson, 2005:8).

Coprolites from Hogup Cave and Danger Cave in Utah reveal the same pattern of consumption of small whole mammals (Steward 1941, Stewart, 1941). In 1976, Fry analyzed 46 coprolites from Danger Cave, 60 from Hogup Cave, (both in Northern Utah), and 40 from Glen Canyon areas in Southern Utah in the Colorado River drainage. Dating of the Northern Utah sites showed that Danger Cave was occupied from 10,500 BP to 2,000BP and Hogup Cave from 8,800BP to 150BP. Glen Canyon was occupied by Fremont and Anasazi peoples from 2,000BP to 700BP. All of the coprolites analyzed exhibited large percentages of plant materials, with as many as 16 taxa present with a primary focus on pickleweed (*Allenrolfea occidentalia*) and goosefoot (*Chenopod sp.*).

One or both of these plant groups was present in over 95% of the coprolites from Danger and Hogup caves. Both of these plant taxa are present and plentiful in California wetland environments occupied by Bay Area natives.

Bone, presumably from small mammals, was present in 67% of coprolites from Danger Cave and 71% from Hogup Cave. One fecal sample from a mummified Anazazi infant (age unknown) was composed of 55% bone. Unidentified animal hair was present in 91% of coprolites from Hogup and Danger Caves providing further evidence of small mammals consumed either whole or with minimal processing.

Sobolik (1991) found that 53% of the coprolites examined from Baker Cave in the Pecos region of Texas contained small rodents, fish, bird, and lizard bones and concluded that the rodents were eaten whole because all types of bones were present. Rhode (2003) analyzed 19 coprolites from Hidden Cave in Nevada and found they were all from women, and evidencing a diet of cattail pollen seeds as well as small mammals and birds.

In California, there are two known coprolites sites. One is Bamert Cave in Amador County which yielded four coprolites (Nissen, 1973). She found three of four coprolites containing either small mammal bones, mammal fur or both. Sutton (1993) conducted a large coprolite study of a population in the ancient Lake Cahuilla area, near present day Salton Sea, and analyzed coprolites found in six open air sites. He used cluster analysis and found fish bones in all coprolites to varying degrees. He concluded that fish was an everyday resource, with additions of plant, reptile, small and large mammals were present but further down on the resource scale. This culture was situated in a lakeshore resource environment and was based on an aquatic acquisition of fish,

plant, bird, and animal resources. Midden remains showed evidence of varieties of goosefoot, cattail, bulrush, and purslane, while only goosefoot and cattail were found in coprolites.

In an experimental archaeology study, a micro mammal, a shrew, was skinned, eviscerated, quartered, and consumed uncooked in whole segments. The feces were retrieved for the next three days and analyzed. The results showed that 60-70% of the bones of the shrew survived the passage through the human digestive system (Crandall and Schultz, 1995). Based on the evidence of small bones in these coprolite studies, it is reasonable to add crushing of small mammal bones by the teeth to the list of potential causation factors for the scratching and abrasion of dental enamel.

Tools. There are two types of mortars, bedrock (deep and shallow hopper types) and portable boulder styles. The bedrock mortars are geographically attached to sedentary village sites with large flat rock spaces for creating the bedrock mortars. Portable mortars are only portable in the largest sense of the word. They are usually large round or conical boulders that have been transported to village sites and processed into mortars, by hollowing out the interior of the bowl. They weigh anywhere from 40 to 150 pounds. Pestles ranged from modified river cobbles to tall cylindrical carefully rounded art works.

It is widely assumed in California archaeology that metates were primarily used for hard seeds (Wohlgemuth, 1996) and mortars were used for acorns. In coastal middens spanning 8,000 years of deposition, manos and metates were only found in the lower levels dating prior to 6700BP, identified as the Milling Stone Horizon (McClure,

2004). It is widely assumed that acorns, and thereby mortars, became the primary processing tools after that period and intensified after 4,000BP. It is also widely presumed that mortars were only used to process acorns. The ethnographic literature does not support this assumption. Schultz (1981) summarized it best:

Even a brief survey of available sources provides a list of additional substances that includes pea vines (Thompson and West, 1879), screw beans (Steward, 1933), Clover (Harris, 1885), eulophus bulbs (Barrett and Gifford, 1933), wild sunflower roots (Barrett and Gifford, 1933), pine nuts (Beals 1933; Steward, 1933; Aginsky, 1943), hard seeds (Gibbs, 1853; Kern, 1855; Harris, 1885; Chestnut, 1902; Sparkman, 1908; Gifford, 1932; Kelly, 1932; Barrett and Gifford 1933; Beals, 1933; Steward, 1933; Nomland, 1935; Gifford and Klimek, 1936; Voegelin, 1938; Foster, 1944; Gayton, 1948). Madrone berries (Wilkes, 1958), barberries (Sapir and Spier 1943), gooseberries (Barrett and Gifford), blackberries (Latta 1949) Manzanita berries (Gifford, 1932) Skunk berries (Garth, 1953), juniper and boxthorn berries (Voegelin, 1938), Buckeyes (Beals, 1933, Voegelin, 1938), fish (Harris, 1885, Aginsky, 1943), grasshoppers (Thompson and West, 1879; Harris, 1885; Uldall and Shipley, 1966), meat (Sparkman, 1908; Gifford and Kroeber, 1937; Merriam, 1967), deer vertebrae (Gifford and Klimak, 1936, Aginsky, 1943), tobacco (Garces, 1900; Gifford and Kroeber, 1937; Harrington, 1942), tolache (Kroeber, 1925; Strong, 1929), medicines and poisons (Gifford and Klimek, 1936; Gifford and Kroeber, 1937; Harrington, 1942; Voegelin, 1942; Garth, 1953; Latta, 1977, and paint (Harrington, 1942). This list is certainly not exhaustive, and for references consulted it includes only items explicitly recorded as being ground in mortars; additions of substances noted only as being “pounded” or “pulverized” would add dozens, perhaps scores, of entries. The association between mortars and acorn processing then, while it may be strong, is hardly complete. Steward (1933) moreover found the mortar and pestle in Death Valley, 50 miles from the nearest oak tree, in use among people who probably never ate acorns, and who employed these tools for tasks in which their neighbors used manos and matates (Schultz 1981:65).

In addition, the use of manzanita berries and young tule roots are noted by Jeff Mayfield who lived for ten years among the Central Valley Yokuts during the 1850's. Leigh records the incorporation of smoked salmon, deer, and rabbit bones to the list of

foods, with a focus on vertebrae that is pounded and stored for soup. Tobacco, mixed with lime, was ground in mortars, and eaten (Leigh, 1928; Harrington, 1942).

Retouching projectile points. The last category of materials that might involve processing with teeth is stone or obsidian points. There are several ethnographic indications of Indians using their teeth to retouch points. Hester (1973) reports, secondhand, on J.E. Harston's account of the Comanche:

The writer has seen Indians sharpening old flint arrowheads by biting with their teeth against the edge, thus breaking off small particles. Although the common use of these flints has been discarded for many years, they were still being made and used when iron barrel hoops or steel could not be used (Hester 1973:23).

Gould (1968) reports observing Australian Aborigines using their teeth to resharpen flint points. Winship (1896), reporting on the Coronado expeditions in 1540-1542, notes they observed Apaches using teeth to retouch points. Additionally, research by Gunnerson (1969) reports the same behavior among the Omaha. Roydhouse and Simonson (1975) mention flint chipping as a potential causation factor for dental attrition among Australian Aborigines.

Evidence for the ethnographic reports of teeth being used to retouch points is supported by coprolite analysis reports. Gary Fry (1975) reported that three coprolites specimens from dry caves in Northern Utah, Hogup Cave and Danger Cave, each contained chips: one specimen evidenced tiny obsidian chips, and two specimens had chalcedony fragments (Fry, 1975). In a dry cave in Amador County California named Bramert Cave, Nissen (1973) found an obsidian chip in one of four coprolites examined.

Summary: “Whatever it was they were doing, it was real important to them”

(Robert Jurmain, 2000: Personal Communication). The literature has one primary causation factor when dental attrition is addressed, grit in the food. It appears that the causation for dental attrition is more multifactorial than previously assumed. Teeth are used to masticate food. California Native Americans appear to have used mortar and pestle for processing most of the foods they consumed, not just acorns. Wooden mortars were employed for acorns, at least during contact times (Leonard, 1839; Menzies, 1924; Wagner, 1923). They might have also been employed in prehistory but do not survive in archaeological context. Food plants are consumed regularly and in quantity and are implicated in dental wear as they process phytolith rich leaves. Basketry materials were processed by women who utilizing their teeth as tools to hold and strip materials. Men processed cordage materials utilizing teeth. Men straightened arrow shafts using teeth. Men retouched points using their dentition. Both basketry and cordage were critical foundations to their material culture and producing these material artifacts consumed a large percentage of their time, attention, and involved the processing of underappreciated amounts of plant materials.

Small mammals were consumed as a regular, important component of the aboriginal diet. They were consumed with minimal processing. Both the small and large bones of small mammals supplied calcium and nutrient rich marrow but also caused dental abrasion, scoring, and striations. Insects are an overlooked part of the aboriginal diet. Chitinous insect elements could not be completely removed and possibly contributed to dental wear.

Based upon the above, it can be concluded that teeth were an essential part of their tool kit. They used teeth to grasp, hold, tear, strip, and process raw materials. Teeth were the pliers and vice grips of their tool kit. The question is not how could they use their teeth? Rather it should be how could they not use their teeth? In their lifestyle, adaptability was important. Problem solving was important. They used whatever they had to improve their lives and more effectively process materials needed for everyday usage. Teeth were just another tool, like a chert or obsidian knife, a bow, an arrow, a net, or a rabbit stick. The reality that teeth wore down, caused pain, and eventually exfoliated was just the normative reality of their existence.

VI. SITE DESCRIPTIONS

This study will be restricted to those individuals with preserved dentition. Teeth and dental enamel are the hardest of skeletal materials, being fully mineralized. They are usually some of the best preserved material, but not all archaeological excavations extract perfectly preserved skeletons with dentition. A number of factors influence this differential preservation: acidity of the soil, ground movement, turbidity, age of the skeletal material, depth of the original burial, ground water seepage, excavation damage, and construction activity with the use of heavy equipment, among others. We also have a considerable percentage of excavated skeletons with only partially preserved dentition, some either missing the entire maxilla or mandible, some with teeth lost either during or after excavation and a large number with teeth lost antemortem. In addition, we have some examples of teeth only, with little or no supporting bone remaining.

The available skeletal population is further restricted because younger individuals will be eliminated from the study population. Children with deciduous dentition will be eliminated, even though at times they show some of the characteristic wear patterns. Their overall low wear scores would bias the larger sample. This research will also eliminate individuals below the postulated biological age of 15. This will result in a study population made up only of adults whose cultural activities have had sufficient time to impact their dentition in a substantive manner.

Study site section: population sample, site context, and description

The skeletal populations selected for this study are derived from seven sites. The total number of burials used in this study is n=406. Two of the sites are CA-ALA-329,

with n=160 burials out of a possible 285. CA-CCO-548, Vineyards, has a total number of n=208 burials out of a possible 479. The remaining five sites are located in the Santa Clara Valley and included a total of 38 burials. These sites are CA-SCL-287, CA-SCL-134, CA-SCL-287/CA-SMA-263, CA-SCL-851, CA-SCL-869 and CA-SCL-870. Total burials for these smaller sites is n=38 (See Figure 1).

Fig.1. Map of locations

CA-CCO-548 Vineyards Site. CA-CCO-548 is a large mortuary site, recently discovered, associated with a housing development southeast of the California town of Brentwood. It is located at the western edge of the Central Valley and east of the Diablo Range. The site comprises 481 acres. Radiocarbon and obsidian hydration dating ages the site from 4000 BP to 2930 BP (Bartelink et al., 2008). At least 479 burials were recovered, of which 208 with dentition were used in this study. The site location indicated that a mixed- use diet was utilized with an emphasis on Delta fish populations of sturgeon and small fish species. Undoubtedly small grass seeds, acorns, as well as small and large game were also exploited. Preservation is fragmentary and impacted by caliche deposits (calcium carbonate) clinging to the bones and teeth resulting in a pre-mineralized condition (Weiberg, 2004; Griffin, 2007).

CA-ALA-329 Coyote Hills, Ryan Mound. This large mortuary site was classified as a shellmound from 1910 onward but a lack of habitation features brings this designation into question (Leventhal, 1993). In the mid 1960s a large number of individuals were excavated from this site. Some were housed at San Jose State and some at Stanford University. The Stanford population of 139 individuals was reburied in 1991. The remaining population of 284 individuals is curated at San Jose State. Of the 284 individuals, 160 were selected for this study. Preservation for this population is excellent. The oldest burial in this group is dated to 2200BP (193BC) and the latest to 250BP or contact with the largest population dating from 1100BP to 500BP, Late period.

CA-SCL-287/ CA-SMA-263, Stanford Golf Course. This site contributed 11 individuals (out of 24 available) to this study. This site is located adjacent to San Fransquito Creek in Palo Alto, just south of Embarcadero Road and east of Foothill Expressway at Stanford California. Heavy equipment impacted and revealed burials which were consequently excavated. Dating of these individuals places them between 1800 BP and 1300 BP. The location of this site is near a riverine catchment area which had exposure to mixed hardwood forest to the west and prairie grassland surrounding the site with numerous oak trees present, which would have supplied acorns to the diet (Leventhal, et al. 2010).

CA-SCL-134, Corvin Site. This site is in the City of Santa Clara about a quarter mile away from a water course. This prehistoric cemetery contributed 16 individuals to this study. It was discovered during utility trenching and 24 individuals were recovered. The site location indicated that the population exploited a wide variety of resources. These ranged from marsh and riverine, grassland with scattered oaks and grass seeds, as well as mixed hardwood forests to the west.

CA-SCL-851, MST Site. This site was excavated in 2000 during the construction of a mini storage building and contributed seven individuals to this study. The catchment area was generalized with no water being evident in close proximity. It would have evidenced prairie grassland with scattered oaks supplying acorns and small grass seeds including chia.

