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I am submitting herewith a thesis written by Kimberly Anne Dingess entitled "Captive Chimpanzee-Induced Tooth Modifications on Bone: Implications for the Interpretation of Plio-Pleistocene Archaeofaunal Assemblages." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Arts, with a major in Anthropology.

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Captive Chimpanzee-Induced Tooth Modifications on Bone: Implications for the Interpretation of Plio-Pleistocene Archaeofaunal Assemblages

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Abstract

Numerous actualistic studies have been devoted to identifying diagnostic criteria for differentiating hominid-induced bone modifications from those produced by non-hominid agents, notably carnivores. Little attention, however, has been given to potential carnivore tooth mark mimics. In light of the hominid involvement with the Plio-Pleistocene faunal assemblages, as demonstrated by the presence of stone tool marks, it is likely that hominid teeth produced at least some of the tooth marks.

In order to develop signature criteria for distinguishing hominoid and carnivore tooth marks, a series of bone feeding experiments were conducted with captive chimpanzees and four species of African carnivores. Chimpanzees and carnivores were experimentally fed fresh sheep and lamp bones at four zoological parks. Both specimen-level and assemblage-level analyses were employed to distinguish chimpanzee and carnivore tooth modifications on bone. At the assemblage-level, the density and incidence of chimpanzee and carnivore tooth marks were examined in relation to anatomical location and bone size. At the specimen-level, chimpanzee and carnivore tooth mark morphologies were described and characterized using both macroscopic and microscopic (stereomicroscopy and scanning electron microscopy) techniques. The secondary goal of this study was to identify individual agents from their tooth marks on bone. Quantitative techniques were used to examine differences in the size and shape of tooth marks between all five species (chimpanzees, African lions, striped hyenas, African wild dogs, and cheetahs).

The results show that while common chimpanzees can produce damage types (tooth scores, tooth pits, tooth punctures, and even fractures) identical to those inflicted by carnivores, there are diagnostic differences in the density and incidence of chimpanzee and carnivore tooth marks on bone. The most diagnostic trait of chimpanzee bone mastication is the morphology of the incisal tooth scores.

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Chapter I

Introduction

Because of the implications for other aspects of early hominid biological and social evolution, a multitude of hypotheses have arisen in paleoanthropology concerning the mode of meat acquisition by Plio-Pleistocene hominids. Various hypotheses depict early hominids as mere opportunistic scavengers of carnivore-ravaged carcasses (Binford, 1981, 1986; Shipman, 1983, 1984), as opportunistic scavengers of skeletally intact carcasses (Blumenschine, 1995; Capaldo, 1995; Selvaggio, 1994a), and as procurers of substantial quantities of meat and marrow through either opportunistic hunting or confrontational scavenging (Bunn, 1991; Bunn and Kroll, 1986; Bunn and Ezzo, 1993). The surface modification data (stone tool marks and carnivore tooth marks) on which these hypotheses are based, however, do not entirely resolve questions about the primacy of hominid versus carnivore roles in accumulating and modifying the archaeological bone assemblages.

The inability of surface modification data to resolve these questions is attributed to the less than adequate attention given to potential carnivore tooth mark mimics. In view of the hominid involvement with the Plio-Pleistocene faunal assemblages, as evidenced from the presence of stone tool cut marks (Bunn,1981; Potts and Shipman, 1981), it is certainly possible that hominid teeth inflicted at least some of these tooth marks. Others have commented on the potential for carnivore tooth mark mimicking of hominid tooth marks. As early as 1871, Mark Twain states:

> If the student should ask me how the paleontologist tells the difference between hyaena and human teeth-marks on a *bone*, and particularly a bone that has been rotting in a cave since the everlasting hills were builded, I should answer that I don't know (in White, 1992:155).

Almost a century after Twain's statement, Brain comments on the substantial damage modern humans produce on bones with their teeth. Of the goat bones given to the Hottentots and their dogs, "fifteen tail vertebrae were chewed and swallowed, while limb bones, such as femora and metapodials suffered severely at their ends" (Brain,1969:16). Hottentots were also observed to produce "ragged-edge chewing" on goat bones that is "practically indistinguishable from that produced by hyaenas on the more frail skeletal elements" (Maquire et al.,1980:88). In an ethnoarchaeological study of carcass processing, Oliver (1993:214) observes the Hadza to break and gnaw bones, producing damage that "without careful inspection of fractures... could easily be interpreted as the results of chewing by a small carnivore." Oliver (1994) also suggests that early *Homo* could produce tooth marks on bone that mimic those produced by carnivores. Oliver (1994:272) predicts that while severe damages such as furrowing and tooth notches on large animal bones are clearly indicative of carnivore gnawing, "the gnawing of smaller animals, notably hominids, may create damages such as tooth pits and scores." Although Binford (1981:148) believes that it is "highly unlikely" that hominid gnawing patterns would ever mimic those produced by carnivores, he does advocate actualistic experimentation to develop diagnostic indicators of human bone mastication. White (1992:155) states that "tooth striae, punctures, and tooth pits should not be attributed to taxon in the archaeological bone assemblages until further actualistic work is completed."

This thesis is the first systematic attempt to develop signature criteria for distinguishing hominoid and carnivore tooth marks on bone. Captive common chimpanzees (*Pan troglodytes*) serve as the modern analog for early hominid-induced tooth modifications. The comparative sample is comprised of tooth marks from four captive African carnivore species (African lion, striped hyena, African wild dog, and cheetah).

TAPHONOMY, ACTUALISM, AND ANALOGY

As defined by I.A. Efremov (1940:85), taphonomy denotes "the study of the "transition (in all its details) of animal remains from the biosphere into the lithosphere." Simply, taphonomy is the study of the laws of burial. It is not concerned only with the fossils themselves but the entire chronology of taphonomic agents and processes affecting animal remains from death to lithification to collection (Behrensmeyer,1984). A taphonomic agent (or actor) is the "immediate physical cause" of bone modification, such as a hyena gnawing a bone or a mammoth trampling a bone (Gifford-Gonzalez, 1991:228). The mechanism by which modification occurs, the action of an agent, is referred to by Lyman (1994) as a taphonomic process, such as gnawing or trampling. The resultant modification is the taphonomic effect or trace (Fisher,1995). Taphonomic analysis involves the identification and/or measurement of taphonomic effects in order to identify taphonomic processes and agents in the archaeological record. (Lyman,1994).

This thesis is an example of actualistic research pioneered in South African paleontology by C.K. Brain (1967). In actualistic studies, observations of modern

processes and effects are studied in order to understand the causal relationship between the taphonomic processes that formed the archaeological record and the effects that remain in the archaeological record (Gifford,1981; Selvaggio,1994a). The theoretical justification for this approach lies in two of Lyell's concepts of uniformity: 1) "natural laws are constant in space and time and, 2) processes in operation now were operating in the past" (Selvaggio, 1994a:41).

In this thesis, chimpanzees and carnivores serve as referential models for interpreting past processes and their effects. Referential models can provide a "heuristic framework" for examining a problem or can be used to "set up middle-range tests of hypotheses" (Moore 1996:278). The greatest criticism of referential models is that they mask variation between the model and what is being modeled (Potts,1987 and Moore,1996). In this study, chimpanzees and carnivores are not viewed as prototypes for extinct hominids and carnivores. On phylogenetic and analogical grounds, however, it is believed that modern chimpanzees and carnivores provide useful models for delineating extinct hominid and carnivore mastication damage on bone. Based on similarities in body size and proportions, dental traits, bite force, and technological grade, it is argued that chimpanzees best serve as models for bone mastication damage inflicted by gracile australopithecines (*Australopithecus afarensis* and *Australopithecus africanus*) and early *Homo*. The appropriateness of the chimpanzee model is discussed in greater detail in the following chapter.

PROJECT GOALS

The primary goal of this research is to identify signature criteria for differentiating chimpanzee and African carnivore tooth modifications on bone. In order to achieve this goal, multiple lines of evidence are employed ranging from the specimen-level to the bone assemblage as a whole. At the specimen-level (individual tooth marks), chimpanzee and African carnivore tooth score morphologies are described and characterized using both macroscopic and microscopic (stereomicroscopy and scanning electron microscopy) techniques. At the assemblage-level, the density and incidence of chimpanzee and carnivore tooth marks are examined in relation to anatomical location and bone size. The secondary goal is to identify individual agents from their tooth marks on bone. Quantitative techniques are used to examine differences in the size and shape of tooth marks between all five species (chimpanzees, African lion, striped hyena, African wild dog, and cheetah). Tooth pit area and shape are quantified using digital images and computer-generated measurements.

In acknowledgment of the morphological similarity that can occur between individual marks on bone, a number of researchers advocate analyses based on a configurational strategy (Bunn,1991; White,1992; Oliver,1994; Blumenschine et al.,1996). A configurational strategy, such as used in this study, is simply a comprehensive analytical method which takes into account such factors as the proportion of marked bones in the assemblage, the number of marks per specimen, the anatomical location of the mark, the orientation and position of the mark on the specimen, the shape and size of the mark, and other macroscopic and microscopic attributes.

The ability to distinguish hominoid and carnivore tooth marks and to identify individual agents would greatly aid zooarchaeologists in their efforts to reconstruct site formation processes and to determine the sequence by which Plio-Pleistocene hominids and carnivores modified bones.

In this thesis, I attempt to answer the following questions:

1). Can chimpanzees and carnivores be distinguished by the morphology of their tooth marks on bone?

2) Are there diagnostic differences in the patterning of tooth marks in the chimpanzee sample and carnivore sample?

3). Can specific agents be differentiated from their tooth marks on bone?

Chapter II

Literature Review

The origins and early practices of hunting and butchering have intrigued paleoanthropologists for decades. During the early years, inferences on the subsistence behavior of early hominids were drawn largely from the spatial association of stone tools (or bone tools, Dart 1953, 1957) and animal bones. The earliest appearance of stone tools in the Plio-Pleistocene archaeological record was often "... interpreted as evidence for a complex set of functionally linked hominid behaviors" (Binford et al., 1988:99). These behaviors included a sexual division of labor, long-term mating bonds between males and females, male and female responsibility for the care of offspring, and the development of language. All of these behavioral innovations were attributed to a shift to a hunting mode of subsistence on the part of early hominids.

In the 1970s, however, a heightened interest in taphonomy prompted a reassessment of the agents responsible for bone assemblage formation at the Plio-Pleistocene sites. Because of Brain's (1967, 1969) early taphonomic research and Binford's (1981) later insistence that a clustered association of stone tools and animal bones at archaeological sites was inadequate evidence to declare hominids as the primary agent of bone assemblage formation, archaeologists began to assess alternative explanations for the co-occurrence of stones and bones. Following a taphonomic agenda,

many actualistic studies were constructed to distinguish hominid bone assemblage formation from that of other non-hominid agents, particularly carnivores.

The first two sections of this chapter describe some of the most influential interpretations of the earliest archaeological sites in relation to their inferences on early hominid subsistence behavior. The following two sections describe the morphological and behavioral characteristics of chimpanzees and carnivores that make them suitable models for Plio-Pleistocene hominids and carnivores.

EARLY INTERPRETATIONS

Dart (1953, 1957) is credited for proposing perhaps the most theatrical interpretation of early hominid behavior. From the commingling of hominid and faunal remains at Makapansgat, Dart portrayed australopithecines as "... carnivorous creatures, that seized living quarries by violence, battered them to death, tore apart their broken bodies, dismembered them limb from limb, slaking their ravenous thirst with the hot blood of victims and greedily devouring livid writhing flesh" (Dart, 1953:209). Dart believed that the large quantity of broken animal bones found at the South African cave sites were collected by australopithecines who had used them as food and tools. To account for the disproportionate skeletal element representation, Dart suggested that australopithecines only brought back bones to the cave that made good tools, such as mandibles as saws and knives and antelope heads as picks and digging tools.

Although Dart's osteodontokeratic culture was largely dismantled by Brain's (1967,1969) subsequent taphonomic research, his pioneering work and dramatic writing

style had a major impact on his intellectual successors, notably S.L. Washburn. The hunting hypothesis climaxed in the publication of Richard Lee and Irven Devore's *Man the Hunter* (1968). In this publication, Washburn and Lancaster emphasized meat-eating, cooperative male hunting, and male dominance as the impetus for early hominid success.

The hunting hypothesis prevailed until the 1970's, when Isaac's (1971,1978) interpretation of the two million year old archaeological sites of Olduvai Gorge and Koobi Fora shifted the emphasis from hunting to food sharing. Isaac's "sharing" model was based on the fact that stone tools were found in dense patches in association with the faunal remains of many species. Isaac believed these Plio-Pleistocene sites represented places where hominids transported food for group consumption, which to him implied a social system involving home bases, a sexual division of labor, and long-term mating bonds between males and females. Although the hunting hypothesis is not invoked as a primary explanation for these innovations, Isaac and Crader (1981:95) believe that it is "likely that the portability and high food value of meat helped establish an adaptive complex that involves the transport and sharing of food obtained by the complementary endeavors of different members of the same society."

Like Isaac, Leakey (1971) also maintained that the faunal remains at Olduvai Gorge were the remnants of early hominid subsistence activities. Although she recognized some of the taphonomic processes (carnivores and water disturbance) that could have affected the archaeological evidence, she chose to allocate primary responsibility to hominids. On the basis of modern hunter-gatherer subsistence practices, Leakey viewed the early

archaeological site as living floors or "home bases", places to which early hominids cooperatively transported meat, bones, and plant foods for group consumption.

TAPHONOMIC REINTERPRETATION

Beginning in the 1970s, archaeologists recognized that they could not automatically proclaim hominids as the dominant agents responsible for bone assemblage formation at Plio-Pleistocence sites. Brain's (1967, 1969) pioneering research on Hottentot bone middens forced archaeologists to acknowledge other taphonomic agents, notably carnivores. A plethora of taphonomic studies ensued, dedicated to distinguishing the effects of carnivores and hominids on the accumulation, modification, and dispersal of bone assemblages (e.g., Binford,1981; Binford et al.,1988; Blumenschine, 1986,1988; Brain,1980; Bunn,1981, 1982, 1983b; Capaldo,1995; Capaldo and Blumenschine, 1994; Cook, 1986; Haynes, 1981, 1982, 1983; Marean and Spencer,1991; Marean et al., 1992; Potts and Shipman, 1981; Shipman, 1986a; Selvaggio, 1994a, 1994b; Sutcliffe, 1970).

While early interpretations relied most often on the spatial association of stone artifacts and animal bones, taphonomic studies sought to employ specific criteria for recognizing hunting or scavenging in the Plio-Pleistocene fossil record. Several criteria were advanced for distinguishing hunting and scavenging by early hominids, including size and age profiles (Blumenschine, 1991b), skeletal part profiles (Blumenschine, 1986; Bunn, 1986; Potts, 1983), and surface modifications on bone (Binford, 1981; Bunn, 1981, 1982; Bunn and Kroll, 1986; Shipman, 1981; 1984). Of these criteria, surface modifications (stone tool marks and carnivore tooth marks) were touted as providing perhaps the most

direct and unambiguous line of evidence for establishing the mode of meat acquisition by early hominids.

Bunn (1981), in his initial analysis of cut marks and percussion marks on archaeological bone assemblages from Olduvai Gorge and Koobi Fora, concluded that early hominids were consuming substantial quantities of meat and marrow. He felt the evidence of meat-eating and the concentrations of bones at particular sites were in accordance with Isaac's food-sharing model. He was uncertain, however, as to the means of meat acquisition. In subsequent publications (Bunn, 1983a, 1986; Bunn and Kroll, 1986; Bunn and Ezzo, 1993), however, Bunn argued that early hominids obtained intact carcasses of large animals through confrontational scavenging and acquired carcasses of small animals through opportunistic hunting. The evidence for this argument was derived from the frequency and distribution of cut marks. Bunn believed the distribution of large numbers of cut marks on meaty limb elements and on midshaft specimens were comparable to the frequency and location of defleshing marks on bones of more recent archaeological sites and ethnoarchaeological assemblages.

Oliver's (1994) analysis of hammerstone- and carnivore-induced damage frequencies at FLK *Zinjanthropus* supports Bunn's hypothesis that early hominids were the primary agents of bone accumulation and modification. Like Bunn, he noted the high frequency of cut marks on the meatiest limb elements. Although he recognized a significant carnivore involvement with the faunal assemblage, he contended that it was secondary to that of hominids. He reported that most of the carnivore damage was minor, consisting largely of tooth pits and scores. More severe damage types such as furrows and

fractures were rare. To Oliver, this suggested that carnivores were involved in assemblage formation but were not responsible for the majority of fractures. This also suggested that the carnivore responsible for the damage was not a large, bone crunching animal like the hyena, but a smaller carnivore incapable of easily fracturing bone.

In contrast, Binford (1981, 1986) argued that the cut mark frequencies at FLK *Zinjanthropus* are relatively low compared to North American ethnographic and prehistoric butchered assemblages, suggesting to him that early hominids were scavenging from carcasses previously consumed by carnivores. Binford (1986:446) also contented that the high frequency of cut marks on long bone shafts reported by Bunn and Kroll (1986) were not reminiscent of hominids removing significant quantities of usable meat, but reflective of the "extreme difficulty" hominids had "in processing already desiccated limb parts that had been previously ravaged by carnivores...".

Shipman (1983, 1984, 1986a, 1986b) also presented a case for scavenging based on the location of cut marks and the consistent overlap of cut marks on top of carnivore tooth marks on Olduvai bones. She observed that carnivore tooth marks occur most often on meaty bones, whereas cut marks tend to be roughly equally distributed between meaty and non-meaty bones. The unusual distribution of Olduvai cut marks compared to cut marks on bones at other Neolithic sites suggested to Shipman that hominids were utilizing carcasses as a source of skin and tendon. Further evidence for scavenging, came from the overlap of cut marks on top of carnivore tooth marks. Shipman reported that out of thirteen sets of overlapping marks on Olduvai limb bones, eight had cut marks over carnivore tooth marks. Despite the small sample sizes, she contended that these data

supported her hypothesis of an opportunistic foraging-scavenging subsistence strategy by early hominids.

More recently, archaeologists have focused on assessing the timing and extent of hominid and carnivore involvement with archaeological bone assemblages through the use of dual-agent experiments (Capaldo, 1995; Capaldo and Blumenschine, 1994; Blumenschine, 1988; Blumenschine, 1995; Blumenschine and Marean, 1993; Marean et al., 1992; Selvaggio, 1994a, 1994b). Advocates of dual-agent models argue that single agent models of assemblage formation are not sensitive indicators for assessing the relative roles of carnivores and hominids in dual-patterned assemblages. Dual-agent models are based on the premise that "the feeding activities of one agent will influence the range of choices available to the other and, hence, the extent and nature of damage to and dispersal of remaining bones and bone portions" (Blumenschine and Marean, 1993:274).

For example, Blumenschine (1995) demonstrates how bones first processed by hominids then consumed by carnivores can be used to address issues concerning the timing of carnivore and hominid involvement with archaeological bone assemblages. From a dual-agent experiment comparing three experimental scenarios (hammerstone only, carnivore only, and hammerstone to carnivore) to the FLK *Zinjanthropus* site, Blumenschine (1995) rejects both Bunn's and Binford's hypotheses. In examining the incidence of percussion marks and carnivore tooth marks between the experimental scenarios and the FLK assemblage, Blumenschine concludes that the sequence of hominid and carnivore involvement in the creation of FLK assemblage is more complex than interpreted by either Bunn or Binford. The surface modification patterns indicate a three

stage sequence of events where carnivores had first access to carcasses, followed by hominids, and then carnivores again. Blumenschine suggests that hominids had secondary access to meat but first access to marrow by scavenging from defleshed felid kills. Bone-crushing carnivores, like hyenas, had secondary access to grease from hominid discarded epiphyseal bone fragments.

CHIMPANZEE MODEL

While common chimpanzees may not be an appropriate model for other aspects of Plio-Pleistocene hominid behavior, they provide an ideal model for early hominid-induced tooth modifications on bone. As our closest living relatives (Goodman, 1992; Ruvolo, 1994), chimpanzees are alone among nonhuman primates in that they hunt and eat mammals on a routine basis. Stanford (1996) notes that although the amount of time spent feeding on mammals is usually only 1 to 3 percent, the annual amount of meat eaten (>600 kilograms) is substantial and approximates that of human foragers. Stanford (1995) also reports that chimpanzee predation at Gombe is severe enough to limit group size and population growth in red colobus monkeys. Gombe chimpanzees are known to eat at least 25 species of mammals ranging in size from small rodents and birds to juvenile bushpigs estimated to weigh more than 20 kilograms (Goodall, 1986; Stanford et al., 1994; Wrangham and Riss, 1990). The most preferred prey species, however, are red colobus monkeys and juvenile bushpigs and bushbucks (Boesch and Boesch, 1989; Teleki, 1975).

According to Stanford (1996), fat intake is the primary motivation for red colobus monkey consumption in the dry season at Gombe. Evidence for his argument is based on

prey consumption sequences, that is, body parts with the densest concentration of fat (brain and limb bone marrow) tend to be eaten first by chimpanzees. Blumenschine (1986, 1987) proposes a similar argument in that early hominids are inferred to scavenge for marrow and crania from abandoned lion kills in the dry season.

Like humans, chimpanzees are known to scavenge from other predators (Goodall, 1986; Hasegawa et al., 1983). Bunn and colleagues (1991) report that the Hadza employ an aggressive-confrontational scavenging strategy to appropriate carcasses from lions. As McGrew (1992) points out, the main difference between chimpanzee and human scavenging is that humans displace larger or more threatening competitors from large prey, whereas chimpanzees appropriate small prey from less dangerous competitors.

Chimpanzees are also known to use and transport stone tools. At Tai, stones are used as hammers for cracking nuts and are generally transported from one anvil to another throughout the forest (Boesch-Achermann and Boesch, 1994). The artifacts chimpanzees produce while pounding on nuts are almost indistinguishable from Oldowan tools found in the paleoarchaeological record (Boesch-Achermann and Boesch, 1992; McGrew, 1992; Potts, 1993). Chimpanzees also use stone tools to capture prey (Plooij, 1978). Stone tool-use by chimpanzees, however, has never been observed in the context of prey processing (butchering). The closest wild chimpanzees come to this is when they smash red colobus skulls against a hard surface, root or tree trunk (Boesch and Boesch, 1989). The lack of use of hammerstones is not attributed, however, to their inability to apply the technique. Kitahara-Frisch and colleagues (1987), demonstrate that captive chimpanzees easily learn to use stone hammers and anvils to smash open pig long bones.

Observations of chimpanzee tool-use combined with the simplistic nature of the Oldowan tools and the anatomical capability of australopithecines to make tools has lead Potts (1993:61) to question whether "Oldowan toolmaking was truly the key adaptive innovation and distinction between *Homo* and the australopithecine hominids...". It was not until the appearance of the Acheulian stone technology about 1.5 million years ago that hominids began to produce "an artifact of a particular target design" (Potts, 1993:67).

Body Size and Proportions, Bite Force, and Dental Traits

Common chimpanzees are of similar size and have body proportions comparable to gracile australopithecines and early *Homo* (Aiello, 1992; Hartwig-Scherer and Martin, 1991; Johanson et al., 1987; McHenry, 1992; Susman et al., 1985). In fact, all hominid species are small (approximately chimpanzee size) relative to modern humans until the appearance of *Homo erectus* about 1.7 million years ago (McHenry, 1994). The bite force of modern chimpanzees also resembles that of gracile australopithecines and early *Homo* (Demes and Creel, 1988).