CA-SCL-869, The Four Matriarchs Site. This site was discovered in 2007 and subsequently excavated during construction of Fire Station 12 for the City of San Jose.

Four elderly (55+) female individuals were recovered, and three are included in this study. The isotonic study reveals a marsh habitat as a basis for the food web in this area. There are three riverine water sources within a one and one-half mile radius of this site. Food resources would have been concentrated on riverine and marsh constituents, with contributions from prairie grass seeds and acorns, as well as large and small game.

CA-SCL-867, Coolidge Avenue Site. This was a single burial recovered in 2006 after being discovered during PG& E utility trenching activities. Catchment would have involved riverine, marsh, prairie grasslands, and small and large game.

This study follows previous archaeological studies focusing specifically on dental wear patterns, including the seminal work by Molnar (1968), Hinton (1981), and Keiser (2001a, 2001b). Molnar's work provides the foundation. This author is independently employing Molnar's criteria to test those criteria against seven Central California archaeological sites in the San Francisco Bay area. This research further expands upon the description and classification of four distinct wear patterns.

VII. MATERIALS AND METHODS

Glossary of dental terms

The maxilla is the upper jaw and is designated MX. The mandible is designated as MN, followed by right (R) or left (L), then the type of tooth and, if needed the number. MXLM¹ is maxillary left first molar. MNRPM₂ is the mandibular right second premolar.

Age Bands—Individuals are grouped into 10 year age bands, 20-30, 31-40, 41-50, and 51-60. In some graphs this is reduced to teens, 20s, 30s, 40s, and 50s to conserve space.

AMTL---- Ante Mortem tooth loss.

CEJ -----Cementum Enamel Junction.

CRM-----Gray Literature—Cultural Resource Management (CRM) reports from archaeological excavations which are not peer reviewed.

PMTL---- Post Mortem Tooth Loss.

Form and shape of dental wear

All scoring systems are ordinal and occlusal oriented; the view is from above the tooth looking down. Molnar (1968) was the first researcher who attempted to quantify the form of wear as well as the shape of the wear. Molnar's form and shape of wear system is a trinomial approach, with one digit denoting attrition, one denoting the angle of wear, and the last one describing the shape of the wear. This system was reprinted in Hillson (1996) but has been used just twice by Hinton (1981) and Keiser (2001a, 2001b) working with a population of Maoris. It is 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. Presently, no widely accepted scoring system is used to record them. Forms of patterned wear are classified into five groups: flat or no wear, slants, rounding, scoops, and grooves. The literature for each category of wear is reviewed as a distinct category.

Flat Wear. In researching the literature on flat wear or normative wear, there are only two studies, both by Keiser et al. (2001a, 2001b). In dental studies, normative flat wear is presumed to be present (See Fig.2). It is the default assumption and is the inherent basis for all of the normative attrition scoring systems (Murphy, 1959; Miles, 1962; Brothwell, 1963; Molnar, 1968; Scott, 1979; Smith, 1984; Lovejoy, 1985; Littleton and Frohlich, 1993; Drier, 1994). A few studies have tried to enlarge this envelope, specifically Molnar (1968), Hinton, (1981) and the two Keiser et al. (2001a, 2001b) studies mentioned above. Keiser found in the study utilizing 50 Maori skulls, that 43% of males and 55% of females had flat wear. In the second study using 225 Maori skulls, he found that 62% of males and 57% of females had flat occlusal wear. Other studies have implied that the wear found is relatively flat and level but no quantitative statistics are mentioned.

Fig. 2. Flat or normal wear in archaeological dentitions

Slants. Slants are created on mandibular molars as the lingual cusp of the maxillary molar engages with the buccal cusp of the mandibular molar during normal masticatory behavior. This creates 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. Its complimentary maxillary molar becomes steeper towards the lingual side. The slopes become extreme depending upon the abrasiveness of the diet, grit that may be included in the food, as well as being caused by non-masticatory activities involving the teeth (See Fig.3).

Fig. 3. Slant wear pattern

Slants are created on mandibular molars as the lingual cusp of the maxillary molar engages with the buccal cusp of the mandibular molar during normal masticatory behavior. This creates 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. Its complimentary maxillary molar becomes steeper towards the lingual side. The slopes become extreme depending upon the abrasiveness of the diet, 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: 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 somewhat like a helix therefore the term Helicoidal (Campbell, 1925; Ackerman, 1953; Butler, 1970; Hall, 1975; Osborn, 1982). Campbell (1925) first described it as a “compound plane”, Ackerman (1953) as a helix, and from that the term helicoidal evolved. Helicoidal is used as a descriptive term, not implying any causation factors; although Smith (1986) states that the helicoidal plane 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 third molar. This last finding was unexpected. Smith 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. Smith found the slope of wear on the M1s for the agriculturalists had a steeper wear plane by about 10 degrees than the hunter-gatherer population. Smith suggested that grit added in the grinding process of the crops was responsible. Keiser et al. (2001a), working with Maori skulls found 33% of males and 44% of females had what he termed reversed curve of Monson, or “Fern root plane”, a pattern that this author is labeling as slant wear. In a second study, Keiser (2001b), working with a larger population of 225 Maori skulls, found 22.5% of males and 25.5% of females showed reversed curve of Monson wear pattern (slant wear pattern). He attributed this wear to a diet dominated by fern root and gritty shell fish. Reinhardt (1983), working with 40 individuals from two sites in Southern California, notes that eight percent of teeth had “lingual tilting.” Leigh (1928) noted an obtuse plane of wear on upper and lower molars in a Santa Barbara Native population.

Roydhouse and Simonsen (1975) disagree; they feel that helicoidal occlusion is not caused by food abrasion, but by tooth-to-tooth contact. These researchers used a population of 300 skulls from British Columbia (B.C.) and compared their occlusion and the subsequent wear with other populations comprising Maoris, Australian Aborigines,

Huron Indians, and Egyptians samples. They did not state how many dentitions from each site were examined. These authors attribute the wear seen in the contrasting populations to grit ingested with the food in the Australian, Maori and Egyptian samples with detailed food analysis. They feel that since the observed wear seen is similar to that seen in B.C., there must be another explanation available.

These researchers cite ethnographic accounts of B.C. natives being very careful to wash the grit off and out of their food. Instead, they suggest that grit in the food could not be the causative agent in the B.C. population. Roydhouse and Simonsen (1975) suggest that the side to side movement of the jaws is the prime determining factor in creating the form of wear seen in this population. Whether slanted wear is created or just accelerated by grit in the food, the fact that slanted wear on mandibular and maxillary molars does manifest in substantial quantities is not being adequately reported or recorded.

Butler used 100 individuals from South Dakota and 36 from Georgia and defined slant wear on molars using eight categories defined by increasing oblique slant wear. He defines 1 as being 1-5 degrees and 8 being 42-47 degrees (Butler, 1970).

Anterior rounding. Rounding of the anterior teeth, especially on the mandibular arch, has not been readily recorded in archaeological populations (See Fig. 4)

Fig. 4. Rounding wear pattern

Brace (1967) explored the size of teeth in fossil and modern humans. He mentions, briefly, that Neanderthals have heavily rounded incisors and that these incisors were used as extra hands for non-masticatory activities. Hinton (1981) was one of the few researchers, besides Molnar (1968) and Merbs (1983), who mentioned rounded anterior incisors. He surveyed two hunter-gatherer populations, Australian Aborigines and Eskimos. He compared them to two agricultural populations, Ohio farmers and Southwestern Pueblo peoples for forms of dental wear. Hinton 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 were Eskimos, numbering 195, Australians 151, Ohio farmers 129, and Southwestern Pueblo farmers, 248. Hinton found both rounding and cupping in all populations but in substantially different distributions. Eskimos and Australians had rounded anterior teeth 30% of the time, when wear levels reached 5 to 8 on a modified Molnar wear scale. Cupped wear was present on Eskimo and Australian teeth but, depending on the tooth,

only 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 minor incidence of rounded wear. Hinton uses histograms and graphs but had no statistical analysis stating that his sample and scoring method made for double ordinal scoring. Hinton states he could not assume that the steps from 1-8 were equal in grade. He also could not assume that the wear between different tooth classes was comparable, so he declined to do parametric statistics.

Merbs (1968, 1983), working with the extinct populations of Sadlermuit from Southampton Island in the Canadian Arctic, documents anterior tooth loss in both males and females. The sketch on the cover of Merb's publication shows a male Inuit holding a line in his teeth to wrap a harpoon and another sketch in the interior showing a female processing a skin with her teeth. He makes a point of noting that the chewing of skins involved both the premolars and molars and not necessarily just the anterior teeth. He found that females had twice as much osteoarthritis in the tempomandibular joints as males and attributed it to skin processing by females. Males are noted to have drilled holes in various materials by holding a bow drill in their mouth; this technique was also noted by Murdoch (1888) at Point Barrow, Alaska. Marchiarelli (1989) worked with a 6,000-7,000 BP population of 49 individuals from the Arabian Peninsula exhibiting rounded incisors and premolars but only on the upper arches. He attributed the wear to a diet of dried fish and shellfish, with windblown sand being the primary causative agent.

Scoops/Cupping. Cupping, as defined by Hinton (1981), is a rim of enamel surrounding a deep trough in the dentin. He did not explore causation. But since dentin is softer than enamel it is presumed 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 Hinton (1981) explains above, Southwestern Pueblo farmers exhibit up to 50% of their teeth with cupped forms of wear on the upper canine and 30% on the lower canine (See Fig. 5)

Fig. 5. Scoop wear pattern

Elvery et al., (1998) working with an Australian Aborigine population mentions a scooped pattern but makes no recording or definitions. Scooping, as seen in Northern California populations, differs from cupping in that the mesial and distal enamel rims are worn away to form a deep scoop with rims only on the buccal and lingual sides of the tooth. This wear form is seen most often on the lower molars.

Grooves: Occulusal Grooving. Occulusal grooves have been reported in many populations worldwide (See Fig. 6). One of the oldest individuals recovered in North America, Spirit Cave Man dated to 9,460BP. He is a semi-mummified individual found in Spirit Cave Nevada in 1940. The remains resided at the Nevada State Museum, when

a researcher in 1992 asked to take hair samples and have them carbon dated. The dating yielded a date of 9460 BP. In the skeletal inventory six occlusal grooves are noted on the anterior teeth. There were no pictures, locations, or measurements noted, but the author cites Schultz and Larsen as antecedents for processing grooves (Damadio, 1996).

Fig. 6. Groove wear pattern

Esched et al., (2006) working with an ancient Middle Eastern population dating from 12,500BP to 7500BP, mentions finding grooves in the maxilla and mandible but does not quantify or document them. They do have two clear pictures of anterior mandibular occlusal grooving, as well as a drawing illustrating a male holding a basket stave between his upper and lower first molars to illustrate occlusal wear found on those teeth. They state:

That teeth were used as tools (such as holding staves) while making baskets or fishing nets, thus incurring a pulling action across the first molar and second premolar (Eshed et al. 2006:153).

Cybulski (1974) found thin linear grooves on the occlusal surfaces of mandibular anterior teeth in five out of 154 (3.2%) individuals from British Columbia. These five individuals were all female, and the wear was concentrated on the canines.

This population was British Columbian natives from the Prince Rupert region dating from 4,000BP to 250BP. Cybulski attributed the thin occlusal grooves to basket making and weaving. Two neighboring tribes, the Eyak and the Tlingit, have ethnographic descriptions of women holding and splitting spruce roots with their teeth for basketry. He also found 12 other 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 (Cybulski, 1974).

Schultz (1977) found ten individuals out of 21, with grooves. They were both male and female, from Stone Lake, near Stockton in the Central Valley of California. Schultz described these individuals as having occlusal and interproximal grooves, and he attributes the grooving to fiber processing to make nets and lines to support a fishing economy. The five males and five females aged from 18 to 50 years old, dating from 2100BP to 800BP. These individuals had 26 grooves, involving 32 out of 187 (17%) teeth overall. All teeth affected by grooves were anterior canines or incisors. The direction of all grooves was buccal lingual, with the exception of one occlusal groove that ran across both canines and one incisor. Three individuals had grooves across the occlusal surface of the incisors; the other seven had interproximal grooves.

Owsley and Bellande (1982) describe three out of 120 (2.5%) individuals from a Cherokee population located in Georgia. Two individuals had interproximal grooves which they attribute to chemical or acid erosion and one individual, aged 15-19 years old, had matching notches on upper and lower central incisors which they attribute to an unknown cultural activity. Larsen (1985) found five out of 171 (2.9%) individuals with

occlusal grooves from a population inhabiting the Great Basin of the Western United States. Larsen's study population comprised individuals from 38 different sites in the Great Basin, with populations ranging from 1 individual to 36. Three of the 38 sites had more than ten individuals, the rest were single or small burial populations. A total of 16 teeth from five individuals, all male, displayed grooved occlusal surfaces. Direction of the grooves was mesial/distal and varied in width from 0.4 to 2.0 mm. Larsen attributes the grooved dentitions to fiber processing for the manufacture of nets, fowling bags and other hunting gear, and possibly sinew preparation, as noted in Greenlandic Eskimos.

Littleton and Frohlich (1993) analyzed twelve skeletal samples from four different subsistence patterns in the Arabian Gulf. They mention the two earliest populations from Bahrain dating from 4300BP to 3800BP in one sample with 69 adults. A second sample had 98 adults dating to 2750BP to 2500BP. These individuals showed "distinct grooving" on the anterior teeth, due to use of the teeth as tools and, possibly, fiber cordage processing for the manufacture of baskets and rope. These researchers mention that all adult dentitions were affected. Unfortunately, they do not include any data, numbers, measurements, or pictures.

The shape of the wear suggests a pulling action across the premolars and canines, abrading the lingual and finally incisal surfaces of the incisors. The nature of the attrition suggests that pulling fibers, possibly for rope or basket making may have been the cause (Littleton and Frohlich 1993:441).