In regards to dental traits, there are notable similarities between chimpanzees and early hominids. Both chimpanzees and early hominids possess broad, spatulate incisors and share a similar overall molar morphology. Like chimpanzees, some members of the *Australopithecus afarensis* species possess long, narrow, and straight-sided dental arcades which contain large, pointed canines that project above the tooth row (Conroy, 1990; Johanson and White, 1979). Because of their large canines, both hominoid taxa have sectorial lower third premolars and a diastema between the upper lateral incisor and upper

canine and between the lower canine and lower first premolar (Kimbel et al., 1994; Leonard and Hegmon, 1987; White et al., 1993). Although *Australopithecus africanus*, early *Homo*, and some members of *Australopithecus afarensis* are different from chimpanzees in having smaller non-procumbent incisors, smaller incisiform canines, and bicuspid lower third premolars, it is argued that the morphology of the incisors and posterior dentition of the four taxa are more similar to each other than any are to the carnivores. The broad spatulate incisors and bunodont molar morphology that characterize chimpanzees and the three extinct hominid taxa are dramatically different from the small, pointed incisors and blade-like posterior dentition of some carnivores.

Captive Chimpanzees

While free-ranging chimpanzees may provide a more naturalistic model for making predictions of early hominid mastication damage on bones, there are several disadvantages of studying wild chimpanzees. First, free-ranging chimpanzee carcass mastication is difficult to observe due to the unpredictability and arboreal setting of the hunting event. Second, faunal remains discarded from a chimpanzee feeding episode are scant because they generally consume all parts of their small prey including the flesh, viscera, and bone (Stanford, 1996; Takahata et al., 1984). Finally, given that wild chimpanzees are known to hunt and consume only small prey falling into Bunn's (1982) size group 1 (< 50lbs.), it is difficult to model Plio-Pleistocene hominids that are thought to utilize larger carcasses.

In contrast, captivity provides a controlled environment for easy observation of chimpanzee bone mastication and thorough collection of the bone refuse. Captivity also allows for the introduction of animal bones representing larger size groups.

CARNIVORE MODEL

The African carnivore species used in this study consist of the African lion (*Panthera leo*), cheetah (*Acinonyx jubatus*), African wild dog (*Lycaon pictus*), and striped hyena (*Hyaena hyaena*). The ancestors of all these species were present in East Africa during the Plio-Pleistocene. Their fossil remains have been found at two of the earliest archaeological sites, Oluvai Gorge and Koobi Fora (Blumenschine, 1986; Leakey, 1971; Turner, 1990). Carnivore guilds of the Plio-Pleistocene differ from modern African carnivore guilds in that the diversity of large carnivores was greater in the Plio-Pleistocene than in the present. In addition to the modern felids represented during the Plio-Pleistocene, there were three other large felids present. These included *Homotherium* and *Megantereon*, commonly referred as "true saber-tooths", and *Dinofelis*, usually known as a "false saber-tooth"(Marean, 1989).

Dictated largely by tooth morphology, the carnivore species used in this study differ in their abilities to consume flesh and bone. As flesh specialists, both cheetahs and lions have relatively long carnassial cutting blades and average size premolars compared to other carnivore species (Ewer, 1973). Although cheetahs and lions have similar dental arrays, they differ in respect to the relative emphasis on the anterior as opposed to the posterior dentition. Cheetahs are characterized by relatively reduced upper and lower

canines and well developed premolars and carnassials (Van Valkenburgh,1996). The posterior dentition, however, is extremely narrow and blade-like, adapted primarily for slicing through flesh (Ewer, 1973). Because of this adaptation, cheetahs are only capable of breaking bones of the smallest sized bovids (Marean,1989). In contrast, lions have more massive, somewhat flattened canines and less well developed premolars (Van Valkenburgh, 1996). Lions are capable of crunching through bones of small and medium sized bovids (Marean, 1989).

African wild dogs, compared to other large African carnivore species, use their incisors and canines more often to pull meat off the carcass. They rely on their carnassials and post-carnassials for crushing bone (Van Valkenburgh and Koepfli, 1993). They have the ability to break at least medium sized bones (Blumenschine, 1986).

Hyenas possess felid-like carnassial teeth, moderately developed canines, and massive, hammer-like premolars. The massive premolars and extremely powerful jaws make it possible for hyenas to crush larger bones than any other species. While hyenas do scavenge more frequently than any other carnivore species, they are also very effective primary predators (Ewer, 1973; Van Valkenburgh, 1996). Striped hyenas differ from spotted hyenas (*Crocuta crocuta*) in that there carnassials are less well suited for flesh slicing (Marean, 1989).

Chapter III

Materials and Methods

INTRODUCTION

The purpose of this thesis is to diagnose criteria for differentiating chimpanzee and African carnivore tooth modifications on bone. This quest for the development of signature criteria combines assessments ranging from the level of the individual tooth mark to the bone assemblage as a whole. The assemblage- level analyses were designed to reveal patterning in the experimental samples in relation to bone size, skeletal element group, long bone group, long bone portion, and tooth mark types. The specimen- level analyses (individual tooth marks) were constructed to define and characterize morphological attributes for distinguishing chimpanzee and carnivore tooth marks and for identifying specific agents from their tooth modifications on bone. Both qualitative and quantitative techniques were employed to distinguish individual tooth marks: tooth score morphology and size, and tooth pit size and shape. The following sections outline the specific methods I used and offer justification for them.

EXPERIMENTAL BONE FEEDINGS

Between November 1996 and July 1997, twenty-nine bone feeding experiments were conducted with common chimpanzees (*Pan troglodytes*) and four species of African carnivores (African lion, striped hyena, African wild dog, cheetah) at four zoological parks

(Table 1). For the chimpanzees, a total of 16 experiments were observed representing 15.34 hours of observation. Over the course of the 16 experiments, a total of 170 bones were fed to 26 chimpanzees. Of the 170 bones, 43 were excluded from all analyses due to lack of interest in them by the Jackson Zoo chimpanzees. Demographically, the four chimpanzee groups were represented by a roughly equal number of males and females and individuals of all age classes from infancy to old age. The size of the chimpanzee groups ranged from five to eight individuals. Thirteen bone feeding experiments representing 9.4 hours of observation were conducted among the four carnivore species. Here, 83 bones were fed to 17 animals. Seven of the 83 bones fed were excluded from analyses because of lack of interest in them from an African wild dog. The number of animals per carnivore species ranged from 9 cheetahs to one striped hyena. Most of the carnivores were fed separately due to the likelihood of intragroup aggression during feedings.

Both the chimpanzees and carnivores were fed fresh sheep (*Ovis aries*) and pig (*Sus scrofa*) bones purchased from meat distributors. All bones were presented raw except those given to the chimpanzees at the St. Louis Zoo, which were sterilized in an autoclave at 121°C, 15 lbs. of pressure for twenty minutes. Due to the butchery practices of the distributors, the bones most readily available in a complete state were the humerus, radius, ulna, femur, tibia, metacarpal with articulated carpals and first phalanges, metatarsal with adhering tarsals and first phalanges, pelvis, and scapula. In most cases, the butchers had cut the ligaments to separate the joints and trimmed off much of the muscle tissue. All of the periosteum remained on the bones. All bones were inspected prior to being fed to the chimpanzees and carnivores in order to eliminate those that had been damaged in

Table 1. Characteristics of the experimental bone feedings.

Species	Location	Number of Experiments	Number of Animals	Number of Bones	Hours of Observation
Pan troglodytes					
Chimpanzee	Jackson Zoo	4	8	43	2.26
	Little Rock Zoo	4	7	67	4.08
	Knoxville Zoo	5	5	43	5.32
	St. Louis Zoo	3	6	17	3.28
Chimpanzee Total		16	26	170	15.34
Panthera leo					
African lion	St. Louis Zoo	1	3	7	1.05
	Knoxville Zoo	3	2	21	2.45
Lion Total		4	5	28	3.5
Lycaon pictus					
African wild dog	Knoxville Zoo	4	2	26	2.11
Wild dog Total		4	2	26	2.11
Acinonyx jubatus					
Cheetah	Jackson Zoo	1	2	2	0.32
	St. Louis Zoo	1	7	7	1.12
Cheetah Total		2	9	9	1.44
Hyaena hyaena					
Striped Hyena	Knoxville Zoo	3	1	20	2.35
Hyena Total		3	1	20	2.35
Total		29	43	253	25.14

butchering. The bones were fed to the animals in their indoor and/or outdoor holding facilities. All bones were recovered after the animals no longer exhibited interest, which was defined as no chewing, sniffing or tactile manipulation of the bones for fifteen minutes.

Behavioral observations on both chimpanzees and carnivores were conducted during each bone feeding experiment to assess the length of time the bones were of interest. The level of interest was measured as the percentage of time spent performing the selected behaviors. For carnivores, it was determined by the level of three event behaviors: gnawing, sniffing, and transporting. Level of interest for chimpanzees was measured as the time spent gnawing or manipulating the object. Object manipulation included manipulation of the bones with the hands and/or feet, hitting the bones on the substrate, transporting, or holding. All bone feeding experiments were photographed and videotaped. Every effort was made to investigate the presumed relationship between tooth type and mark morphology. However, it was difficult to keep the animal in view, much less its teeth, during a feeding session. Even zoo animals habituated to the presence of observers, became agitated by my presence and either hid, charged the fencing, or stopped gnawing on the bones, so this part of the study was terminated.

SAMPLE PREPARATION

Three different processing procedures were used to clean all bone specimens. First, dermestids were used to remove the majority of adhering soft tissue. The remaining soft tissue and periosteum were removed by soaking the bones in gallon jars of water for

roughly one week. Finally, all specimens were thoroughly degreased by immersing them in Ward's skeletal degreasing solution (50% isopropyl alcohol, 48% water, 2% sulfonate detergent) for an average of three weeks. Cleaned specimens were then air-dried slowly in a dark closet to prevent cracking.

The term specimen as used here and throughout this thesis is defined as a complete (unfragmented) element or fragment of an element (Capaldo, 1995). A specimen can refer to a complete femur or a distal epiphysis of a femur. While an element refers to a "discrete, natural anatomical unit of a skeleton" (Lyman, 1994:100).

All specimens less than two centimeters in maximum length were excluded from analyses. Exclusion of these specimens was warranted for several reasons. Firstly, specimens less than two centimeters in length may be biased by incomplete recovery. Secondly, specimens this small retain few if any morphological landmarks from which to identify them to element. Lastly, the frequency of tooth-marked specimens declines as specimen size decreases (Blumenschine, 1988).

All recovered specimens greater than two centimeters in length were identified to skeletal element. Specimens were identified by refitting, morphological characteristics (bone size, bone shape, and morphological landmarks) and/or illustrations and descriptions from an anatomical source (Sisson, 1921). After identification, all specimens were assigned catalog numbers and labeled with indelible ink.

ANALYTICAL PROCEDURES

The following sections outline the procedures used to locate and examine tooth marks and describe and explain the assemblage-level analyses (tooth mark densities and incidence of tooth marks) and tooth mark morphology analyses (tooth score morphology, tooth score widths, and tooth pit morphology). All analytical procedures were chosen based on their ability to distinguish chimpanzee and African carnivore tooth modifications on bone.

Locating and Examining Tooth Marks

Chimpanzee and carnivore tooth marks were located and examined by procedures described by Bunn (1982), Blumenschine (1995), Capaldo (1995), and Selvaggio (1994a). Each specimen was first examined macroscopically under strong (100 watt) light to locate marks on the cortical, medullary, and intermediate surfaces. The specimens were systematically examined again with a 14x hand lens and strong directional light to ensure that all marks (conspicuous and inconspicuous) had been located. In both examinations, the bone with respect to the light source was angled at 90 degrees to maximize detection of all marks.

The tooth marks exhibited on the specimens in the chimpanzee and carnivore samples included scores, pits, punctures, furrows, and gross gnaw damage. These categories of tooth marks have been thoroughly described in the literature (Binford, 1981; Bunn, 1981; Shipman, 1981; Cook, 1986; Oliver, 1994; Selvaggio, 1994a). Tooth scores appear as linear grooves with small sideways deviations along the cortical perimeter of the

mark. They may be U or V shaped in cross section depending on the morphology of the tooth cusp. Their occurrence on bone specimens ranges from a single, isolated mark to clusters of intersecting marks. Tooth pits are circular to oblong depressions which display either an inward crushing or scraping away of the cortical surface. Pits tend to be concentrated on the epiphyseal ends and near the medullary cavity of broken bones. Tooth punctures may be described as depressed areas which are circular to oblong in plan form. The puncture walls consist of small, irregular pieces of fractured bone pushed downward into the softer tissue below. Furrows refer to an area of cancellous bone with numerous large troughs (furrows) graduated up towards harder compact bone. Gross gnaw damage is simply an exaggerated form of furrowing. That is, if considerable gnawing occurs, individual furrows are generally obliterated as the cortical and cancellous tissue is gnawed away. Here, the bone is broken producing an array of fracture patterns including channeled bone, chipped back bone, mashed edges, and crenulated edges.

In this thesis, the actual number of tooth marks for each tooth mark type (score, pit, puncture, furrow, and gross gnaw damage) were recorded with respect to skeletal element, bone size group, and long bone portion for each specimen in the sample. Any tooth mark type was counted as one mark. Gross gnaw damage was counted as one mark, irrespective of the size of the area of damage. In instances where overlapping marks occurred, each mark was again counted as a separate mark.

Since the degree of confidence in mark counts can vary, particularly with the inclusion of inconspicuous marks, a test was performed to verify the accuracy of the counts. Here, a random sample of 50 bone specimens from the carnivore sample was

drawn and the marks on the specimens were recounted. Of the 50 specimens randomly drawn, 43 had an original total of 239, while 7 specimens did not have marks. For 39 specimens, the second count was identical with the first. For three specimens, however, the second count was lower by a total of three and for one specimen it was lower by two. Thus, from the second count it can be inferred that 95.4% of the marks were accurately recorded in the original count.

Assemblage- Level Analyses

The analyses describe below were designed to examine the assemblage-wide density and incidence of chimpanzee and carnivore tooth marks. Assemblage-level analyses serve to uncover patterning in a large number of bone specimens and "enable assessments beyond the simple presence-absence statements provided by individual specimens" (Bunn, 1991:439).

Two experimental samples are compared in the assemblage-level analyses, the chimpanzee sample and the carnivore sample. The chimpanzee sample is comprised of 127 skeletal elements represented by 132 specimens. Of the 127 elements, size group 2 (lamb) elements comprise 76% of the sample, while size group 3 (pig) elements make-up 24% of the sample. The skeletal group composition of the chimpanzee sample is represented by 17 (13%) flat bones, 47 (37%) compact bones, and 63 (50%) long bones. Of the 63 long bones, 23 (37%) are proximal, 31 (49%) are intermediate, and 9 (14%) are distal. The carnivore sample is comprised of 76 skeletal elements represented by 151 specimens. Of the 76 elements, size group 2 elements make-up 32% of the sample, while

size group 3 elements are represented by 68% of the sample. The skeletal group composition of the carnivore sample is comprised of 8 (11%) flat bones, 13 (17%) compact bones, and 55 (72%) long bones. Of the 55 long bones, 27 (49%) are proximal, 24 (44%) are intermediate, and 4 (7%) are distal. Tables 2, 3, and 4 describe these samples in greater detail. The unevenness of the samples with respect to skeletal elements and bone size groups is attributed to the availability of bones and captive animal management policies.

In both experimental samples, the density and incidence of tooth marks are calculated for the actual number of elements (ANE) recovered. The use of ANE's as opposed to the number of identified specimens (NISP) is justified in that it controls for differential fragmentation between the two samples. Selvaggio (1994a) notes that larger specimens are expected to exhibit higher numbers of tooth marks than smaller specimens if the tooth marks are randomly distributed. Thus, comparisons of tooth mark densities on chimpanzee- produced specimens and carnivore- generated specimens "could be biased by different frequencies of small and large-sized specimens within each sample (Selvaggio,1994a: 89). For long bones only, the chimpanzee experimental sample is comprised of 60 (95%) complete bones and 3 (5%) epiphyseal fragments. The carnivore sample, however, contains only 37 (30%) complete bones and 84 (70%) epiphyseal, near-epiphyseal, and midshaft fragments.

Table 2. Skeletal element composition of the chimpanzee and carnivore samples by size group. SC= scapulae; HU= humeri; RA= radii; MC= metacarpals; CA= carpals; PHL= phalanges; PE= pelves; FE= femora; TI= tibiae; MT= metatarsals; TA= tarsals. Below the solid line is a break down of the carnivore sample by species.

Sample	Size Group	SC	HU	UL	RA	MC	CA	PHL	PE	FE	TI	MT	TA	Total
Chimpanzee	2	8	0	6	6	5	25	6	7	6	7	4	16	96
	3	0	4	6	6	0	0	0	2	13	0	0	0	31
Chimpanzee Total		8	4	12	12	5	25	6	9	19	7	4	16	127
Carnivore	2	2	0	1	1	2	5	0	2	1	0	2	8	24
	3	1	11	11	11	0	0	0	3	15	0	0	0	52
Carnivore Total		3	11	12	12	2	5	0	5	16	0	2	8	76
Lion	2	0	0	0	0	1	0	0	1	0	0	0	0	2
	3	1	4	6	6	0	0	0	1	8	0	0	0	26
Lion Total		1	4	6	6	1	0	0	2	8	0	0	0	28
Hyena	2	1	0	1	1	1	5	0	1	1	0	1	4	16
	3	0	3	0	0	0	0	0	0	1	0	0	0	4
Hyena Total		1	3	1	1	1	5	0	1	2	0	1	4	20
Wild dog	2	1	0	0	0	0	0	0	0	0	0	1	4	6
	3	0	1	3	3	0	0	0	2	4	0	0	0	13
Wild dog Total		1	1	3	3	0	0	0	2	4	0	1	4	19
Cheetah	2	0	0	0	0	0	0	0	0	0	0	0	0	0
	3	0	3	2	2	0	0	0	0	2	0	0	0	9
Cheetah Total		0	3	2	2	0	0	0	0	2	0	0	0	9

Table 3. Skeletal group composition of the chimpanzee and carnivore samples by size group. Skeletal groups are presented by number of elements (numerator) and number of individual specimens (denominator). Flat bone group includes scapulae and pelves. Compact bone group includes carpals, tarsals, and phalanges. Long bone group includes humeri, radii, ulnae, metacarpals, femora, tibiae, and metatarsals. Below the solid line is a break down of the carnivore sample by species.

Sample	Size Group	Skeletal Groups: Flat Bones	Compact Bones	Long Bones	Total
Chimpanzee	2	15 / 20	47 / 47	34 / 34	96 / 101
	3	2 / 2	0 / 0	29 / 29	31 / 31
Chimpanzee total		17 / 22	47 / 47	63 / 63	127 / 132
Carnivore	2	4 / 8	13 / 13	7 / 9	24 / 30
	3	4 / 9	0 / 0	48 / 112	52 / 121
Carnivore total		8 / 17	13 / 13	55 / 121	76 / 151
African lion	2	1 / 2	0 / 0	1 / 3	2 / 5
	3	2 / 7	0 / 0	24 / 80	26 / 87
Lion total		3 / 9	0 / 0	25 / 83	28 / 92
Striped hyena	2	2 / 2	9 / 9	5 / 5	16 / 16
	3	0 / 0	0 / 0	4 / 12	4 / 12
Hyena total		2 / 2	9 / 9	9 / 17	20 / 28
African wild dog	2	1 / 4	4 / 4	1 / 1	6 / 9
	3	2 / 2	0 / 0	11 / 11	13 / 13
Wild dog total		3 / 6	4 / 4	12 / 12	19 / 22
Cheetah	2	0 / 0	0 / 0	0 / 0	0 / 0
	3	0 / 0	0 / 0	9 / 9	9 / 9
Cheetah total		0 / 0	0 / 0	9 / 9	9 / 9

Table 4. Long bone group composition of the chimpanzee and carnivore samples by size group. Long bone groups are presented by number of elements (numerator) and number of individual specimens (denominator). Proximal long bone group includes humeri, and femora. Intermediate long bone group includes radii, ulnae, and tibiae. Distal long bone group includes metacarpals and metatarsals. Below the solid line is a break down of the carnivore sample by species.

Sample	Size Group	Long Bone Groups			
		Proximal	Intermediate	Distal	Total
Chimpanzee	2	6 / 6	19 / 19	9 / 9	34 / 34
	3	17 / 17	12 / 12	0 / 0	29 / 29
Chimpanzee total		23 / 23	31 / 31	9 / 9	63 / 63
Carnivore	2	1 / 1	2 / 2	4 / 6	7 / 9
	3	26 / 69	22 / 43	0 / 0	48 / 112
Carnivore total		27 / 70	24 / 45	4 / 6	55 / 121
African lion	2	0 / 0	0 / 0	1 / 3	1 / 3
	3	12 / 47	12 / 33	0 / 0	24 / 80
Lion total		12 / 47	12 / 33	1 / 3	25 / 83
Striped hyena	2	1 / 1	2 / 2	2 / 2	5 / 5
	3	4 / 12	0 / 0	0 / 0	4 / 12
Hyena total		5 / 13	2 / 2	2 / 2	9 / 17
African wild dog	2	0 / 0	0 / 0	1 / 1	1 / 1
	3	5 / 5	6 / 6	0 / 0	11 / 11
Wild dog total		5 / 5	6 / 6	1 / 1	12 / 12
Cheetah	2	0 / 0	0 / 0	0 / 0	0 / 0
	3	5 / 5	4 / 4	0 / 0	9 / 9
Cheetah total		5 / 5	4 / 4	0 / 0	9 / 9

Tooth Mark Densities

This analysis examines the density and anatomical patterning of chimpanzee and carnivore tooth marks on the experimental samples described above. Here, the percentage of the samples (chimpanzee and carnivore) exhibiting specific densities of tooth marks are examined by bone size group, skeletal element group, long bone group, and long bone portion. Tooth mark densities are used to estimate the extent to which the bones were consumed by the chimpanzees and carnivores.

The chimpanzee and carnivore samples are stratified by bone size because bone density and the quantity of flesh and marrow differed between bone size groups. The bone size groups are adopted from Bunn (1982), where size 2 (50- 250 lbs.) bones are represented by sheep and size 3 (250- 750 lbs.) bones are represented by pigs.

Following Capaldo (1995), skeletal elements from both experimental samples are categorized into skeletal element groups based on their natural anatomical associations, relative within-bone food values, and mechanical properties (size, shape, and density). Three skeletal element groups were constructed: the flat bone group (scapulae and pelves), compact bone group (carpals, tarsals, and phalanges), and long bone group (humeri, radii, ulnae, metacarpals, femora, tibiae, and metatarsals). Due to their high representation at the earliest archaeological sites, particularly FLK Zinjanthropus, I felt it necessary to examine the long bones in greater detail. The long bones were categorized into three groups: the proximal long bone group (humeri and femora), intermediate long bone group (radii, ulnae, and tibia), and distal long bone group (metacarpals and metatarsals).

The chimpanzee and carnivore samples are also stratified by long bone portion. Portions can refer to a specific segment along an intact (unfragmented) bone or describe a specific fragment. Long bone portions are categorized into epiphyseal, near-epiphyseal, and midshaft portions. The following definitions for long bone portions are taken from Blumenschine (1988:487) with some modifications to accommodate complete long bones.

> **Epiphyseal portion:** Bearing all or part of the proximal and/or distal articular surface of long bones (Figure 1).
>
> **Near-epiphyseal portion:** For an intact specimen, refers to the proximal and distal two-thirds of the diaphysis. Near-epiphyseal fragments lack articular surfaces but preserve cancellous tissue on the medullary surface that is indicative of proximity to an epiphysis. Near-epiphyseal portions are equivalent to Marean and Spencer's (1991) proximal and distal shaft portions.
>
> **Midshaft portion:** For an intact specimen, refers to the middle one-third of the diaphysis. Midshaft fragments are diaphyseal fragments that lack articular surfaces and cancellous bone.

The chimpanzee and carnivore experimental samples are compared using the nonparametric Kruskal- Wallis test. This test may be applied to any "r x c contingency table in which the rows (r) are unordered but the columns (c) are ordered" (Mehta and Patel, 1995:145). Monte Carlo and/or Exact p values were calculated for each test. The Monte Carlo and Exact methods allow you to obtain accurate results when your data set is small, your tables are sparse or unbalanced, or the data are not normally distributed (Mehta and Patel, 1995). For the statistical analyses, all specimens lacking tooth marks are excluded. These specimens are reported in the tables but for descriptive purposes only.