Fong and Brittan (1994), in a site excavation report from Pleasanton, California, report six out of 45 (13%) individuals with interproximal and occlusal grooves. One individual's grooving is ascribed to toothpicking because the groove is on a molar afflicted with caries and an abscess. The other five individuals displayed grooves on the

anterior teeth. They do not provide scoring, descriptions, or numbers, but the two pictures show what appear to be interproximal grooves located above the CEJ.

Macchiarelli (1989) surveyed a population from Oman, dating to 7,000-6,000 BP, numbering 49 individuals. He noted that wear was extreme on all teeth present and from a very young age. Macchiarelli (1989) noted the average age at death was the mid-20s. He noted that the upper incisors were rounded, and that the premolars in both upper and lower positions were also rounded. There were no occlusal grooves seen, but he mentioned that there were interproximal grooves “episodically observed on the buccal aspect of lower molars.” Macchiarelli presents no quantification of these observations.

Minozzi et al. (2003) wrote about a single adult male burial from Libya that is dated to 7800 BP. The skeleton was in poor condition and had seven loose teeth present. All seven teeth were premolars, canines, and incisors. All the teeth showed grooves ranging from 1.6 to 3.3 mm, which ran in a buccal/lingual direction. They attribute the grooves to fiber processing for the manufacture of baskets, nets and mats. These researchers ran an experimental study using an extracted medieval tooth abraded with *Typfa latifolia* leaves which were used in local basketry construction. They found that the machine they constructed produced “microscopically appreciable modifications of the tooth surface”. It took 245 hours of abrasion to produce that effect (Minozzi et al. 2003:226). They suggest two possible causation scenarios for the grooves found: 1) dragging thin fibers or sinews across the teeth and/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 exhibit groove depth on the surface of the teeth but show only

grooves located on the enamel rim surrounding the exposed dentin. The occlusal surface appears flat with elevated enamel rims which are cut by grooves.

Turner and Anderson (2003) recorded one individual from a burial population of 70 individuals from medieval Kent, England. The anterior dentition looks carved with sharp concave abrasions on the occlusal and interproximal surfaces of the anterior dentition. This individual was male and aged at 30-40 years old. They attribute the extremely unusual abrasion pattern to a carpenter's occupational habit of holding nails in his teeth (Turner and Anderson, 2003).

Erdal (2007) found five out of 36 (14%) individuals from a tenth century population in Turkey with mesiodistal grooves in the dentitions. The five women had nine incisors affected with grooves. The grooves were thin, from 0.9 mm to 1.7 mm in width. Grooves were distributed with six out of nine (67%) maxillary and three out of nine (33%) on the mandibular incisors. Erdal found that, in that region of Turkey, wool is presently 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 further suggests that this is a sex-based division of labor (Erdal 2007).

Burials that were not included from these seven sites either did not have any intact adult dentitions or were sub-adults under the age of 15. They were excluded because their permanent dentitions did not have enough time to develop discernibly significant wear patterns. Dentitions were judged to be under 15 if no evidence of third molar emergence was evident and/or using the conventional dental growth aging in Standards

(Buikstra and Ubelaker, 1994). Each adult dentition has 32 potential sockets available for scoring, with a total of 12,996 sockets potentially available. Frequency details are listed below with each socket/tooth being scored as genetically absent, lost ante mortem (AMTL), lost post mortem (PMTL), or present. If a tooth was recorded as being present, it was also scored as having: 1) no patterned wear or flat wear, 2) a slant pattern, 3) rounded shape, 4) scoops, or 5) groove pattern. If a pattern and wear were observed, an ordinal scale from 1 to 4 was utilized to indicate degree of severity of the patterned wear.

All burials were sexed using standard morphological traits. The indices utilized were the characteristic morphology of the *osa coxae*, and the cranial morphological elements as featured in Standards and Griffin's (2007) lab manual (Suchey and Brooks, 1986; Buikstra and Ubelaker, 1994; Griffin, 2007). CA- ALA-329 was sexed by Jurmain (1990) and CA-CCO-548 by Griffin (2009). The other sites were sexed by graduate student staff at San Jose State University, including the present author, utilizing the methods detailed above.

Aging was accomplished by conventional methods using the pubic symphysis and morphological changes in the auricular surface of the illium (Lovejoy 1985; Suchey and Brooks, 1986). Jurmain (1990) aged CA-ALA-329 and Griffin (2009) aged CA- CCO-548. In addition, Griffin and this author used dental aging criteria to age CA-CCO-548 and to augment the existing aging for CA-ALA-329 as well as the other five Santa Clara Valley sites. The revised aging criteria utilized Brothwell's (1963) criteria for seriating a specific population. There were 57 sub-adults available in CA-ALA329 for seriation to establish an aging base. They were seriated utilizing the changes and attrition rates for

the first, second, and third molars as well as Brothwell's formula of 6-6.5-7 years of age differential of wear for the three molars. These individuals were not included as individuals in this study.

Photographic protocol: Historically, photography has been a controversial element in archaeology, not to archaeologists, but to Native American populations. While a number of Native American populations find photographic recording of their ancestral dead uncomfortable, the Muwekma Ohlone encourage research that will give them additional information about their history and ancestry.

The reason a photographic protocol needs to be developed is that there is none in place now. In trying to be consistent, a stratified regular routine of photographic applications needs to be used. Data recording in the archaeological research field has been on traditional black and white standardized data collection sheets. In the last ten years, cultural resource firms doing archaeological fieldwork have increasingly been using digital photography, especially for burials. In a large percentage of excavations the excavated burials are re-interred immediately with no osteological data recorded or research done. In lab work, traditional pen and paper data recording has also been the standard. Digital photography is important because it provides a permanent record to confirm or challenge observations made by the original researchers. Digital photos can be easily stored, modified, and enlarged to reveal details. They can be transmitted electronically to other distant researchers to enlarge and improve their data sets.

A second, and more important reason, is that curated collections are limited in quantity, highly restricted and very difficult to access. Some, such as U.C. Berkeley,

restrict not only the number of researchers, but also the amount of time that researchers can work with the collections. The importance of accurate extensive photographic recording cannot be overstated. It is probable that at some time in the near future, most, if not all, of these archived collections will be reburied and no longer available for research. Having a complete and extensive inventory of high resolution digital photographs will help preserve information that otherwise would be permanently lost.

Digital photography is a more accurate way to record observations and information that is present. One option is that the wear on a molar can either be recorded as a quarter inch oval, filled in with a pencil with no three dimensional component. Another option is five or six digital photographs from different angles of that same molar, capable of being magnified to fill a computer screen. These can be shared with other researchers instantly by email transmission. These images can be stored permanently for future research.

A Sony MVA FD 92 and a Sony DSC 120 were used to collect data on the dentitions. The FD 92 has a relatively small pixel count, 1.6 million pixels, but has a resolution of 1482 X 1280, with an 8X optical zoom and a minimum focal length of only 4 mm. The macro setting allows extreme close-ups to be taken that reveal details that are not seen easily with the naked eye. The macro setting of the DSC 120 provides a more detailed Macro setting of up to eight megapixels. Lighting is provided by two 100 watt incandescent bulbs in gooseneck lamps, positioned to eliminate as many shadow as possible. The background used is off-white aquarium sand in a 12" X 9" X 2" plastic storage tray. This provides a light colored neutral background for the pictures, and also

allows for positioning of the dental material at angles that maximize the photographic potential. The sand is malleable and easily rearranged to support odd positions needed to get details of the dentition.

Starting with the mandible, the jaw is placed in correct anatomical position, with the bottom of the mandible in the sand. The first shot is of the complete mandible from a superior position including all of the dentition. Following is an anterior photo of the mandible from the front. A posterior shot of the mandible, then left buccal (cheek) shot of the molars and premolars, left lingual (tongue) shot of the left side, right buccal shot of the molars and premolars, and right lingual shot of the molars and premolars. This is the minimum number needed, but usually there are individual teeth with patterned occlusal, buccal, or lingual surfaces that need additional pictures. The same procedure is followed for the maxilla with the same number of shots in the same order and details on individual teeth as called for. Pictures are taken of any carious lesions and abscesses. There is an absolute minimum of 14 pictures needed for a complete dentition. The average number usually taken is approximately 25-30 photos per individual. Photo files are downloaded from the camera's memory stick onto a password protected computer and stored in a file labeled with the site number and name as well as segregated by burial. A back-up copy is also made and stored separately on either a flash drive or portable hard drive.

Rationale for developing a patterned dentition scoring protocol. Traditional scoring of the dentition comprises eight separate recording sheets in the Standards skeletal recording system (Builasta and Ubelaker, 1994). Nowhere in these recording sheets is a space, method or criteria for recording wear patterns observed. The etiology

of these patterns will be the subject of further research but first a nomenclature and scoring system needs to be developed to accurately record the patterns observed.

Utilizing observations of dozens of dentitions certain categories emerged. It is determined that the dominant categories are rounding and grooving on the anterior teeth, incisors, and canines. Slants occur on the premolars and molars, and scooping predominately occurs on the premolars and molars.

Scoring Protocol. Scoring for patterned wear of the dentition can be done in either of two ways. It can be done visually, using the attached scoring sheet (see Appendixes K and L) and the accompanying explanatory sheets at the time the photos are taken. Scoring can also be done from the photographs themselves. If time is an issue and access to the collection is restricted, it is recommended that scoring be done visually on site and then crosschecked using the photos. Given the extreme magnification of the photographic process, where it is possible to have one or two teeth enlarged to fit the whole computer screen, details are often observed that were missed on visual macroscopic examination.

Culturally induced dental wear patterns fall into four classifications. They are slants, rounding, scoops, and grooves. Grooving can occur on only one tooth such as an incisor, canine or premolar. More commonly the pattern occurs on a series of two or three connected teeth, which were used as a working platform. Scores range from 0; no patterned wear; to 1, 2, 3 and 4 with 4 being deeply grooved, erasing almost all of the enamel. This may occur bi-laterally across both right and left sides of the dentition. There is currently no quantitatively accurate way to measure this type of wear. By the

time the score reaches 3 or 4 most of the dental landmarks are obliterated. It is possible to use a ranked ordinal scale of 1-4 to score this type of wear.

The sequence is as follows: progressive deterioration of the dental enamel through stage 1, with distinct groove apparent. Stages 2 and 3 show deepening and expansion of the groove across the enamel usually exposing the dentin and forming higher walls. A stage 4 is a deep distinct groove, and can be either buccal/lingual or mesial/distal. In all cases, a lack of occlusion between upper and lower dentition is a defining criteria.

Fig.7. Lower premolar groove

Slanting is seen on premolars and molars with 1 to 4 scoring. (See figure 8 below). The degree of severity is measured in the steepness of the slope, ranging from 0, no slope, to 1, (<15 degrees) 2, (>15 to 30 degrees of slope) 3, (>30 to 45 degrees), and 4 (>45 degrees of slope). Slanting on the molars of the mandible always occurs with the high side of the slant being on the lingual side and the low being on the buccal side. On the maxilla, this slope is reversed with the low side of the slope being on the lingual side and the high side being on the buccal side. This conforms to what is termed the normal curve of Monson. Degree of slope is measured with a Craftsman Laser Trac level, which can measure the degree of slope accurately from 0 to 90 degrees, and a hand held compound protractor with a bar extension to accurately confirm and measure the degree of slope.

Fig. 8. Lower molar slant pattern

Scooping occurs only on the molars with occasional involvement of the second premolar to form a 2, 3 or 4 tooth working surface or platform. Scores range from 0 to 4, with 0 being no occlusal wear, and 4 being little or no enamel left, normally only tiny rims of enamel on either the lingual or buccal sides. Surface wear is always in a distal to mesial direction. Please refer to the attached scoring explanation sheets which show both graphic and photo representations of the wear descriptions above (Appendix L).

Fig. 9. Upper molar scoop pattern

Rounding occurs primarily in the anterior dentition, incisors, and canines, but in heavily worn dentitions the premolars and molars can also become rounded. The wear progression is top down until one rim of enamel about 25% of the enamel rim is lost. This is a grade 1. A stage 2 is the loss of 50% of the enamel rim. Stage 3 is when 75% of the enamel rim is lost. Stage 4 is the loss of 100% of the enamel rim. The tooth becomes domed and completely rounded at that stage.

VIII. RESULTS: DENTAL WEAR PATTERNS

Demographics

A number of authors have remarked on the extreme wear observed in the dentitions of California populations (Leigh, 1925; Schultz, 1977; Fong, 1994; Jurmain, 1990). It was felt that creating a modified scale of attrition as defined by Smith (1984), coupled with a 10-year aging progression would be beneficial (Griffin, 2007). Table 1 (Appendix A, Table A-1) presents the distribution breakdown for all sites by age and sex. Table A-2 (Appendix A) combines all the South Bay sites into one summary and contrasts that with the North Bay site. Table A-2 shows approximately equal numbers of burials for North and South components of the study group when the South Bay sites are aggregated. There are n=198 individuals represented in the South Bay and n=208 in the North Bay. It is noted that there are a significant number of indeterminate individuals, n=109, which distorts the sex ratios. Of the total population, males represent 40.9%, females represent 32.3% and indeterminate individuals constitute 26.8% of the population. Table A-3 (Appendix A) reflects the sex and age distribution when the indeterminate individuals are removed from the study population. Males = 56% of the population and females = 44%. The demographic breakdown reveals differences in age-at-death curves.

Fig. 10. North and south populations, age at death

All of the age bands between the North and South populations are significantly different at $p < .05$ except for the 41-50 male and female age groups and the 60+ age group. The mean age at death for the Southern population is 33.4 years and for the Northern population the mean age at death is 45.7 years. This represents individuals that can be positively sexed. When the indeterminate individuals are factored in, there are only 6 in the south Bay and 103 in the North Bay; the mean ages at death remain nearly constant: 33.33 in the South and 45.33 in the North.

These sample populations are large enough to be presumed to have normal distributions within their own populations and between the two population areas. The calculation of t scores between the two means yields a t score of 1.89 which makes the

result significant at $p < 0.05$. Figure 10 above and tables (appendix Table A-3) exclude the indeterminate individuals.