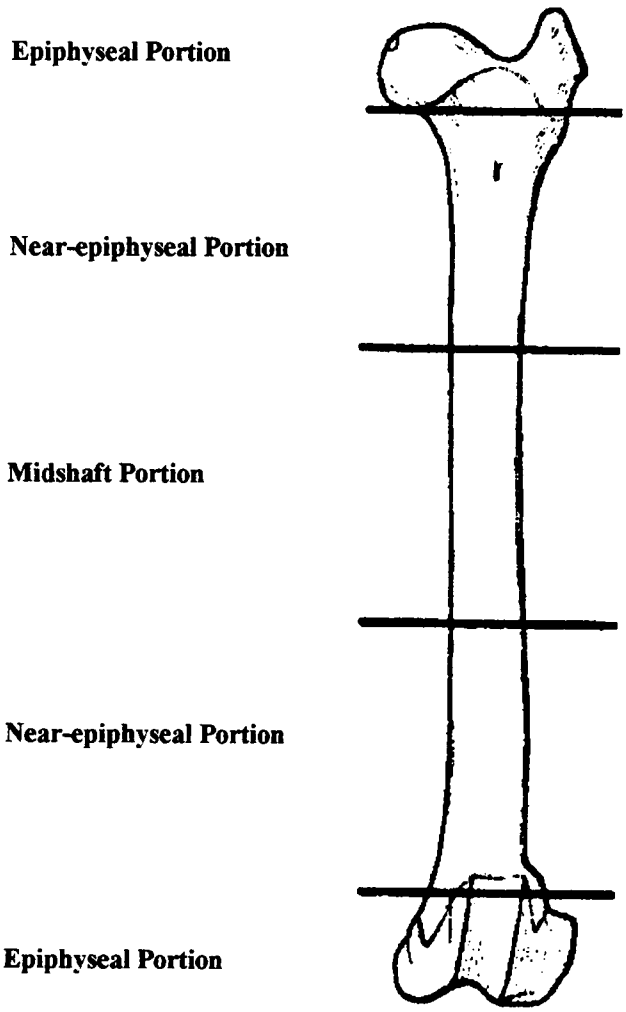


Figure 1. An example of the long bone portion procedure used in this study. Illustration adopted from Marean and Spencer (1991) with some modifications.

Incidence of Tooth Marks

In this analysis, the incidence of tooth-marked and unmarked specimens are compared between the chimpanzee and carnivore experimental samples. Variation within each sample is examined by comparing the number and percent of specimens bearing at least one of a specific tooth mark type or no marks by bone size group and skeletal element group. Tooth mark types include specimens that exhibit type 1 marks (scores and/or pits), type 2 marks (punctures, furrows, and/or gross gnaw damage), type 1 and type 2 marks (specimens bearing both type 1 and type 2 marks), or that are unmarked (specimens that do not exhibit marks). Type 1 and type 2 marks are synonymous with Oliver's (1994) minor and severe tooth mark damage classes. Minor damages (scores and pits) are restricted to the bone surface, whereas severe damages (punctures, furrows, and gross gnaw damage) are more obvious damages in which the bone is often broken and removed. According to Oliver, assessments of damage types may reveal the size and type of carnivore involved with the bone assemblage. Noting the relatively high frequency of minor damages and the rarity of severe damages, Oliver (1994) concludes that the tooth mark damage patterns at FLK Zinjanthropus are not characteristic of a large, bone-crushing carnivore like the hyena, but rather a smaller animal that could make use of small amounts of meat adhering to bone fragments.

The incidence of tooth-marked and unmarked specimens are compared using Pearson's Chi-square test. This test is the most commonly used procedure for testing for "independence of row and column classifications in an unordered r x c contingency table" (Mehta and Patel, 1995:138). Exact p values were calculated for each test.

Tooth Mark Morphology

Unlike the density and incidence analyses, where the assemblage is the unit of analysis, individual tooth marks are the unit of analysis for tooth mark morphology. Both macroscopic and microscopic techniques (scanning electron microscopy) are employed to distinguish chimpanzee and carnivore tooth scores. The methods for identifying individual species (chimpanzees, African lions, striped hyenas, African wild dogs, and cheetahs) employ several quantitative attributes including tooth score size and tooth pit size and shape.

Tooth Score Morphology

In this analysis, tooth scores from all five species were examined and characterized both macroscopically and microscopically. The first stage in this analysis was to document any macroscopic attribute of the tooth score including its gross morphology, position, and orientation on the surface of the bone. This type of information serves to reveal distinct patterns which can be used to corroborate results from microscopic analyses (Cook, 1986).

In the next stage, replicas of 50 tooth scores (10 from each species) were examined using a standard, reflected light dissecting stereomicroscope (Olympus SZH10) at 7x and 20x magnifications. Photomicrographs were taken using an attached Olympus 35mm camera and Tmax 100 black and white film.

Replicas of the 50 tooth scores were made using Silastic T-2 Silicone Moldmaking Rubber. Silastic T-2 is a low viscosity, low shrinkage replicating material designed for the

detailed reproduction of surfaces. It is a two-component molding compound, consisting of a translucent silicone base and curing agent. Ten parts base and one part curing agent were mixed until the curing agent was completely dispersed in the base. Entrapped air was removed by placing the compound in a vacuum chamber until it completely expanded and then collapsed. Before casting the compound, a release agent of ten parts mineral spirits and one part petroleum jelly was lightly brushed over the surface of the bone. Using a disposable plastic syringe, the compound was applied to the surface of the bone to be replicated. After application, it took roughly 14 hours at 68° F for the compound to cure.

In the final stage, ten negative tooth score replicas (two from each of the five species) of the original fifty, were randomly selected for further examination using an S3200 environmental scanning electron microscope (ESEM). The advantage of the ESEM over the conventional SEM is that it permits direct imaging of physical and biological materials without a conductive coating such as gold, palladium, platinum, or chromium (Uwins,1994). The uncoated replicas were then mounted to the ESEM stub using double-sided carbon tape. Assisted by the staff of the University of Tennessee, Knoxville EM Facility, the replicas were scanned to locate the tooth scores. Photomicrographs of the tooth scores were taken at 20x, 50x, and 90x magnifications. The photomicrographs were used to examine and characterize the tooth scores.

Tooth Score Widths

In an attempt to identifiy individual agents by their tooth modifications, tooth score widths are compared between all five species. Justification for this analysis is based on

Haynes's (1981) findings that species of carnivores can be distinguished by the examination of tooth mark lengths and widths. Only tooth score widths are examined in this thesis due to the difficulty in attaining accurate length measurements with an ocular micrometer at 20x magnification. Both maximum and minimum score widths were measured because mark widths can vary considerably along the length of an single mark (Shipman,1983; Shipman and Rose, 1983).

The total sample is comprised of 174 tooth scores. The chimpanzee and African lion samples are the largest with 52 and 53 tooth scores, while the striped hyena, African wild dog, and cheetah are less well-represented with 18, 36, and 15 tooth marks. Statistical analyses are performed on the $\log_{10}$-transformed minimum and maximum widths. Log_{10}-transformations can be used in any situation where the mean is positively correlated with the variance (Sokal and Rohlf, 1981). The Manova with the Tukey HSD (Honestly Significant Difference) post hoc test is used to test for significant differences in mean values between all five species. The multivariate analysis of variance (Manova) is used to tests for significant differences between means when there is more than one dependent variable. For a discussion of Manova procedures, see Finn (1977) and Olson (1976). Again, Monte Carlo p values are calculated.

Tooth Pit Morphology

The methodology described in this section was designed to quantify morphological differences between the five individual species. Here, computerized images of tooth impressions and computer-generated measurements were used to quantify the area and

shape of individual tooth pits. Following criteria described by Selvaggio (1994a), tooth pits were chosen from the experimental bone samples based on their resemblance to a tooth cusp or a complete tooth. Only tooth pits that exhibited minimal extraneous crushing of their perimeter were included in the sample. Tooth pits were distinguished from tooth scores based on the relative breadth of the impression compared to its length. Tooth scores were distinguished as impressions where the length was at least three times greater than its breadth, while tooth pits are impressions where the length is less than three times greater than its breadth. Tooth pits that met the above criteria were replicated using Reprosil medium viscosity hydrophilic vinyl polysiloxane impression material (regular body catalyst and regular body base). Tooth pit replicas were photographed at 10x magnification using a standard, reflected light dissecting stereomicroscope (Olympus SZH10) and Tmax 100 black and white film.

Quantification of tooth pit shape and area was conducted under the guidance of Drs. David and Caroline Joy of the EM (Electron Microscopy) Facility at the University of Tennessee, Knoxville. Data on tooth pit area and shape were collected using the following procedures. First, all photomicrographs were scanned into Adobe Photoshop. The acquired images were then transferred to NIH Image 6.1. NIH Image is a public domain image processing and analysis program developed by the U.S. National Institutes of Health. Once in NIH Image, a computer mouse was used to outline the perimeter of the mark on the computer monitor. The outlined mark was then thresholded to segment the image into objects of interest (tooth pits) and background on the basis of gray level. Next, the thresholded image was made binary, that is all threshold pixels were converted to

black and all background pixels to white (Figures 2 and 3). All digitized images were calibrated from a digitized image with a known scale. In this case, a photomicrograph of a millimeter measure taken at 10x magnification. The pixel aspect ratio was also adjusted using a digitized image with a known 1:1 aspect ratio. Here, a photomicrograph of a penny taken at 10x magnification. For both calibrations, the pixels of the computer monitor were converted to millimeters. Finally, the analyze particles command generated three tooth pit measurements including area, major axis length, and minor axis length.

The total sample is comprised of 80 tooth pits (Table 5). The African lion sample is the largest with 34 marks, while the chimpanzee, striped hyena, African wild dog, and cheetah are less well-represented with 18, 4, 15, and 9. The unevenness of the sample sizes is attributed to both the number of bones modified by specific species and the degree to which the tooth pits in each sample conformed to the prescribed criteria. Based on Selvaggio's (1994a) recommendation , the samples are stratified by bone type to control for the effects of bone density on the area of tooth pits. Bone types were distinguished based on their resistance to tooth penetration. Although Selvaggio uses cancellous, thinning cortical, and cortical bone, this analysis only distinguishes between cancellous and cortical bone due to the small sample sizes. Because cancellous bone is softer than cortical bone, it is predicted that larger-sized tooth pits will be inflicted on cancellous bone compared to cortical bone.