TABLE 1. Demographic Profiles from North and South Sites Excluding Indeterminate Individuals

	North	South	χ^2
Teens M	1	9	6.4
Teens F	0	8	8.0
21-30M	1	31	28.1
21-30 F	2	20	14.7
31-40M	15	41	12.1
31-40 F	6	32	17.8
41-50 M	27	23	0.32
41-50 F	18	24	0.86
51-60 M	18	0	18.0
51-60 F	15	4	6.37
60+ M	0	0	0
60+ F	2	0	2.0
Totals	105	192	297

When the total population, including indeterminate individuals, is analyzed there is no significant difference between the total populations from the North and the South. In fact, they are close to identical. Each individual 10-year age band χ^2 significantly different at $p < 0.05$ except for the 60+ male and female age bands which only has 2 individuals, see figure 11, below (also see appendix A, Table A-5).

The sex ratios between the North and the South populations are presented in Table 6 (Appendix A, Table A-6). In total populations, the numbers are close to identical

but when broken into three components, male, female and indeterminate; significant differences emerge. Due to the fragmentary nature of many of the burials from CA-CCO-548 there was enough skeletal material to age effectively but not enough definitive markers to determine sex. Chi² analysis yields significant differences in all North/South profiles at $p < 0.05$.

Fig. 11. North and south age band breakdown

Post mortem tooth loss (PMTL)

Before starting discussion on the patterned wear, it is important to account for the teeth that are not present, due to post mortem tooth loss (PMTL) and ante mortem tooth loss (AMTL). Postmortem tooth loss is a common occurrence in most archaeological burial contexts. Teeth are either lost through taphonomic processes after the individual is buried and prior to archaeological discovery, or they were not recovered during the excavation process. Tables B-1 and B-2 (Appendix B) and Figure 12 present maxillary right and left PMTL counts for each tooth position. The overall tooth loss for the maxilla is 2,963, or 45.6% of available teeth, in the maxilla are lost PMTL. In the Northern population 1,819, or 28%, of the potential sockets are empty due to PMTL. In the Southern population, 1,144, or 17.6%, of potential sockets are empty due to PMTL. Fourteen of sixteen individual tooth positions are significantly different at $p < .05$, with the northern population having more PMTL than the southern population. The total tooth loss between the northern and Southern populations is also significant at $p < .05$.

Fig. 12. Maxillary post mortem tooth loss (PMTL)

Tables B-3 and B-4 (Appendix B) and Figure 13 present the PMTL for the mandible by tooth position. Fifteen out of sixteen individual tooth positions are significant at $p < .05$, with the north having more PMTL. There are a total of 1,996 teeth missing PMTL on the mandible or 30.7% of the available sockets are missing PMTL. Of those 1,309, 20.1% are in the northern group and 687, or 10.6%, are in the southern population.

Fig. 13. Mandibular post mortem loss (PMTL)

The total number of teeth lost to PMTL is 4,947, or 38.1%, of the total sockets available. Of that total, 3,118, (63%) are in the northern population and 1,829, (37%) in the southern population. Some of that difference is accounted for by differential preservation. The CA-CCO-548 population is older in time depth. The northern population is dated 4,000BP to 2,930BP and the southern is much more recent in time depth and dates from 2,200BP to 250BP. The northern population would logically have more taphonomic damage, resulting in greater PMTL.

Ante mortem tooth loss (AMTL)

AMTL is defined as teeth that have been lost prior to death due to trauma, ablation, (intentional or unintentional), periodontitis, and advanced attrition when the tooth exfoliates. To qualify as AMTL, the socket must show some degree of resorption.

The next set of tables, C-1 and C-2 for the maxilla and C-3 and C-4 for the mandible (Appendix C), and Figures 14 Maxilla, and Figure 15 Mandible present the number of teeth lost due to AMTL from the Northern and Southern populations. In the maxilla, a total of 473 teeth were lost, 7.3% of the total available sockets. The dominant amount of AMTL is in the Southern population. In the maxilla, 78 sockets (1.2%) are found in the northern population, and 395 (6.1%) are found in the southern population. Fourteen out of sixteen teeth show significance at $p < .05$, with the southern population having significantly more AMTL than the northern population.

Fig. 14. Maxillary, Ante Mortem Tooth Loss (AMTL)

In the mandible, a total of 436 teeth were lost AMTL, 6.7% of the available sockets. The same pattern found in the maxilla is repeated in the mandible with 156 teeth (2.4%) lost in the northern population, and 280 teeth (4.3%) lost in the southern population. Only four teeth show significant differences between the northern and southern populations with $p < .05$. Interestingly, they encompass the four incisors, with the southern population having more AMTL than the northern population.

Fig. 15. Mandibular, ante mortem tooth loss (AMTL)

In analyzing the dentition components that are absent (AMTL and PMTL), conflicting results emerge. Regarding PMTL there are, clearly, substantially more teeth missing in the northern population than in the southern with fourteen out of sixteen χ^2 results significant in the maxilla and fifteen out of sixteen significant in the mandible.

Conversely, looking at AMTL, the southern population has significant differences in fifteen out of sixteen Chi² results for the individual maxillary teeth, but only four out of sixteen in the mandible, encompassing all four incisors. Aggregating these teeth into operating quadrants, which is how they are functionally used, may provide additional information. A posterior quadrant is defined as the molars and premolars, on the left and right sides, and on both upper and lower dentitions. The anterior quadrant is defined as the canine and the two incisors; although in reality, the section of dentition from canine to canine tends to be used functionally as one grouping of six teeth. Aggregation is defined as grouping the molars and premolars together for the right and left antimeres and for the anterior teeth, comprising the canine and the two incisors on the right and left antimeres.

When teeth are aggregated into functional quadrants, seven out of the eight quadrants are statistically significant between the southern and northern groups. The southern group has significantly more AMTL than the northern group. This finding is unexpected and counter-intuitive. The northern population is significantly older in age-at-death, 45.7 yrs versus 33.4, for the southern population. If wear is assumed to be progressive and unidirectional, with the end result being loss of, or exfoliation of, the tooth, it would be expected that the older age-at-death northern population would be expected to have more AMTL than the younger age-at-death southern population.

Table 2, Maxillary AMTL aggregated by quadrants

	MXR Post	MXR Anterior	MXL Anterior	MXL Post.
North	24	3	9	42
South	171	31	28	165
Totals	195	34	37	207
χ^2	110.82	23.06	9.76	73.09

Table 3, Mandibular AMTL aggregated by quadrants

	MNR Post	MNR Anterior	MNL Anterior	MNL Post
North	55	30	27	44
South	77	64	57	81
Totals	132	94	85	125
χ^2	3.67	12.30	11.31	10.95

Fig. 16. Maxillary, AMTL, male and female

Fig. 17. Mandibular, AMTL, male and female

Remaining number of teeth to be scored

Before proceeding to the scoring of the teeth, it is important to delineate the number of teeth actually available to score. The potential is for 406 sockets in each tooth location, but, as shown above, there has been substantial tooth loss from PMTL and AMTL in all 32 tooth positions. The tables D-1 and D-2, for the maxilla, and D-3 and D-4 (Appendix D) for the mandible, as well as Figures D-3 and D-4 (Appendix D) show the actual number of teeth available for scoring by individual tooth position. The maxilla has 3,476 teeth present (53.5%) and the mandible has 3,952 present (60.8%) for a total number of 7,428 (57.7) teeth surviving.

The number of teeth present in the maxilla ranges from a low of n=166 (42% maxillary LI¹) to as high as n=262 (72% maxillary RC^{*}). In the mandible, the range is

from a low of n=158 (39% mandibular I₁), to a high of n=293 (72% mandibular M₂). The bilateral symmetry of both maxilla and mandible is notable. When analyzing individual tooth positions in the mandible and maxilla, the range in the number of teeth present varies from left side to right side by no more than 3%. More commonly the variance is 2%. Given the large sample size and the number of potential causes of tooth exfoliation, which include trauma, caries, peritonitis, vertical periodontal apical infections, and severe apical infection due to open root canals, the fact that the survival rate from right to left varies no more than 3% is remarkable.

The mirror image of that reality is that in the maxilla the missing teeth (combined AMTL and PMTL) range from a high of 59% (maxillary LI¹) to a low of 35% (maxillary RC^{*}). The average number of maxillary teeth lost is 46.4%. In the mandible, the percentage of missing teeth ranges from 61% (mandibular LI₁) to 28% (mandibular LM₁), with the average percentage of teeth lost being 39.8%. The greatest number of lost teeth was in the central and lateral incisors in both the maxilla and mandible.

Statistical analysis issues

Before commencing statistical analysis of wear patterns a decision had to be made about how to conduct the analysis. The raw data is comprised of counts of each tooth and its associated wear pattern. Comparing counts for males and females, north and south, looking for inter and intra-population variation is somewhat deceptive since the potential number of sockets sometimes differs radically between north and south. There are also large differences between males and females due to preservation issues with the CA-CCO- 548 population. Also, affecting the statistics is the large number of indeterminate

individuals in the northern population. After several trial runs, conducting the basic analysis as a percentage of each individual pattern displayed and as a percentage of the occupied sockets for that particular tooth was determined to be the most accurate representation of the data. This works well for comparisons between large clusters of data such as the flat wear, slants, and rounding patterns. For the other two patterns, scoops and grooves, the percentages of existing examples is comparatively small. It was decided for these patterns to use raw data counts. This method reflects the reality of these pattern populations accurately.

In many situations, working with percentage results on each of 16 or 32 teeth gives confusing or indeterminate results. Aggregation is chosen as a technique in this study to tease statistical information using a wider baseline than individual teeth can reasonably provide. A determination was made to utilize functional groupings of teeth for analysis. Anterior teeth, the eight teeth from right first premolar to left first premolar, are used as an aggregated functional grouping to illustrate rounded wear on both upper and lower arches. Slant wear primarily appears on the molars, so the eight first and second molars, upper and lower are used to analyze slant wear. Chi² is the primary tool used in conjunction with that formula being entered into Excel and also utilizing SPSS Version 16.

Research Question #1. Do dental wear patterns differ from the flat normative model?

Yes, there are patterns that are not flat and level. All teeth present are scored for patterned wear, and if there was no patterned wear present that tooth was scored as

having flat wear. The other wear patterns present include slants, rounding, scoops, and grooves. The following sets of tables (Tables 4, 5, 6, and 7) detail the percentages of teeth present for each form of wear pattern recorded as a percentage of surviving teeth available. Percentages are a more relevant comparison measure of the different forms of wear than raw counts of the number of teeth since the counts vary widely depending upon the survival rate for each tooth. The first set of tables and figures is for the maxillary percentages of each form of wear present. The tables above 4, 5, 6, and 7 and the figures below 18, 19, 20, 21, 22, 23, 24, 25, 26 and 27 for the maxilla and mandible, present the percentage distribution of the several wear forms for each arch.

Table 4, Maxillary Forms of Wear Right Arch Percentages

Form	RM³	RM²	RM¹	RPM²	RPM¹	RC[*]	RI²	RI¹
Flat	80.2%	37.8%	22.4%	45.6%	48.0%	58.0%	67.7%	66.9%
Slant	16.0%	54.4%	61.9%	31.3%	17.9%	8.0%	3.7%	4.1%
Scoop	0.0%	2.6%	2.2%	1.0%	1.2%	0.4%	0.0%	0.6%
Grooves	1.1%	0.0%	0.0%	0.5%	2.0%	3.1%	1.6%	1.7%
Rounding	2.7%	5.2%	13.5%	21.6%	30.9%	30.5%	27.0%	26.7%

Table 5, Maxillary Forms of Wear Left Arch Percentages

Form	LI¹	LI²	LC[*]	LPM¹	LPM²	LM¹	LM²	LM³
Flat	72.3%	69.5%	63.1%	50.6%	40.2%	17.5%	35.7%	79.6%
Slant	2.4%	2.1%	7.1%	19.8%	35.7%	67.9%	53.5%	19.4%
Scoop	0.6%	0.0%	1.2%	1.6%	0.5%	1.7%	3.7%	0.5%
Grooves	1.2%	2.1%	1.2%	1.2%	0.5%	0.0%	0.0%	0.0%
Rounding	23.5%	26.3%	27.4%	26.8%	23.1%	12.9%	7.1%	0.5%

Table 6, Mandibular Forms of Wear Right Arch Percentages

Form	RM₃	RM₂	RM₁	RPM₂	RPM₁	RC.	RI₂	RI₁
Flat	63.3%	38.2%	24.4%	61.5%	61.9%	69.5%	67.2%	67.0%
Slant	31.5%	49.8%	52.3%	17.2%	7.8%	3.6%	2.0%	2.5%
Scoop	3.5%	6.3%	9.1%	0.0%	1.2%	0.0%	1.0%	0.0%
Grooves	0.0%	0.7%	1.7%	2.6%	2.3%	0.6%	1.0%	0.0%
Rounding	1.7%	5.0%	12.5%	18.7%	26.8%	26.2%	28.8%	30.5%

Table 7, Mandibular Forms of Wear Left Arch Percentages

Form	LI₁	LI₂	LC.	LPM₁	LPM₂	LM₁	LM₂	LM₃
Flat	67.4%	65.0%	70.2%	63.4%	56.0%	25.0%	40.0%	72.8%
Slant	2.0%	3.5%	3.4%	9.8%	22.0%	51.0%	49.4%	20.0%
Scoop	0.0%	1.0%	0.4%	1.5%	0.3%	11.3%	4.8%	3.6%
Grooves	0.6%	1.6%	1.1%	0.3%	0.7%	1.0%	1.0%	0.5%
Rounding	30.0%	28.9%	24.9%	25.0%	21.0%	11.7%	4.8%	3.1%

Figure 18 shows the proportion of wear in each wear category for the entire population. Flat wear is 55%, slants 22.9%, rounding 19%, scoops are 2% and grooves are 1% of the total wear patterns present. In the maxilla, flat wear is dominant for the canines and incisors, with rounding being the primary form of wear caused by extramasticatory forces. Slant wear is dominant in the molars with flat wear being secondary (with the exception of M 3's). The premolars are a transition zone with flat wear being the most prominent at 40-50%, the remainder is evenly split between slants and rounding. There are two major wear patterns, slants and rounding, and two less populated wear patterns, scooping and grooving.