Two statistical analyses were performed on the tooth pit data. In the first analysis, the Kruskal-Wallis test is used to test for differences in mean rank between the five species for tooth pit area and the arcsin-transformed minor to major axis ratio. The arcsin

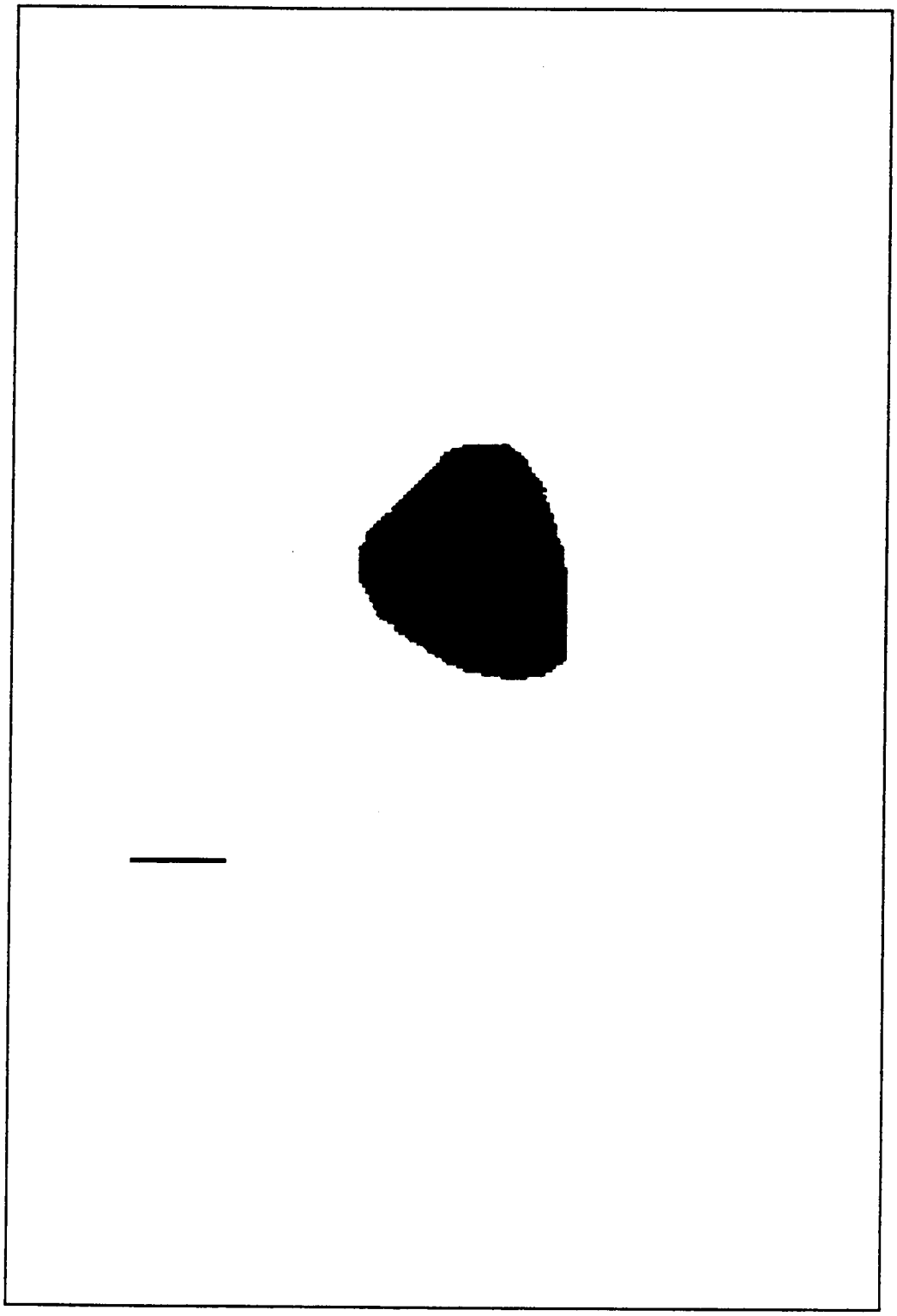


Figure 2. Binary image of a tooth pit inflicted on bone by an African lion. Scale bar represents two millimeters.

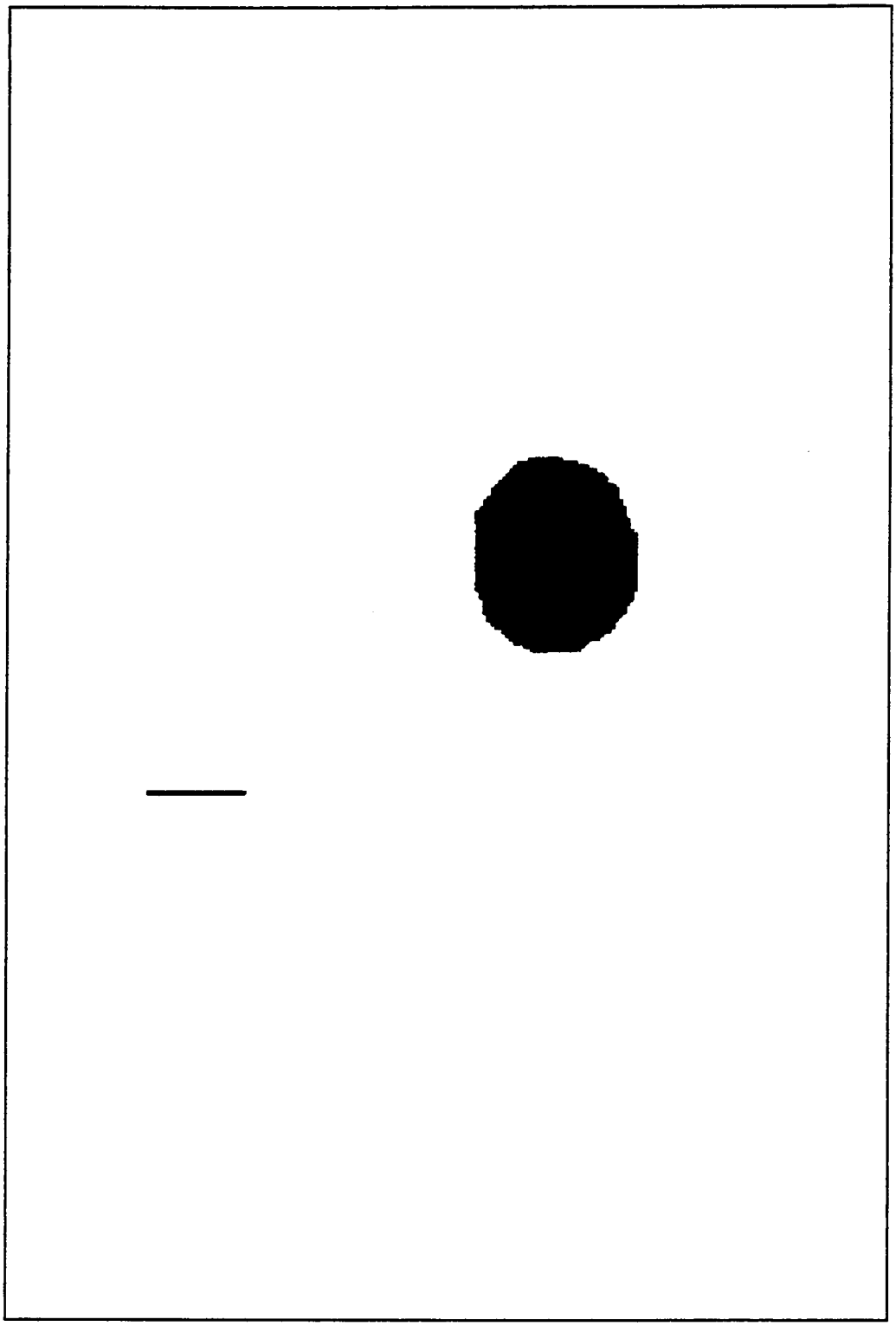


Figure 3. Binary image of a tooth pit inflicted on bone by a chimpanzee. Scale bar represents two millimeters.

Table 5. Number of tooth pits stratified by species and bone type.

	Bone Type		
Species	Cancellous	Cortical	Total
Chimpanzee	12	6	18
African lion	15	19	34
Striped hyena	2	2	4
African wild dog	6	9	15
Cheetah	9	0	9
Total	44	36	80

transformation is commonly applied to proportion and percentage data (Sokal and Rohlf,1981). The second analysis examines differences between the five species stratified by bone type for tooth pit area, major axis length, and minor axis length. Data are presented in probabilistic terms by reporting the measurements as means and standard deviations.

CONCLUSION

All procedures described in this chapter were designed to discriminate between chimpanzee and African carnivore tooth modifications by taking into account factors such as the proportion of bones in the assemblage that are tooth-marked (tooth mark densities), the incidence of tooth-marked and unmarked specimens, the macroscopic attributes of individual tooth marks, the microscopic morphology of individual tooth marks, and tooth mark size and shape. I feel the use of a configurational strategy, such as employed in this study, can serve to accurately and reliably distinguish between chimpanzee and carnivore tooth modifications given adequate sample sizes. The sample sizes in this study are simply too small to provide the necessary accuracy and reliability. Therefore, the results presented in the next chapter are considered preliminary.

Chapter IV

Results

The results presented in this chapter represent the first attempt to develop signature criteria for differentiating chimpanzee and African carnivore tooth modifications on bone. As detailed in Chapter I, the primary goals of this study are to describe the similarities and differences between the two experimental samples at the assemblage level and the specimen level (individual tooth mark). At the assemblage level, the density and incidence of tooth marks are examined between the chimpanzee sample and the combined carnivore sample. For tooth mark densities, intrasample variation is examined in relation to bone size, skeletal element group, long bone group, and long bone portion. Intrasample variation for the incidence of tooth-marked and unmarked specimens is explored in regards to bone size and skeletal element group. At the specimen level, both qualitative and quantitative techniques are employed to characterize morphological attributes for identifying individual agents from their tooth modifications on bone. The results of each analysis are presented separately.

ASSEMBLAGE-LEVEL

Tooth Mark Densities

When both experimental samples are compared, tooth mark densities are significantly higher in the carnivore sample compared to the chimpanzee sample (Table 6 and Figure 4). 34% of the specimens in the carnivore sample have tooth mark densities greater than 10, while only 2% of the specimens in the chimpanzee sample have tooth mark densities greater than 10. Although excluded from the statistical analysis, it should be noted that 63% of the specimens in the chimpanzee sample bear no tooth marks, whereas only 24% of the specimens in the carnivore sample have no marks.

Bone Size Groups

With respect to bone size groups, the Kruskal-Wallis test shows no significant difference in the distribution of tooth mark densities between size group 2 and size group 3 bones in the chimpanzee sample (Table 7 and Figure 5). For both size 2 and size 3 bone groups, the majority of specimens have tooth mark densities between 1-5. There is, however, a significant difference in size 2 versus size 3 bones in the carnivore sample (Table 8 and Figure 6). In the carnivore sample, 46% of the size 3 bones have tooth mark densities greater than 10, while only 8% of the size 2 bones have tooth mark densities greater than 10.

Table 6. Distribution of tooth mark densities for the chimpanzee sample and carnivore sample.

	% OF SAMPLES	
TOOTH MARK DENSITY	CHIMPANZEE	CARNIVORE
0	63.	24.
1-5	29.	25.
6-10	06.	17.
11-15	01.	17.
16-20	0	06.
21-25	0	03.
≥26	01.	08.

Data on tooth mark densities are shown by the percent of samples that exhibit a particular tooth mark density. Chimpanzee sample (n=127); Carnivore sample (n=76). Tooth mark density of 0 excluded from statistical test. Kruskal-Wallis Test (Chi-square Approximation) chi-square= 25.276, d.f= 1, Monte Carlo p= .000. There is a significant difference at the .05 level.

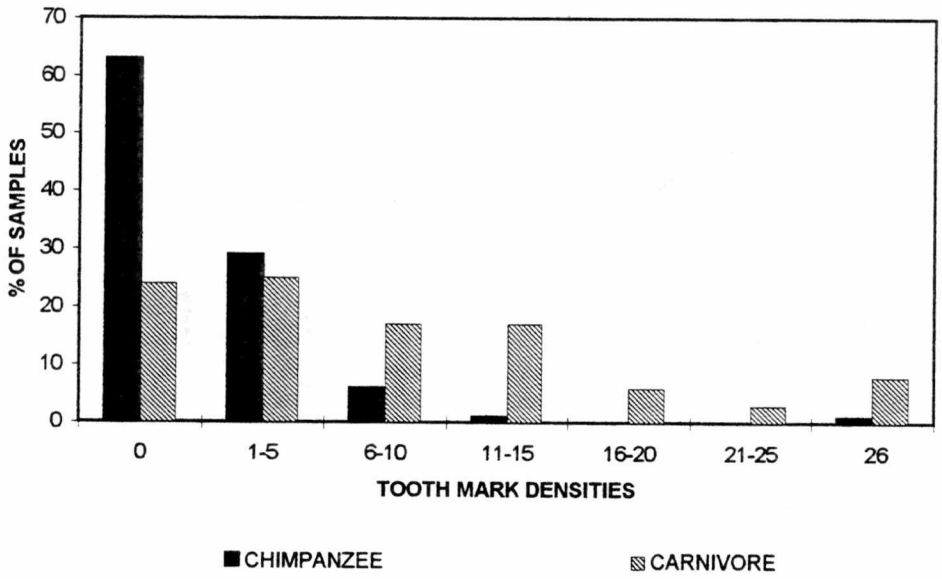


Figure 4. Distribution of tooth mark densities in the chimpanzee sample and carnivore sample. Data shown in Table 6.