The next set of figures (21, 23, 25 and 27) and the two tables 6 and 7 present the wear forms for the mandibular teeth. The first, figure E-1 (Appendix E), encompasses all of the wear patterns in one figure, the next one, figure E-2 (Appendix E), all of the wear patterns without the flat wear. The next four, figure 21, slants, figure 23, rounding, figure 25, scoops, and figure 27, grooves, delineate each of the individual wear patterns. The graphs are shown as percentages of the remaining teeth for the flat, slant and rounding patterns. Scoops and grooves are displayed as counts present in the maxilla and mandible.

Flat wear is dominant in the canines and incisors (65-70.2%), with rounding being the secondary wear pattern. The molars show slant wear as dominant with flat wear secondary. The premolars are a transition zone, with flat wear dominant but slants and rounding being coeval. Grooving and scoops are less frequent wear patterns, but clearly present.

Fig. 18. Percentage of forms of wear for the total population

Fig. 19. Flat wear percentage frequency maxilla and mandible total population

Fig. 20. Maxilla, percentage of teeth with slant pattern

Fig. 21. Mandibular, percentage of teeth with slant pattern.

Fig. 22. Maxillary, percentage of teeth with the rounding pattern.

Fig. 23. Mandibular, percentage of teeth with the rounding pattern

Fig. 24. Maxillary, number of teeth with the scoop pattern

Fig. 25. Mandible, number of teeth with the scoop pattern

Fig. 26. Maxillary, number of teeth with the groove pattern

Fig. 27. Mandibular, number of teeth with groove pattern

Research Question #2a. Are there differences in dental wear patterns between posterior and anterior teeth?

Yes, slants are found predominately on the molars and account for 55% of the wear patterns found when the eight molars are aggregated. The eight molars are the maxillary and mandibular M1s and M2s. Rounding form of wear is found on the anterior teeth. The anterior teeth encompass the sixteen upper and lower teeth. They are the first premolar, canine, lateral and central incisors on the left and right sides on both the maxilla and the mandible. The average amount of rounded wear on these sixteen teeth is 27.5%. Over the whole arch the wear averages 19%.

Fig. 28. Combined slant wear on the molars and rounded wear on the anterior teeth

Research Question 2b. Are there differences between young and old individuals?

Yes, there are differences. All dental wear is age progressive, unidirectional and irreversible. Flat wear decreases as people age. The decrease in flat wear is replaced by increases in slant wear on the molars and rounded wear on the incisors (See Fig. 28).

Slant wear and rounded wear increase dramatically as people age. Scoop wear patterns and groove patterns do not appear until individuals are in their 30's and 40's.

Fig. 29 (left.). Flat wear percentage decrease through time on maxillary right first molar as population ages

Fig. 30 (right.). Flat wear percentage decrease through time on mandibular right first molar as population ages

Fig. 31(left.). Increasing rounded wear on lateral maxillary incisor through time

Fig. 32 (right.). Increasing rounded wear on lateral mandibular incisor through time

Fig. 33(left.). Slant wear increasing through time on maxillary first molar

Fig. 34 (right.). Slant wear increasing through time on mandibular first molar

Scoops and groove wear are patterns that do not appear until people in these populations reach their 30s and 40s. Apparent in figures 35 and 36, scoop wear has 152 examples present in the total population, but only 20 (13.2%) are present in the 20s age group. The rest are distributed principally in the 30s and 40s age demographic.

Fig. 35. Maxilla, age distribution of scoop pattern

Fig. 36. Mandible, age distribution of the scoop pattern

Groove distribution follows the same age-related pattern. There are 77 examples present throughout the population. Only 3 (3.9%) present in the 20s age group. Figures 37 and 38 show similar age distributions to the pattern of scoop wear form. The main occurrences of this wear form are in the 30s, 40s and 50s age group.

Fig. 37(left.). Maxilla, age distribution of groove pattern

Fig. 38 (right). Mandible, age distribution of the groove pattern

Research Question 2c: Are there differences between the Northern and Southern populations?

Yes, there are differences. The northern population dates from 4000BP to 2930BP. The southern population dates to 2200BP to 250BP. There is an 800 year gap in time between the two populations. The northern population has an average age-at-

death of 45.7 years, and the southern population is aged to 33.4 years age-at-death. In looking at AMTL, disparate results are present. Logically, it would be reasonable to expect more AMTL from the older age-at-death northern population. The assumption underlying this expectation is that loss of a tooth is the last stage of wear. This would be the result after the tooth has been worn down and exfoliated due to terminal attrition or apical infection. All 32 teeth have more AMTL in the Southern population. When aggregated into operating quadrants seven of eight quadrants show statistically significant differences with χ^2 with $p < 0.05$. The only exception is the mandibular right posterior quadrant, and that χ^2 score falls just short of significance.

When aggregating flat wear scores for the maxilla and mandible, the southern population has significantly more flat wear than the northern population as shown in figure 39.

Fig. 39. Flat wear north and south maxilla and mandible, total population

Using the same strategy of aggregating scores for rounded wear, the south has four comparisons between males and females, maxilla and mandible, with $p < 0.05$. By defining the anterior arches as the right first premolar to the left first premolar captures the bulk of rounded wear. The second premolar and the three molars have minimal amount of rounded wear. Southern males show significantly more rounded wear for the mandible only. Females have significant differences in both maxilla and mandible with southern females having significantly more rounded wear than northern females with $p < 0.05$ (See figure 41).

Fig. 40. Rounded wear males, north and south

Fig. 41. Rounding wear females, north and south

The slant wear pattern has a similar occurrence of slant wear in both the north and south populations with no apparent differences. The scoop wear pattern is dominated by the southern population, as seen in Figure 42. Of the 140 examples present in the total population, 21 are in the north and 119 in the south.

The groove pattern is equally split between the north and south populations. There are 33 present in the north and 34 in the south.

Fig. 42. Scoop wear frequency between north and south

Research Question 2d. Are there differences between males and females?

Males and Females, Flat wear. Yes, there are differences between males and females. Males have more flat wear than females in all population subsets. In the total populations, males consistently have more flat wear, tooth by tooth, and by aggregated totals. Figure 43 below, shows that there are statistically significant differences for the maxilla and the mandible with males having more flat wear than females.

Fig. 43. Flat wear comparison, male and female total population

In the north population, looking at individual teeth, males have more flat wear in 32 of 32 teeth than females, with two teeth being significantly different, the mandibular right PM₁ and left M₃. When the percentages of occurrence are aggregated, males have significantly more flat wear in both the maxilla and the mandible, as shown in figure 44 below.

Fig. 44. Flat wear north population, males and females

In the south population, 31 of 32 teeth show males with a higher percentage of flat wear than females, with none of the differences approaching significance. When the percentages of occurrence are aggregated, the following results in figure 45 show significant differences with males having more flat wear than females.

Fig. 45. Flat wear males and females, south population

When comparing the northern population of males with the southern population of males, 15 of 32 individual teeth show significant differences with the south males having more flat wear than the north males. When the percentages are aggregated the results are dramatically different as shown in figure 46, below. South males have significantly more flat wear than northern males.

Fig. 46. Flat wear, males north and south

Comparing the northern females with the southern females shows dramatic differences. Every tooth shows southern females with more wear than northern females. In the maxilla, 13 of sixteen individual teeth show significant differences. In the mandible, 14 of 16 teeth show significance, for a total of 27 of 32 individual teeth having significant differences. When the results for each arch are aggregated, the results are shown in figure 47.

Fig. 47. Flat wear, females north and females south

Males and Females Slant Wear. Slant wear is the most prevalent wear form present on the molars in all population subsets. It was felt that the maximum amount of information could be gleaned by comparing the individual molar teeth as well as aggregating the four molars, maxilla and mandible, and comparing various populations. When comparing total populations of males and females no significance is found by comparing individual teeth and none by aggregation.

When isolating the north population of males and females, males have more slant wear than females in all eight molars with three individual molars exhibiting significant differences. When aggregating all eight molars for males and females, both maxilla and mandible show significance with males having more slant wear than females, see Fig. 48.

The Southern population of males and females show no significant individual tooth differences. When aggregating the eight molars, the mandible shows significance, with males having more slant wear than females (See figure 49).

When comparing north males with south males, no individual teeth approach significant differences. Aggregating the eight molars reveals that southern males have significantly more slant wear in the mandible, as shown in figure 50. Comparing north females with south females, all south females have more slant wear than north females in the molars, with both maxilla and mandible showing significance when aggregated, as shown in figure 51.

Fig. 48. Slant wear, north population, males and females

Fig. 49. Slant wear, south population, males and females

Fig. 50. Slant wear, north males and south males.

Fig. 51. Slant wear, northern females and southern females

Males and Females Rounding wear. The vast majority of this form of wear focuses on the eight anterior teeth for this form of wear, for both the maxilla and mandible. The anterior teeth have the dominant amount of rounded wear across the dental arches. When comparing total populations of males and females, the maxilla shows that males have more rounded wear than females in all eight anterior teeth. Only two of eight individual teeth are significant, the right lateral incisor and the left canine. The mandible shows very mixed results with no trends or direction. When the anterior teeth are aggregated, for the total population of males and females, the maxilla shows significance, and the mandible has almost exactly the same aggregated percentages of wear (see figure 52).

When isolating the northern population, the same pattern emerges with males having significantly more rounded wear present in the maxillary anterior teeth. The mandibular teeth display equal amounts of rounded wear. The southern population, when comparing males and females for rounded wear, shows absolutely no differences in rounded wear between males and females, for either the maxilla or the mandible.

Isolating males from the north and south population shows southern, males having more wear in all eight mandibular teeth, with one being significant the mandibular right canine. When the percentages are aggregated, significant differences are present in the mandible, with southern males having significantly more rounded wear than northern males. No significance between north and south males was found in the maxilla.

Southern females exhibit more rounded wear in all 16 anterior teeth than northern females, with two teeth showing significance the maxillary right canine and the mandibular left central incisor. When percentages are aggregated, both maxilla and mandible exhibit significant differences between the northern and southern populations of females, with the southern females showing significantly more rounded wear.

Fig. 52. Rounded wear, total population, anterior teeth, males and females

Fig. 53 Rounded wear, anterior teeth maxilla, north population, males and females.

Fig. 54. Rounded wear, anterior teeth, comparing males north and south

Fig. 55. Rounded wear, anterior teeth, comparing females north and south

Scoop wear pattern, males and females. The statistical comparison base switches from percentages of occurrence to counts of frequency in this data set. Males exhibit more scoop wear than females in all subsets, with males having significantly more scoop wear than females. The north population has only 12 examples in males and 9 in females showing no significance. The south population has a significant difference, with males having substantially more scoop wear than females. Comparing north males and south males shows that south males have significantly more scoop wear than north males. The same pattern holds true for females. Southern females have substantially more scoop wear than northern females. In general, the scoop pattern is overwhelmingly found in the southern population and in males. Statistically, it is quite rare in the northern population.

Fig. 56. Scoop pattern, total population, males and females

Fig. 57 Scoop southern population, males and females

Fig. 58 Scoop, Males north and males south

Fig. 59 Scoop, females, north and south

Grooves wear pattern, males and females. The groove wear pattern appears in a very uniform pattern across the north and south populations and between males and females. There are 33 examples in the north and 34 in the south. Males have 34 grooves and females have 33 grooves. Northern males have 14 grooves and northern females have 19. Southern males have 20 grooves and southern females have 19 grooves. Northern males have 14 grooves and southern males have 20. Northern females have 19 grooves and southern females have 14.

IX. DISCUSSION

This study builds upon the dental analysis conducted by Molnar (1968) and enlarged on by Hilton (1981) and Keiser (2001a, 2001b). The goal is to define the forms of wear identified in Native American teeth, specifically from North Central California. The focus of this study is to closely define and illustrate the forms of wear observed in these populations and to define the progressive stages of that wear. Special attention is paid to generating visual criteria for each unique form of wear. Currently, attrition in a flat level plane is the only quantitative measurement that is routinely conducted on teeth during skeletal analysis (Murphy, 1959; Miles, 1962, Brothwell, 1963; Scott, 1979; Smith, 1984; Littleton and Frohlich, 1993; Buikstra and Ubelaker, 1994; Drier, 1994; Griffin, 2007). Additional forms of wear can illustrate how California Native Americans used their teeth as tools to cope with and technologically manage their environment.

Grit in the food bolus has been considered the default principal causative agent for the majority of the attrition seen in teeth (Leigh, 1925; Molnar, 1968; Jurmain, 1990). If causation has been discussed, it is usually attributed to grit in the food, specifically associated with acorn processing in stone mortars. This author contends that attrition and wear is the result of multiple and variable forces enacting upon the dentition. Other contributing agents suggested are phytoliths from basketry materials being processed with the teeth. Plants containing phytoliths are also used to manufacture cordage. Cordage is used and processed to make hunting and fishing equipment and general domestic activities. All of these plant materials contain silica phytoliths. Other abrasion contributors are greens being eaten in quantity which contain silica phytoliths, such as

clovers, miner's lettuce, and dozens, if not hundreds of other plant species. Abrasion was also created by crushed small animal bones cracked, chewed upon, and ingested as foods. Chitin and insect parts from hard carapaced insects were abrasion and microwear contributors. Retouching of projectile points with the teeth by males may also have been contributors to dental wear. All of these factors are ethnographically documented or inferred from materials found in coprolites (Fry, 1975; Nissen, 1983; Hartnady and Rose, 1991; Young, 1998; Reinhardt and Danielson, 2005; Reinhardt et al., 2007).

Looking at the PMTL and AMTL for these discrete populations, the total number of teeth lost in the northern population is 50.4% and 39.5% for the southern population. Of the 50.4% tooth loss in the north, the dominant losses were 46.8% PMTL with only 3.5% AMTL. In the southern population, 39.5% of the available teeth were lost with 28.9% considered PMTL and 10.6% classified as AMTL. The preservation in the southern populations is, in general, much better. These AMTL figures are considerably below the AMTL percentages gleaned from the few articles in the literature. Graham and Burkart (1976) found the upper range of AMTL in a Fremont population from Arizona to be from 20% to 58%. Costa (1980) working with Alaskan populations found AMTL losses ranged from 19% to 47%.

It is logical to expect the older (age-at-death is 45.7 years) northern population to have substantially more AMTL than the younger (age-at-death is 33.4 years) southern population. This is not the case. The southern population has three times the amount of AMTL than the northern population (North 3.5% versus South 10.65% χ^2 3.61). This suggests that the southern population was using their teeth in a more intense fashion than

the older age-at-death northern population. If loss due to exfoliation is considered the last stage of wear, then the southern population was subjecting their teeth to more intense destructive forces than the northern population and, as a result, lost teeth at a much younger age.

The results show that flat wear, assumed to be caused by normative masticatory wear, is the dominant wear pattern. However, it is not the only wear pattern present on any one tooth across these populations. Flat wear comprises 55% of the wear identified. There is a differential of 60% on the maxilla and 53% of flat wear present on the mandible. Slant wear, overall, constitutes 22.9% of wear present. On the molars, slant wear is the dominant wear pattern, comprising 55% of the wear found. Rounded wear is 19% overall, but on the anterior teeth that percentage climbs to 29%. Scoops are found primarily on the molar teeth and account for 2% of wear patterns overall. Grooves represent 1% of the wear patterns found and are primarily found on the anterior teeth, on both maxilla and mandibular arches. The wear patterns display a complex interaction across the dental arcade with other non-masticatory induced wear patterns, specifically slants on the posterior teeth and rounding on the anterior teeth.

The greater statistically significant amount of flat wear in the southern population over the northern population has two possible explanations. One is that the southern population is younger in age-at-death. It would naturally have more flat wear as there has not been as much time for the other wear patterns to develop. The second possibility is that the younger age-at-death southern population has more flat wear because there is an evolving elite class that is not subjecting its teeth to as much intense material processing

wear. Larger percentages of flat wear are accounted for because these individuals are primarily using their teeth to masticate food and not to process basketry or cordage materials. Since men have more flat wear than women in both northern and southern populations, an argument can be advanced that elites were primarily males, as noted historically (Brown, 1972).

Bean and Vane (1990), speaking of chiefs and craft specialists,

He lived in relative luxury in comparison with other men...he was often but not always released from ordinary labor. Occupational specialization created status differentiation and provided economic advantages for many. Specialists occurred in all groups (trading, basket-making and clam-shell disk manufacturing). Some craftsmen exchanged their products for other goods and were often completely relieved of other subsistence activities (Bean and Vane, 1990:280-281).

Keiser, working with prehistoric Maori populations, found flat wear to comprise 62.5% of the wear in males and females had 57.5% flat or horizontal wear (Keiser et al., 2001a). In a second study (2001b) he found that 43% of males and 55% of females exhibited flat planes of wear (Keiser et al, 2001b). The present study found 55% of the wear found was flat which is close to the flat wear found in Keiser's populations. He attributes all the wear found to grit in the food from a diet of "fish, fern root, birds and rats" (Keiser et al., 2001a:294). Both Keiser and Smith (1984b) attribute the flat plane of wear to a "tough fibrous diet" (Keiser et al., 2001a:294).

Smith (1984a) measured the slope of wear for molars of hunter-gatherers and agriculturists and found that the angle of buccal-lingual wear was about 10 degrees more severe in agricultural populations. In advanced stages of wear the mean slope of wear was 8.9 degrees for the hunter gatherer populations. That would qualify as a stage 1 (of

4) in the present study for slant wear. Keiser (2001a) also describes a molar wear plane that he describes as “fern root plane” which shows a 45-50 degree slant. He notes that other researchers have found the same extreme angled wear pattern in Australian aborigines, Inuit, and archaic Florida Indians. He found 33% of males and 44% of females exhibited this wear pattern. The present study found that 55% of the wear found on the first and second molar teeth exhibited this wear pattern and that it showed up to some degree in all teeth surveyed (see Figures 21 and 22 above).

Rounded wear has been reported a few times in the archaeology literature. Molnar (1968) notes a 4% incidence in the California sub group of his study. Hinton, (1981) did not quantify his results, but a close reading of his graphs shows an incidence of 7% to 35% of rounded wear on anterior teeth among Eskimos. An Australian aborigine population displayed a 15% to 28% incidence of rounded wear. Other studies report this form of wear but rely on ethnographic reports for evidence of causation without reporting incidence or frequency (Merbs, 1968). Hinton (1981) documents an extinct Sadlermuit population of Southhampton Island at Hudson’s Bay, Canada. His pictures show the same grade 4 rounded wear seen in the Central California populations. He attributes this wear pattern in Eskimos to skins being pulled across the teeth thereby abrading the enamel and dentin into dome-like shapes (Hinton, 1981:556).

The scoop pattern, as described above, is not mentioned in any of the previous research reports. Occasional mentions are made of cupped patterns but the descriptions differ (Molnar, 1968; Hinton, 1981). Hinton (1981) describes cupped wear as having a

complete enamel rim with dentine depression in the center. He ascribes causation to grinding of grains with stone tools which are negatively impacting the softer dentine.

As noted previously, grooves have been the most thoroughly documented of all the wear patterns (Cybluski, 1974; Larsen, 1985; Littleton and Frohlich, 1993 among others). All grooves pictured or drawn in articles would be identified as grade 4's in this study. This study attempts to detect earlier forms of this wear pattern, relying principally on lack of occlusion. If a groove was detected, occlusion, or lack of occlusion was important in determining if it was a groove produced by cultural processes. It was important to determine that the groove was not the result of a malocclusion or accidental trauma such as chipping and consequential rounding of the sharp edges of the enamel chip, giving the appearance of a groove.

In general, females have more patterned wear (less flat wear) than men. When men do have patterned wear, it is more intense and severe. Men have more posterior slant wear than women. Women have more rounded anterior wear than men. Men have substantially more scoop wear than women. Both sexes have almost exactly equal amounts of grooving wear. This speaks to a differentiation of labor between men and women. Women made baskets. Men made hunting and fishing equipment based on massive amounts of cordage. Both sexes used their teeth to process and hold basketry and cordage materials.

Most, if not all, of the basketry and cordage materials contain phytoliths (Piperno, 2006). Piperno lists *Poaceae* (Deergrass), *Equisetaceae* (scouring rushes and horsetails) *Cyperaceae* (sedges) and *Urticaceae* (nettles) as being exceptionally high in silica

phytoliths. Scouting rush was used by the Chumash to sand wooden bowls. Phytoliths have been recovered from dental calculus and hold promise as a source of dietary and usage information (Piperno, 2006). The sedge groups contain most of the seed producing grasses found in California.

The grit in the food default causation argument has never been objectively tested. There is one experimental study, of a single individual, by Teafor and Lytle (1996). They showed that the ingestion of one corn muffin (with corn ground on a sandstone mortar) eaten with each meal, for seven days, produced microwear 30 times worse than the normal baseline. They do not describe the critical grinding process beyond saying the corn was ground on “sandstone grinding tools as those used by the Anasazi at Mesa Verde, Colorado” (Teafor and Lytle 1996:143). No other studies were found to quantify the amount of grit actually present in stone ground meal. It must be noted that Native California populations could not have been unaware of the fact that stone spalls were being produced as they manufactured the stone mortars by pounding rocks on boulders to produce spalls and create the bowl of the mortar. Most recreators of primitive technology, when demonstrating acorn processing, leave a pad of acorn meal in the bottom of the mortar to absorb the heavier spalls (Campbell, 1999). It is important to note that acorns were typically ground on a flat rock or slight cupola with a basket hopper to control the spray of acorn particles. Deeper bedrock or portable mortars were used for other harder materials such as multiple species of small seeds. Assuming tiny rock spalls were incorporated into the meal, the leaching process with multiple washings, (up to 10) of water through the meal to leach out the tannins would also have washed out the

heavier rock spalls. The northern leaching method, in sand basins, could possibly have added grit (sand) to the mixture but all ethnographic accounts document how carefully the sand was washed off the meal. The last layer of acorn meal with some adhering sand was carefully picked up with the meal adhering to the hand and gently swished about in a basin of water to wash off the sand (Grinnell, 1893; Harrington, 1926).

Acorns are soft and do not inherently need stone mortars to process. Grass seeds, being much harder, actually require more aggressive pounding (or grinding on a metate) to reduce them to flour. There are several mentions of wooden mortars being created and used in the early contact literature, granting credence to the argument (Wagner, 1923; Menzie, 1924; Harrington, 1942; Leonard, 2001).

The observation has been made by many researchers that dental wear is greater in California than anywhere else in North America (Leigh, 1925; Molnar, 1968; Jurmain, 1990). California Native Americans were a unique group of cultures in a number of ways. Across variable ecological zones, their economy was based on acorns (where available) and small seeds, with multiple additions from a large, widely varied larder of additional food resources (Leigh, 1925; Kroeber, 1925; Heiser and Elsasser, 1980; Lightfoot, 2009). They discovered a method to leach tannins from acorns to create a storable, high caloric, baseline commodity to provide a safety net under their populations. No other North American tribal groups utilized this resource to the degree that Californians did. As a result there is little or no evidence of famine or food shortages in California (Kroeber, 1925).

Their storage technology was also distinctive. They developed basketry as a fully functional baseline utilitarian, yet artistic, medium. Elsewhere in North America, pottery was the material of choice for cooking and storage. California Native Americans were aware of the presence of, and the technology of, pottery. They has substantial trading alliances with the Colorado River tribes (Davis, 1961). The Colorado River tribes utilized pottery and also traded with the Pueblo peoples further east who used pottery as well. California tribal groups chose not to adopt this technology. Both as storage and cooking mediums, pottery and baskets, have advantages and disadvantages. Pottery is durable and heavy yet fragile. It is much more suited to a completely sedentary agricultural population. Baskets are lightweight and portable but take more time and skill to make. Both baskets and pottery are efficient cooking vessels if the proper fire technology is used ie., using hot stones to boil liquids in basketry versus using pottery cooking pots over an open fire.

The manufacture of pottery has no dental implications, and teeth are not involved in procuring, processing or formation of the basic raw materials or the finished products. Basketry has extensive dental implications. The processing of the raw materials into the finished product has women utilizing their teeth to hold and strip raw materials into usable components (see pictures in Wheat, 1967; 92-94; Campbell, 1999: 109, 188; Anderson, 2005, 44). All of these references show women stripping abrasive and phytolith rich raw materials with their dentitions. An underdeveloped and neglected area of research is the usage of cordage and basketry materials as the foundation of their material cultures which supported gathering, cooking, and storage, as well as hunting,

and fishing technologies (Hoover, 1974; Mathewson 1985; Shanks and Shanks, 2006; Anderson, 2005; Lightfoot, 2009). Massive amounts of materials were utilized to produce the baskets, as well as hunting and fishing assemblages. Gathering, processing, and manufacturing of these items had dental components as well as destructive dental implications and consequences. This result is also unique to California.

X. CONCLUSIONS

In support of Molnar's (1968) seminal work on forms of dental wear, Hilton's (1981) research, and Kieser et al's (2001a, 2001b) follow-up work with the Maori, this study attempts to employ, and define the variety of forms of wear commonly found in the teeth of Central California Native American populations. There is no previous comprehensive survey done to quantify wear forms found in Native American teeth. The distribution of wear is 55% for the flat form of wear, 22.9% with slant wear (55% on the posterior teeth), 19% with rounded wear (on the anterior teeth, it is 29%), 2% exhibiting scoops (primarily on the molars), and 1% displaying grooves (primarily on the anterior teeth).

All of these forms are thought to be caused by fiber and cordage processing. The percentage of slants, rounding, and scoops all increased through time from the earlier northern population to the younger, southern, denser population. Northern males had more slant and rounding wear than females. Southern males had more slant wear and were evenly split on the rounding pattern. Scoops, which may be related to arrow shaft processing or peeling, are predominately found in the southern population. The southern population primarily dates after the adoption of the bow and arrow (about 500AD). Grooves were evenly dispersed through north and south and between males and females.

Grit in the food has been the default causation recorded in the literature. This hypothesis of grit in the food being the default causation for dental attrition has never been scientifically tested. This author feels that grit in the food may certainly be a factor, but a closer look at food processing activities, and ethnographic observations and

comments throws doubt on the universality of that explanation. Many other elements impact the destruction of dental enamel and dentin. These causative agents include phytoliths from basketry and cordage materials, phytoliths from seasonal greens being consumed in quantity, and crushed bones of small mammals consumed as a calorie-rich, significant part of the diet. Retouching of projectile points with teeth are all contributors to dental attrition and the creation of defined forms of wear. The differentiation of California Native Americans from other tribal groups in North America in the utilization of acorns and small seeds as high caloric storable food resources resulted in a relative absence of food shortages and famine situations. The development of basketry rather than pottery as food processing, storage, and cooking vehicles also sets them apart. This author argues that these factors may very well have resulted in the usage of teeth as processing tools to a greater degree than in other regions and resulted in unparalleled dental damage and pathology. The operative mechanisms of processing massive amounts of basketry materials, cordage materials, and greens as food sources may well have been silica phytoliths being drawn across the dentition. The thesis results herein suggest that dental attrition is a much more complex series of events and does not have a simple cause and effect causation vector such as grit in the diet.