Table 7. Distribution of tooth mark densities for the chimpanzee sample by bone size group.

	CHIMPANZEE SAMPLE % OF SIZE GROUP	
TOOTH MARK DENSITY	SIZE GROUP 2	SIZE GROUP 3
0	71.	39.
1-5	21.	55.
6-10	06.	06.
11-15	01.	0
16-20	0	0
21-25	0	0
≥26	01.	0

Data on tooth mark densities are shown by the percent of bone size groups that exhibit a particular tooth mark density. Size group 2 (n=96); Size group 3 (n=31). Tooth mark density of 0 excluded from statistical test. Kruskal-Wallis Test (Chi-square Approximation) chi-square= 2.315, d.f= 1, Monte Carlo p= .164. There is no significant difference at the .05 level.

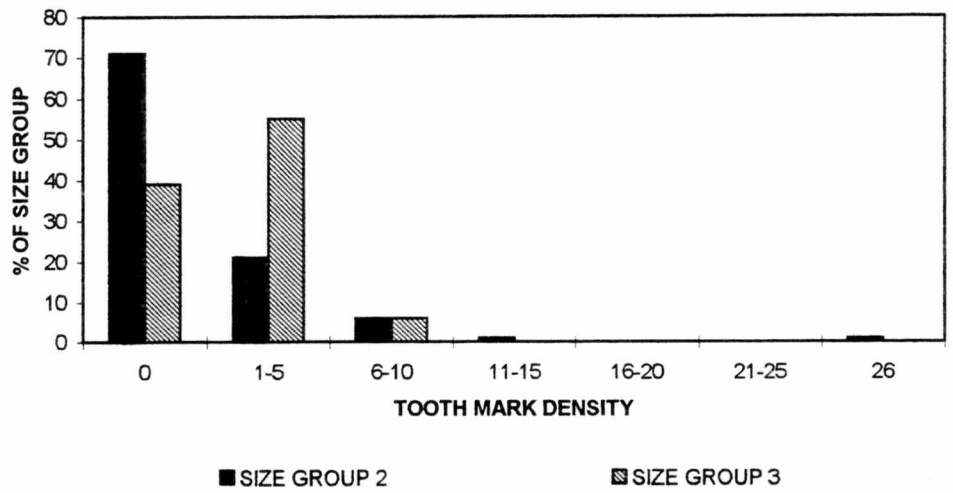


Figure 5. Distribution of tooth mark densities by bone size group for the chimpanzee sample. Data shown in Table 7.

Table 8. Distribution of tooth mark densities for the carnivore sample by bone size group.

	CARNIVORE SAMPLE % OF SIZE GROUP	
TOOTH MARK DENSITY	SIZE GROUP 2	SIZE GROUP 3
0	50.	12.
1-5	34.	21.
6-10	08.	21.
11-15	08.	21.
16-20	0	09.
21-25	0	04.
≥26	0	12.

Data on tooth mark densities are shown by the percent of bone size groups that exhibit a particular tooth mark density. Size group 2 (n=24); Size group 3 (n=52). Tooth mark density of 0 excluded from statistical test. Kruskal-Wallis Test (Chi-square Approximation) chi-square= 8.121, d.f= 1, Monte Carlo p=.004. There is a significant difference at the .05 level.

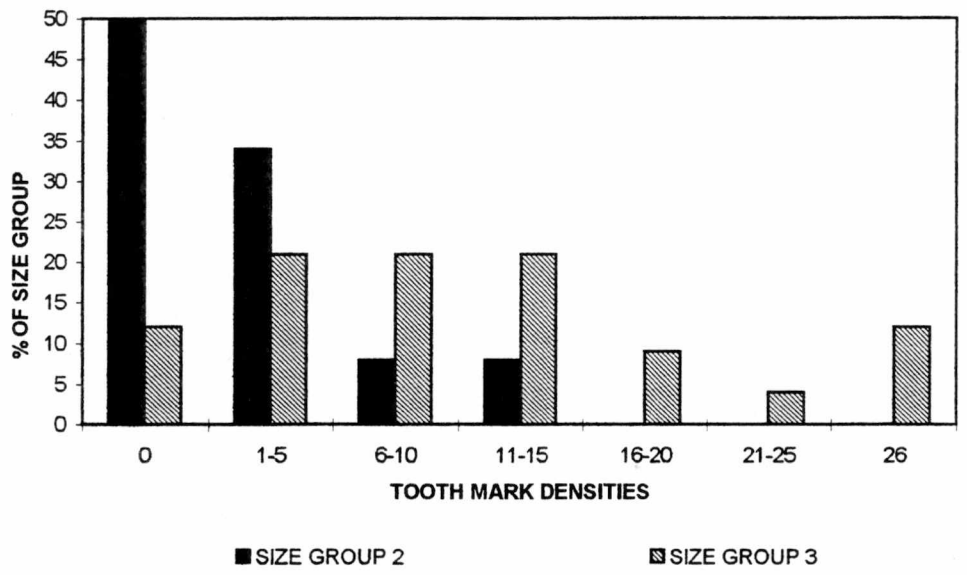


Figure 6. Distribution of tooth mark densities by bone size group for the carnivore sample. Data shown in Table 8.

Skeletal Element Groups

When skeletal element groups are compared, there is no significant difference in tooth mark densities in the chimpanzee sample (Table 9 and Figure 7). The majority of specimens within each skeletal element group have tooth mark densities between 1-5. However, there is a significant difference in tooth mark densities between skeletal element groups in the carnivore sample (Table 10 and Figure 8). In the carnivore sample, 87% of flat bones and 58% of the long bones have tooth mark densities greater than 5, while none of the specimens in the compact bone group have tooth mark densities greater than 5.

Long Bone Groups

When proximal, intermediate, and distal long bones are compared, Kruskal-Wallis tests show no significant differences in tooth mark densities for either the chimpanzee sample or carnivore sample (Table 11 and 12 and Figure 9 and 10). In the chimpanzee sample, there is relatively equal distribution of tooth mark densities between the long bone groups. 65% of the proximal, 39% of the intermediate, and 66% of the distal long bones have tooth mark densities between 1-5 and 6-10. Although not statistically significant, the carnivore sample shows some variation between long bone groups. 74% of the specimens in the proximal long bone group and 50% of the specimens in the intermediate long bone group have tooth mark densities equal to or greater than 6, while none of specimens in the distal long bone group have tooth mark densities greater than 5.

Table 9. Distribution of tooth mark densities for the chimpanzee sample by skeletal element group.

	CHIMPANZEE SAMPLE % OF SKELETAL ELEMENT GROUP		
TOOTH MARK DENSITY	FLAT BONE GROUP	COMPACT BONE GROUP	LONG BONE GROUP
0	47.	91.	46.
1-5	35.	09.	43.
6-10	12.	0	09.
11-15	06.	0	0
16-20	0	0	0
21-25	0	0	0
≥ 26	0	0	02.

Data are shown by the percent of skeletal element groups that exhibit a particular tooth mark density. Flat bone group (n=17); Compact bone group (n=47); Long bone group (n=63). Tooth mark density of 0 excluded from statistical test. Kruskal-Wallis Test (Chi-square Approximation) chi-square= 1.913, d.f=2, Monte Carlo p= .426. There is no significant difference at the .05 level.

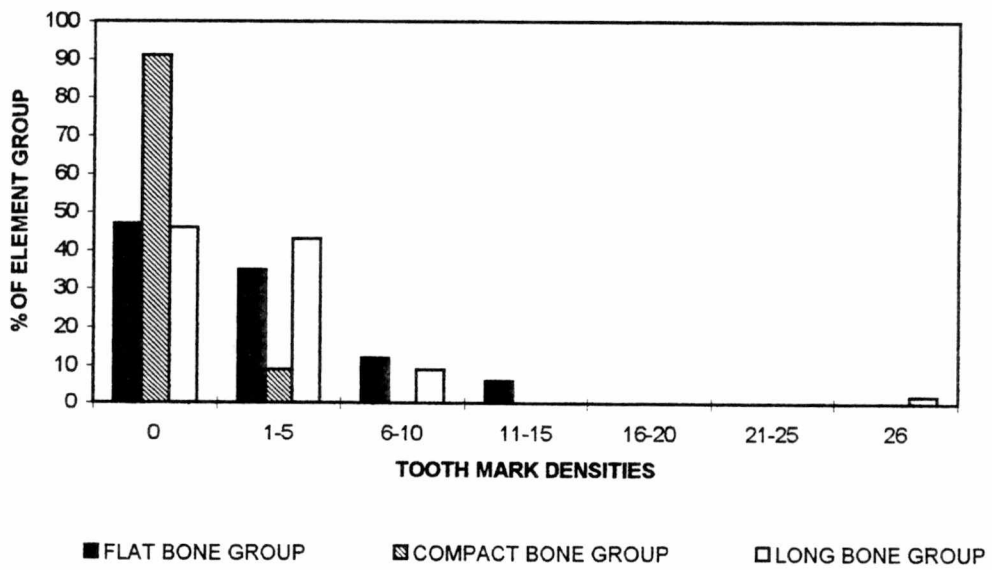


Figure 7. Distribution of tooth mark densities by skeletal element group in the chimpanzee sample. Data shown in Table 9.

Table 10. Distribution of tooth mark densities for the carnivore sample by skeletal element group.

	CARNIVORE SAMPLE % OF SKELETAL ELEMENT GROUP		
TOOTH MARK DENSITY	FLAT BONE GROUP	COMPACT BONE GROUP	LONG BONE GROUP
0	0	77.	15.
1-5	13.	23.	27.
6-10	25.	0	20.
11-15	25.	0	20.
16-20	25.	0	05.
21-25	0	0	04.
≥ 26	12.	0	09.

Data are shown by the percent of skeletal element groups that exhibit a particular tooth mark density. Flat bone group (n=8); Compact bone group (n=13); Long bone group (n=55). Tooth mark density of 0 excluded from statistical test. Kruskal-Wallis Test (Chi-square Approximation) chi-square= 5.688, d.f=2, Monte Carlo p= .045. There is no significant difference at the .05 level.

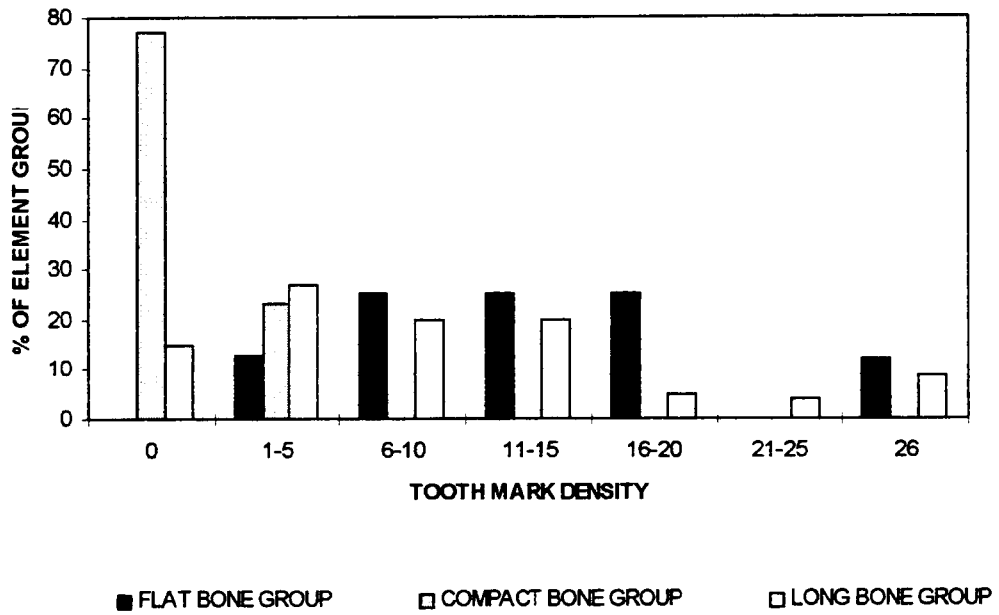


Figure 8. Distribution of tooth mark densities by skeletal element group for the carnivore sample. Data shown in Table 10.