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Appendix A
Demographics

TABLE A-1. Demographic distribution by age, sex, and site

AGES	SEX	ALA 329	SCL 134	SCL 287	SCL 869	SCL 870	SCL 851	CCO 548	TOTAL
15-20	M	8	1	0	0	0	0	1	10
15-20	F	7	1	0	0	0	0	0	8
15-20	I	1	1	0	0	0	0	4	6
21-30	M	23	4	3	0	0	1	1	32
21-30	F	18	1	1	0	0	0	2	22
21-30	I	0	0	1	0	0	0	1	2
31-40	M	39	0	1	0	0	0	15	56
31-40	F	25	3	1	0	1	3	6	38
31-40	I	0	0	1	0	0	0	20	21
41-50	M	17	4	1	0	0	1	27	50
41-50	F	21	1	2	0	0	0	18	42
41-50	I	0	0	0	0	0	2	44	46
51-60	M	0	0	0	0	0	0	18	18
51-60	F	0	0	0	3	0	0	15	19
51-60	I	0	0	0	0	0	0	34	34
61+	M	0	0	0	0	0	0	0	0
61+	F	0	0	0	0	0	0	2	2
61+	I	0	0	0	0	0	0	0	0
Totals		160	16	11	3	1	7	208	406

TABLE A-2. Total demographics by South Bay and North Bay

AGES	SEX	SOUTH BAY SITES	NORTH BAY SITE	MALE	FEMALE	INDET	TOTAL
15-20	M	9	1	10			10
15-20	F	8	0		8		8
15-20	I	2	4			6	6
21-30	M	31	1	32			32
21-30	F	20	2		22		22
21-30	I	1	1			2	2
31-40	M	41	15	56			56
31-40	F	32	6		38		38
31-40	I	1	20			21	21
41-50	M	23	27	50			50
41-50	F	24	18		42		42
41-50	I	2	44			46	46
51-60	M	0	18	18			18
51-60	F	4	15		19		19
51-60	I	0	34			34	34
61+	M	0	0	0			0
61+	F	0	2		2		2
61+	I	0	0			0	0
TOTALS		198	208	166	131	109	406

TABLE A-3. Demographics, South Bay and North Bay without indeterminate individuals

AGES	SEX	SOUTH BAY	%AGE GROUP	NORTH BAY	%AGE GROUP	TOTAL POPULATION	TOT %
15-20	M	9	3%	1	.3%	10	3.4%
15-20	F	8	2.7%	0	0%	8	2.7%
21-30	M	31	10.44%	1	.3%	32	10.8%
21-30	F	20	6.7%	2	.6%	22	7.4%
31-40	M	41	13.8%	15	5.1%	56	18.9%
31-40	F	32	10.8%	6	2%	38	12.8%
41-50	M	23	7.7%	27	9.1%	50	16.8%
41-50	F	24	8.1%	18	6.1%	42	14.1%
51-60	M	0	0%	18	6.1%	18	6.1%
51-60	F	4	1.3%	15	5.1%	19	6.4%
61+	M	0	0%	0	0%	0	0%
61+	F	0	0%	2	.6%	2	.7%
TOTL		192		105		297	
%		64.65%	64.65%	35.35%	35.35%	100%	100%

TABLE A-4. Demographic profiles North and South excluding indeterminate individuals

	North	South	χ^2
Teens M	1	9	6.4
Teens F	0	8	8.0
21-30M	1	31	28.1
21-30 F	2	20	14.7
31-40M	15	41	12.1
31-40 F	6	32	17.8
41-50 M	27	23	0.32
41-50 F	18	24	0.86
51-60 M	18	0	18.0
51-60 F	15	4	6.37
60+ M	0	0	0
60+ F	2	0	2.0
Totals	105	192	297

TABLE A-5. North and South breakdown including indeterminate individuals

	Teens	21-30	31-40	41-50	51-60	60+	Totals
North	5	5	41	89	67	2	209
South	19	51	74	49	4	0	197
χ^2	8.20	37.8	9.47	11.59	55.90	2	.35

TABLE A-6. North and South sex ratios

	Male	Female	Indeterminate	Totals
North	63	43	103	209
South	102	89	6	197
Totals	165	132	109	406
χ^2	9.22	16.03	86.32	0.35

Appendix B. Post Mortem Tooth loss

TABLE B-1. Maxillary PMTL right arch

	RM³	RM²	RM¹	RPM²	RPM¹	RC	RI²	RI¹
North	121	110	98	108	102	96	122	145
South	78	66	85	78	58	47	85	89
Total	197	176	183	186	160	143	207	234
Chi²	10.28	11.00	0.92	4.84	12.10	16.79	6.61	13.40

TABLE B-2. Maxillary PMTL left arch

	RI¹	RI²	RC	RPM¹	RPM²	RM¹	RM²	RM³
North	151	130	112	98	104	95	98	129
South	98	86	42	51	67	77	66	71
Total	249	216	154	149	171	172	164	200
Chi²	11.28	8.96	31.82	14.83	8.01	1.88	6.24	16.82

TABLE B-3. Mandibular PMTL right arch

	RM₃	RM₂	RM₁	RPM₂	RPM₁	RC	RI₂	RI₁
North	75	61	62	65	76	85	104	110
South	32	25	28	41	40	34	61	86
Totals	107	86	90	106	116	119	165	198
χ²		15.07	12.84	5.43	11.17	21.86	11.21	2.44

TABLE B-4. Mandibular PMTL left arch

	LI₁	LI₂	LC.	LPM₁	LPM₂	LM₁	LM₂	LM₃
North	121	112	94	85	66	56	60	77
South	84	58	40	39	37	26	21	33
Totals	205	170	134	124	103	82	81	110
χ^2	6.68	17.15	21.76	17.06	8.17	10.98	18.78	17.60

Appendix C. Ante Mortem Tooth Loss (AMTL)

TABLE C-1. Maxillary AMTL right arch

	RM³	RM²	RM¹	RPM²	RPM¹	RC	RI²	RI¹
North	2	5	8	5	4	1	1	1
South	25	35	55	38	18	9	11	11
Totals	27	40	63	43	22	10	12	12
χ^2	19.59	22.50	8.91	21.5	8.91	6.4	8.33	8.33

TABLE C-2. Maxillary AMTL left arch

	LI¹	LI²	LC	LPM¹	LPM²	LM¹	LM²	LM³
North	4	3	2	5	9	15	8	5
South	9	11	8	16	29	52	38	30
Totals	13	14	10	21	38	67	46	35
χ^2	1.92	4.57	3.60	5.76	10.53	20.43	19.57	17.86

TABLE C-3. Mandibular AMTL right arch

	RM₃	RM₂	RM₁	RPM₂	RPM₁	RC	RI₂	RI₁
North	13	17	11	8	6	5	12	13
South	10	19	20	17	11	11	25	28
Totals	23	36	31	25	17	16	37	41
χ^2	0.39	0.11	2.61	3.24	1.47	2.25	4.57	5.49

TABLE C-4. Mandibular AMTL left arch

	LI₁	LI₂	LC.	LPM₁	LPM₂	LM₁	LM₂	LM₃
North	13	10	4	6	6	10	12	10
South	27	24	7	12	13	22	18	16
Totals	40	34	11	18	19	32	30	26
χ^2	4.90	5.76	0.82	2.00	2.58	4.50	1.20	1.38

TABLE C-5. Maxillary AMTL aggregated by quadrants

	MXR Post	MXR Anterior	MXL Anterior	MXL Post.
North	24	3	9	42
South	171	31	28	165
Totals	195	34	37	207
χ^2	110.82	23.06	9.76	73.09

TABLE C-6. Mandibular AMTL aggregated by quadrants

	MNR Post	MNR Anterior	MNL Anterior	MNL Post
North	55	30	27	44
South	77	64	57	81
Totals	132	94	85	125
χ^2	3.67	12.30	11.31	10.95

TABLE C-7. Maxillary teeth remaining right arch

Position	RM³	RM²	RM¹	RPM²	RPM¹	RC[*]	RI²	RI¹
N=	187	230	223	217	246	262	189	172
%	46%	57%	55%	53%	61%	65%	47%	42%

TABLE C-8. Maxillary teeth remaining left arch

Position	LI¹	LI²	LC*	LPM¹	LPM²	LM¹	LM²	LM³
N=	166	190	252	257	224	234	241	186
%	41%	47%	62%	63%	55%	58%	59%	46%

TABLE C-9. Mandibular teeth remaining right arch

Position	RM₃	RM₂	RM₁	RPM₂	RPM₁	RC.	RI₂	RI₁
N=	229	283	287	273	273	271	204	158
%	56%	70%	71%	67%	67%	67%	50%	39%

TABLE C-10. Mandibular teeth remaining left arch

Position	LI₁	LI₂	LC.	LPM₁	LPM₂	LM₁	LM₂	LM₃
N=	160	201	261	264	282	292	293	221
%	39%	50%	64%	65%	69%	72%	72%	54%

Appendix D. Combined PMTL, AMTL and surviving teeth

Fig. D 1. Total of PMTL and AMTL, maxilla, total teeth missing in north and south populations

Fig. D 2. PMTL and AMTL, Mandible, total teeth missing, north and south populations

TABLE D-1. Maxillary teeth remaining right arch

Position	RM ³	RM ²	RM ¹	RPM ²	RPM ¹	RC*	RI ²	RI ¹
N=	187	230	223	217	246	262	189	172
%	46%	57%	55%	53%	61%	65%	47%	42%

TABLE D-2. Maxillary teeth remaining left arch

Position	LI ¹	LI ²	LC*	LPM ¹	LPM ²	LM ¹	LM ²	LM ³
N=	166	190	252	257	224	234	241	186
%	41%	47%	62%	63%	55%	58%	59%	46%

Fig. D 3. Total number of maxillary teeth present

TABLE D-3. Mandibular teeth remaining right arch

Position	RM ₃	RM ₂	RM ₁	RPM ₂	RPM ₁	RC.	RI ₂	RI ₁
N=	229	283	287	273	273	271	204	158
%	56%	70%	71%	67%	67%	67%	50%	39%

TABLE D-4. Mandibular teeth remaining left arch

Position	LI ₁	LI ₂	LC.	LPM ₁	LPM ₂	LM ₁	LM ₂	LM ₃
N=	160	201	261	264	282	292	293	221
%	39%	50%	64%	65%	69%	72%	72%	54%

Fig. D 4. Total number of mandibular teeth present

Appendix E. Forms of Wear

TABLE E-1. Maxillary forms of wear right arch percentages

Form	RM³	RM²	RM¹	RPM²	RPM¹	RC[*]	RI²	RI¹
Flat	80.2%	37.8%	22.4%	45.6%	48.0%	58.0%	67.7%	66.9%
Slant	16.0%	54.4%	61.9%	31.3%	17.9%	8.0%	3.7%	4.1%
Scoop	0.0%	2.6%	2.2%	1.0%	1.2%	0.4%	0.0%	0.6%
Grooves	1.1%	0.0%	0.0%	0.5%	2.0%	3.1%	1.6%	1.7%
Rounding	2.7%	5.2%	13.5%	21.6%	30.9%	30.5%	27.0%	26.7%

TABLE E-2. Maxillary forms of wear left arch percentages

Form	LI¹	LI²	LC[*]	LPM¹	LPM²	LM¹	LM²	LM³
Flat	72.3%	69.5%	63.1%	50.6%	40.2%	17.5%	35.7%	79.6%
Slant	2.4%	2.1%	7.1%	19.8%	35.7%	67.9%	53.5%	19.4%
Scoop	0.6%	0.0%	1.2%	1.6%	0.5%	1.7%	3.7%	0.5%
Grooves	1.2%	2.1%	1.2%	1.2%	0.5%	0.0%	0.0%	0.0%
Rounding	23.5%	26.3%	27.4%	26.8%	23.1%	12.9%	7.1%	0.5%

TABLE E-3. Mandibular forms of wear right arch percentages

Form	RM₃	RM₂	RM₁	RPM₂	RPM₁	RC.	RI₂	RI₁
Flat	63.3%	38.2%	24.4%	61.5%	61.9%	69.5%	67.2%	67.0%
Slant	31.5%	49.8%	52.3%	17.2%	7.8%	3.6%	2.0%	2.5%
Scoop	3.5%	6.3%	9.1%	0.0%	1.2%	0.0%	1.0%	0.0%
Grooves	0.0%	0.7%	1.7%	2.6%	2.3%	0.6%	1.0%	0.0%
Rounding	1.7%	5.0%	12.5%	18.7%	26.8%	26.2%	28.8%	30.5%

TABLE E-4. Mandibular forms of wear left arch percentages

Form	LI₁	LI₂	LC.	LPM₁	LPM₂	LM₁	LM₂	LM₃
Flat	67.4%	65.0%	70.2%	63.4%	56.0%	25.0%	40.0%	72.8%
Slant	2.0%	3.5%	3.4%	9.8%	22.0%	51.0%	49.4%	20.0%
Scoop	0.0%	1.0%	0.4%	1.5%	0.3%	11.3%	4.8%	3.6%
Grooves	0.6%	1.6%	1.1%	0.3%	0.7%	1.0%	1.0%	0.5%
Rounding	30.0%	28.9%	24.9%	25.0%	21.0%	11.7%	4.8%	3.1%

Appendix F. Flat Wear

Table F-1. Total population, North and South, maxilla, as a percentage of available sockets, right arch

	RM3	RM2	RM1	RPM2	RPM1	RC'	RI2	RI1
North	37.3	10.9	6.3	17.9	19.9	24.7	25.1	23.8
South	37.3	27	16.1	27.5	28	33.1	39.2	43
X²	0.00	6.84	4.29	2.03	1.37	1.22	3.09	5.52

TABLE F-2. Total population North and South maxilla as a percentage of available sockets left arch

	LI1	LI2	LC	LPM1	LPM2	LM1	LM2	LM3
North	23.5	27.4	23.8	20.6	12.8	4.3	12.4	32.3
South	48.8	42.1	39.3	30	25.6	12.8	23	47.3
X²	8.85	3.11	3.81	1.75	4.27	4.23	3.17	2.83

TABLE F-3. Maxillary molars only, flat wear

	MXRM²	MXRM¹	MXLM¹	MXLM²
North	25	14	11	30
South	62	36	30	56
Totals	87	50	41	86
χ^2	15.74	9.68	8.8.	7.68

TABLE F-4. Mandibular molars only, flat wear

	MNRM ₂	MNRM ₁	MNLM ₁	MNRM ₂
North	41	20	25	49
South	67	50	48	68
Totals	108	70	73	117
χ^2	6.26	12.86	7.25	3.09

TABLE F-5. Maxillary anterior teeth only flat wear

	RPM ²	RPM ¹	RC*	RI ²	RI ¹	LI ¹	LI ²	LC*	LPM ¹	LPM ²
North	39	49	65	50	41	39	52	60	53	30
South	60	69	87	78	74	81	80	99	77	60
χ^2	4.45	3.39	3.18	6.13	9.47	14.70	5.94	9.57	4.43	10.00

TABLE F-6. Mandibular anterior teeth flat wear

	RPM ₂	RPM ₁	RC.	RI ₂	RI ₁	LI ₁	LI ₂	LC.	LPM ₁	LPM ₂
North	81	80	87	64	54	53	59	83	77	73
South	87	89	101	73	51	54	72	100	90	85
χ^2	0.21	0.48	1.04	0.59	0.08	0.00	1.29	1.58	1.01	0.91

TABLE F-7. Flat wear males north vs. males south maxilla percentages right arch

	RM ³	RM ²	RM ¹	RPM ²	RPM ¹	RC*	RI ²	RI ¹
North	42.8	44	28.5	38.5	36.7	32	36	34
South	58.6	50	50	56.6	57.9	58.6	52.6	58
χ^2	2.46	0.38	5.88	3.45	4.75	7.81	3.11	6.26

TABLE F-8. Flat wear males north vs. males south maxilla percentages left arch

	LI¹	LI²	LC*	LPM¹	LPM²	LM¹	LM²	LM³
North	28.2	30.8	30	28	26.7	27	36.6	43
South	58	58.8	52.5	57	58	43	55	51
χ^2	10.30	8.75	6.14	9.89	11.57	3.66	3.69	0.68

TABLE F-9. Flat wear males north vs. males south, mandibular percentages right arch

	RM₃	RM₂	RM₁	RPM₂	RPM₁	RC.	RI₂	RI₁
North	41	34	40	38.3	37.5	34.5	36	31.5
South	52	49	50	54	56	57.4	56	60.8
χ^2	1.30	2.71	1.11	2.67	3.66	5.71	4.35	9.30

TABLE F-10. Flat wear males north vs. males south, mandibular percentages, left arch

	LI₁	LI₂	LC.	LPM₁	LPM₂	LM₁	LM₂	LM₃
North	32.1	33.9	33.7	28.6	31.5	32	32.6	37.6
South	64.8	59.7	60	62.2	58.8	50	47	54.8
χ^2	11.03	7.11	7.38	12.43	8.25	3.95	2.61	3.20

TABLE F-11. Flat wear females north vs. females south maxilla percentages right arch

	RM³	RM²	RM¹	RPM²	RPM¹	RC*	RI²	RI¹
North	23.8	24	21	15	10.2	20	24	26.8
South	39.8	47.7	44	40	37.7	37.9	43.5	37.8
χ^2	4.02	7.29	8.14	11.36	15.77	5.53	5.63	1.87

TABLE F-12. Flat wear females north vs. females south maxilla percentages left arch

	LI¹	LI²	LC[•]	LPM¹	LPM²	LM¹	LM²	LM³
North	33	33	21.7	17	20	27.2	16.7	21.7
South	40.7	40.7	45	40.2	41.7	53	42.8	46.6
χ^2	0.80	2.98	8.14	9.41	7.63	8.30	11.45	9.08

TABLE F-13. Flat wear females north vs. females south, mandible percentages right arch

	RM₃	RM₂	RM₁	RPM₂	RPM₁	RC.	RI₂	RI₁
North	16.9	14.6	10	13.6	10	17	17.2	18.5
South	47	51	50	45	47.7	42.5	42.5	39.2
χ^2	14.18	20.20	26.67	16.83	20.29	10.33	10.72	7.43

TABLE F-14. Flat wear females north vs. females south, mandible percentages left arch

	LI₁	LI₂	LC.	LPM₁	LPM₂	LM₁	LM₂	LM₃
North	20.8	18.6	18.1	17.1	13.7	16	10.2	14.3
South	35.2	40.3	40	37.8	31.5	50	53	44
χ^2	3.70	7.99	8.25	7.80	7.01	17.52	28.98	15.13

Appendix G. Slants

Fig. G 1. Slants, north and south, total population maxilla, males and females

Fig. G 2. Slants, north and south total population, mandible, males and females

Fig. G 3. Slants, north population only, males and females, maxilla

Fig. G 4. Slants, north population only, males and females, mandible

Fig. G 5. Slants, south population only, males and females, maxilla.

Fig. G 6. Slants, south population, males and females, mandible.

Fig. G 7. Slants, Males only north and south, maxilla

Fig. G 8. Slants, Males only north and south, mandible.

Fig. G 9. Slants, females only, north and south, maxilla

Fig. G 10. Slants, females only, north and south, mandible

Fig. G 11. Percentage of slant wear present in the teen age group, maxilla

Fig. G 12. Percentage of slant wear present in the 20's age group, maxilla

Fig. G 13. Percentage of slant wear present in the 30's age group, maxilla

Fig. G 14. Percentage of slant wear present in the 40's age group, maxilla

Fig. G 15. Percentage of slant wear present in the 50's age group, maxilla

Fig. G 16. Percentage of slant wear present in the teen age group mandible

Fig. G 17. Percentage of slant wear present in the 20's age group, mandible.

Fig. G 18. percentage of slant wear present in the 30's age group, mandible.

Fig. G 19. percentage of slant wear present in the 40's age group, mandible.

Fig. G 20. Percentage of slant wear present in the 50's age group, mandible.

Fig. G 21(Left) and Fig. G 22 (Right). Percentage of slant wear present on the maxillary and mandibular first molars increasing through age bands from teens to 50's.

Appendix H. Rounding

Fig. H 1. Rounding, percentage of wear per tooth position, maxilla

Fig. H 2. Rounding, percentage of wear per tooth position, mandible

Fig. H 3. Rounding wear pattern present per maxillary tooth, total population, north and south

Fig. H 4. Rounding wear pattern present per mandibular tooth, total population, north and south.

Fig. H 5. Rounding wear pattern, present in anterior maxillary teeth, male and female

Fig. H 6. Rounding wear pattern, present in anterior mandibular teeth, male and female

Fig. H 7. Rounding wear pattern, present in the south population maxillary anterior teeth, males and females.

Fig. H 8. Rounding wear pattern present in the south population mandibular anterior teeth, males and females.

Fig. H 9. Rounding wear pattern present in the maxillary anterior teeth, males, north and south.

Fig. H 10. Rounding wear pattern present in the mandibular anterior teeth, males, north and south.

Fig. H 11, Rounding wear pattern present in the maxillary anterior teeth, females, north and south.

Fig. H 12, Rounding wear pattern present in the mandibular anterior teeth, females north and south

TABLE H-1. Rounded wear comparing females north with females south maxilla and mandible

	Maxilla	Mandible
Females North	64	99
Females South	161	205
χ^2	41.82	36.96

Fig. H 13. Rounding wear present per maxillary tooth position, in the 20's age group

Fig. H 14. Rounded wear present per maxillary tooth position, in the 30's age group

Fig. H 15. Rounding wear present per maxillary tooth position in the 40's age group.

Fig. H 16. Rounding wear present per maxillary tooth present in the 50's age group.

Fig. 17 (Left) and Fig. 18 (Right), rounded wear present in the maxillary and mandibular lateral incisors

Fig. H 19. Rounded wear present in the 10 maxillary anterior teeth, average present per age band from teens through 50's

Fig. H 20. Rounded wear present in the mandible by tooth position in the 20's age band

Fig. H 21. Rounded wear present per mandibular tooth position in the 30's age band

Fig. H 22. Rounded wear present per mandibular tooth position in the 40's age band

Fig. H 21. Rounded wear present per mandibular tooth position in the 50's age band

Fig. H 22 (Left) and Fig. H 23 (Right). Rounded wear present in the mandibular lateral incisors, percentage present through age bands from teens through 50's

Fig. H 24. Rounded wear present in the 10 mandibular teeth, average present from teens through the 50's

Appendix I. Scoops

TABLE I-1. Scoops frequency in maxilla right arch

Tooth	RM³	RM²	RM¹	RPM²	RPM¹	RC[*]	RI²	RI¹
Count	1	9	4	1	4	3	0	1

TABLE I-2. Scoops frequency in maxilla left arch

Tooth	LI¹	LI²	LC[*]	LPM¹	LPM²	LM¹	LM²	LM³
Count	1	0	1	3	2	5	5	0

TABLE I-3. Scoops frequency in mandible right arch

Tooth	RM₃	RM₂	RM₁	RPM₂	RPM₁	RC.	RI₂	RI₁
Count	8	14	33	1	4	1	2	0

TABLE I-4. Scoops frequency in mandible left arch

Tooth	LI₁	LI₂	LC.	LPM₁	LPM₂	LM₁	LM₂	LM₃
Count	0	2	0	3	0	26	18	0

TABLE H-5. Scoops male/female maxilla and mandible

	Maxilla	Mandible
Male	28	63
Female	8	33
χ^2	11.11	9.38

TABLE I-6. Scoops males north and males south

	Maxilla	Mandible
Males North	1	11
Males South	28	52
χ^2	25.14	26.68

TABLE I-7. Scoops females north and females south

	Maxilla	Mandible
North	5	4
South	3	36
χ^2	0.5	25.60

TABLE I-8. Scoops, age distribution, maxilla and mandible

Ages	20's	30's	40's	50's	60's
Maxilla	8	19	8	5	0
Mandible	12	52	39	8	1

Fig. I 1. Scoops wear pattern, frequency in the maxilla by age bands

Fig. I 2. Scoops wear pattern, frequency in the mandible by age bands

Appendix J. Grooves

TABLE J 1. Grooves frequencies in maxilla right arch

Tooth	RM3	RM2	RM1	RPM2	RPM1	RC	RI2	RI1
Count	2	0	0	1	5	8	3	3

TABLE J 2. Groove frequencies in maxilla left arch

Tooth	LI1	LI2	LC	LPM1	LPM2	LM1	LM2	LM3
Count	2	4	3	3	1	0	0	0

TABLE J 3. Groove frequency in mandible right arch

Tooth	RM3	RM2	RM1	RPM2	RPM1	RC	RI2	RI1
Count	0	2	5	7	7	2	2	0

TABLE J 4. Groove frequencies in mandible left arch

Tooth	LI1	LI2	LC	LPM1	LPM2	LM1	LM2	LM3
Count	1	3	3	1	2	3	3	1

TABLE J 5. Grooves males and females north and south

	Males No.	Males So.	Females No.	Females So.
Maxilla	10	7	8	9
Mandible	4	13	11	5
χ^2	2.57	1.80	0.47	1.14

TABLE J 6. Grooves in maxilla and mandible by age bands

	20's	30's	40's	50's
Maxilla	3	13	9	11
Mandible	0	10	31	2
Totals	3	23	40	13

Fig. J 1. Maxillary grooves, present in progressive age bands

Fig. J 2. Mandibular grooves present in progressive age band

Appendix K

DENTAL CULTURAL MODIFICATIONS AND WEAR FORM

Site Name/Number _____/_____ Observer _____

Feature/Burial Number _____/_____ Date _____

Burial/Skeleton Number _____/_____

Present Location of Collection _____

Dental Measurements

Maxilla—Left

Tooth	M ³	M ²	M ¹	PM ²	PM ¹	C	I ²	I ¹
Slants								
Scoops								
Grooves								
Rounding								

Maxilla—Right

Tooth	I ¹	I ²	C	PM ¹	PM ²	M ¹	M ²	M ³
Slants								
Scoops								
Grooves								
Rounding								

Mandible—Left

Tooth	M ₃	M ₂	M ₁	PM ₂	PM ₁	C	I ₂	I ₁
Slants								
Scoops								
Grooves								
Rounding								

Mandible—Right

Tooth	I ₁	I ₂	C	PM ₁	PM ₂	M ₁	M ₂	M ₃
Slants								
Scoops								
Grooves								
Rounding								

This form is intended to be used to record dental modifications and wear that is likely attributable to teeth being used as tools and/or to process fiber/plants for cultural usage. See following page for scoring explanation.

Dental Cultural Modifications and Wear

Wear patterns that are not attributable to mastication of food and/or normal wear require a specialized recording form. This form is intended to survey and record dental wear that may reveal potential behaviors that allowed prehistoric peoples to better utilize the resources their environment offered.

Slant:

This typically is seen on the molars and to a lesser degree on the premolars. It can exhibit as an angling of the occlusal plane from mild >10 degrees to extreme <45 degrees. Stages are again one to four. One would be >10 degrees <20 degrees. Two would be >20 degrees to <30 degrees, a three would be from >30 degrees to <40 degrees and a four would be anything greater than 40 degrees. Examples have been seen exhibiting wear in both lingual/buccal and buccal/lingual directions. The high side would be the first component and low side would be the latter component. Care should be taken in the milder stages, one and two, not to confuse this pattern with wear resulting from malocclusion. If both maxilla and mandible are available, pay close attention to the occlusion and determine if the pattern perceived is from normal mastication or cultural tool/processing usage. Please see examples below.

Stage 1 & Stage 2

Stage 3

Stage 3

Stage 4

Upper Molar--Slant Pattern

Lower Premolar Slant Pattern

Lower Molar Slant Pattern

Rounding: Usually seen on the anterior teeth, incisors and canines, although sometimes seen on premolars and molars in advanced states of wear. Grade 1 has one rim, 25% broken down, grade 2 has 2 rims or 50% lost, grade 3 has 3 rims or 75% of enamel rim lost and grade 4 has lost all of the enamel rim and has rounded into a dome shape. In advanced cases it is common to see all four mandibular incisors as rounded domes.

Grade 1

Grade 1

Grade 2

Grade 3

Grade 4

Scooping:

This is seen on the molars and occasionally on the premolars. Direction of wear is almost always in a distal/mesial direction. Wear stages are one to four. With one being a

mild scoop to a four being very pronounced with small enamel rims left on one or both sides (lingual/buccal) and secondary dentin and/or open root canals being present. See examples below

Stage 1

Stage 2

Stage 3 & 4

Stage 3 & 4

Stage 3 & 4

Stage 4

Stage 4

Grooving:

This usually involves the anterior teeth, incisors, and canines although it could involve the premolars. Stages are from a one, which shows no unusual wear; to a four which shows a distinctive groove mesial- distal or buccal-lingual. See examples below

Grade 1

Grade 1

Grade 3

Grade 4

Grade 4