Table 11. Distribution of tooth mark densities for the chimpanzee sample by long bone group.

	CHIMPANZEE SAMPLE % OF LONG BONE GROUP		
TOOTH MARK DENSITY	PROXIMAL LONG BONE GROUP	INTERMEDIATE LONG BONE GROUP	DISTAL LONG BONE GROUP
0	31.	61.	33.
1-5	52.	36.	44.
6-10	13.	03.	22.
11-15	0	0	0
16-20	0	0	0
21-25	0	0	0
≥ 26	04.	0	0

Data are shown by the percent of long bone groups that exhibit a particular tooth mark density. Proximal long bone group (n=23); Intermediate long bone group (n=31); Distal long bone group (n=9). Tooth mark density of 0 excluded from statistical test. Kruskal-Wallis Test (Chi-square Approximation) chi-square= 1.828, d.f=2, Monte Carlo p= .509. There is no significant difference at level .05.

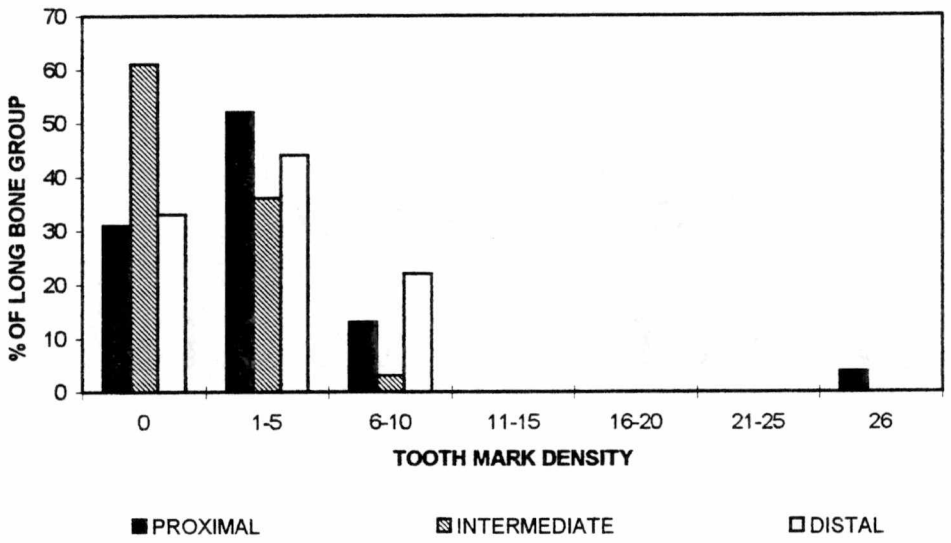


Figure 9. Distribution of tooth mark densities by long bone group in the chimpanzee sample. Data shown in Table 11.

Table 12. Distribution of tooth mark densities for the carnivore sample by long bone group.

	CARNIVORE SAMPLE % OF LONG BONE GROUP		
TOOTH MARK DENSITY	PROXIMAL LONG BONE GROUP	INTERMEDIATE LONG BONE GROUP	DISTAL LONG BONE GROUP
0	0	25.	50.
1-5	26.	25.	50.
6-10	19.	25.	0
11-15	26.	17.	0
16-20	07.	04.	0
21-25	07.	0	0
≥ 26	15.	04.	0

Data are shown by the percent of long bone groups that exhibit a particular tooth mark density. Proximal long bone group (n=27); Intermediate long bone group (n=24); Distal long bone group (n=4). Tooth mark density of 0 excluded from statistical test. Kruskal-Wallis Test (Chi-square Approximation) chi-square= 4.834, df=2, Monte Carlo p= .077. There is no significant difference at the .05 level.

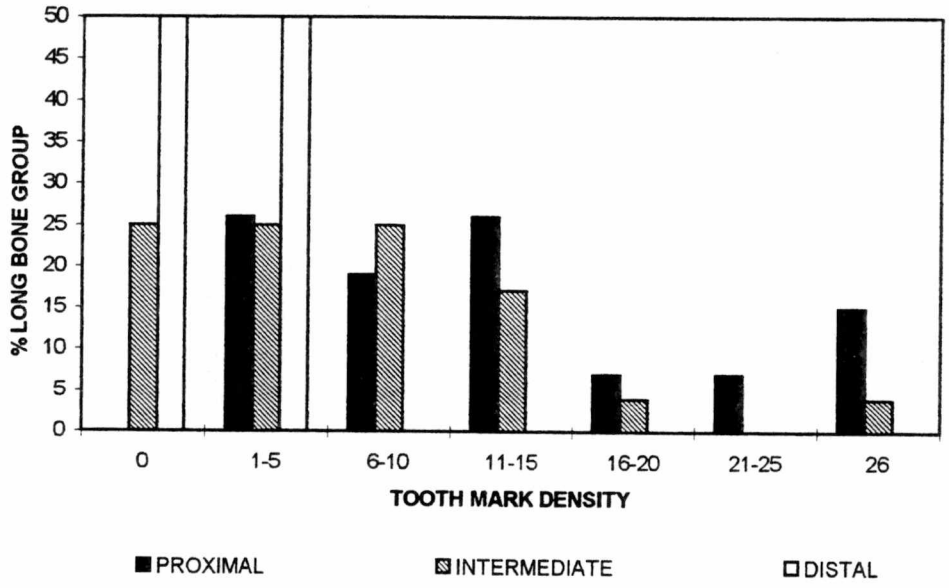


Figure 10. Distribution of tooth mark densities by long bone group in the carnivore sample. Data shown in Table 12.

Long Bone Portions

Intrasample differences are not detectable when tooth mark densities are compared between long bone portions in the chimpanzee sample and carnivore sample. There are no significant differences in tooth mark densities in either the chimpanzee sample or carnivore sample between epiphyseal, near-epiphyseal, and midshaft portions (Table 13 and 14 and Figure 11 and 12). The distribution of tooth mark densities between long bone portions is relatively uniform in both the chimpanzee sample and carnivore sample. In the chimpanzee sample, nearly all of the specimens have tooth mark densities between 1-5 or 6-10, while in the carnivore sample the specimens have tooth mark densities from 1 to greater than or equal to 26.

Incidence of Tooth Marks

The incidence of specimens bearing at least one of a specific mark type or no marks differs significantly between the chimpanzee sample and carnivore sample (Table 15 and Figure 13). Differences between the samples are attributed to the incidence of unmarked specimens and specimens bearing both type 1 and type 2 marks. In the chimpanzee sample, 63% of the specimens are unmarked, while only 24% of the specimens in the carnivore sample are unmarked. For type 1 and type 2 marks, the chimpanzee sample has a lower incidence (12%) of specimens bearing both type 1 and type 2 marks compared to the carnivore sample with 47%.

Table 13. Distribution of tooth mark densities for the chimpanzee sample by long bone portion.

	CHIMPANZEE SAMPLE % OF LONG BONE PORTION		
TOOTH MARK DENSITY	EPIPHYSEAL PORTION	NEAR-EPIPHYSEAL PORTION	MIDSHAFT PORTION
0	65.	89.	79.
1-5	30.	09.	15.
6-10	03.	02.	06.
11-15	0	0	0
16-20	0	0	0
21-25	0	0	0
≥ 26	02	0	0

Data are shown by the percent of long bone portion that exhibit a particular tooth mark density. Epiphyseal portion (n= 63); Near-epiphyseal portion (n=63); Midshaft portion (n=63). Tooth mark density of 0 excluded from statistical test. Kruskal-Wallis Test (Chi-square Approximation) chi-square= 1.433, d.f= 2, Monte Carlo p= .566. There is no significant difference at the .05 level.

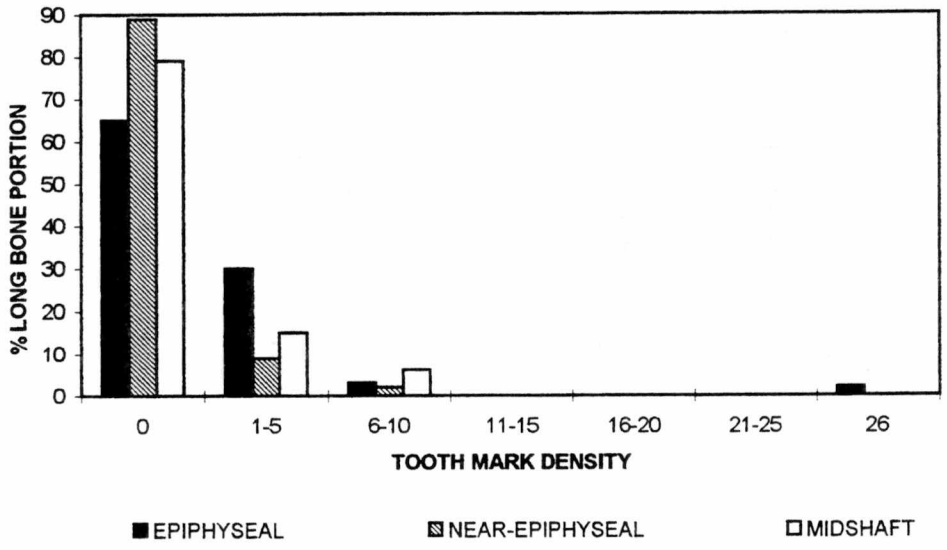


Figure 11. Distribution of tooth mark densities by long bone portion in the chimpanzee sample. Data shown in Table 13.

Table 14. Distribution of tooth mark densities for the carnivore sample by long bone portion.

	CARNIVORE SAMPLE % OF LONG BONE PORTION		
TOOTH MARK DENSITY	EPIPHYSEAL PORTION	NEAR-EPIPHYSEAL PORTION	MIDSHAFT PORTION
0	29.	44.	67.
1-5	44.	31.	23.
6-10	14.	16.	04.
11-15	02.	05.	04.
16-20	05.	0	02.
21-25	04.	02.	0
≥ 26	02.	02.	0

Data are shown by the percent of long bone portion that exhibit a particular tooth mark density. Epiphyseal portion (n=55); Near-epiphyseal portion (n=55); Midshaft portion (n=55). Tooth mark density of 0 excluded from statistical test. Kruskal-Wallis Test (Chi-square Approximation) chi-square=1.032, d.f= 2, Monte Carlo p= .598. There is no significant difference at the .05 level.

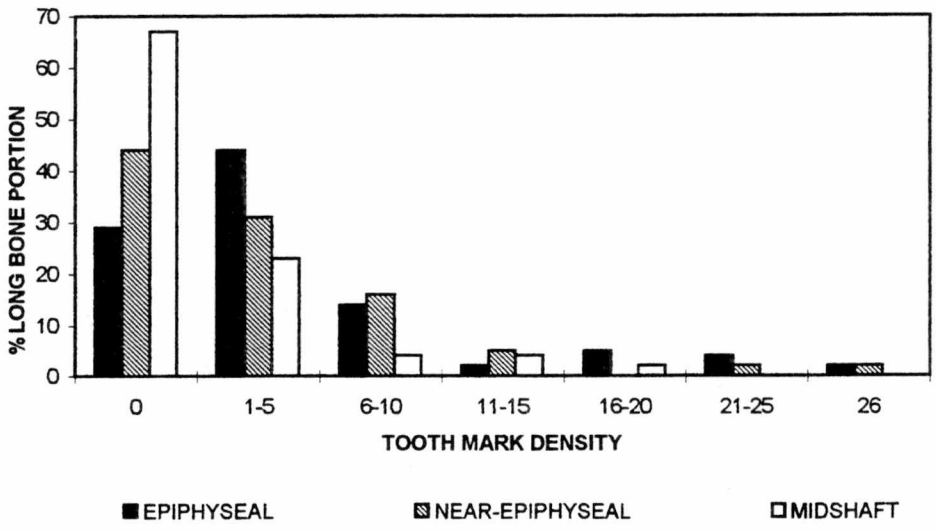


Figure 12. Distribution of tooth mark densities by long bone portion in the carnivore sample. Data shown in Table 14.

Table 15. The number and percent of specimens bearing at least one of a specific mark type or no marks in the chimpanzee sample and carnivore sample.

	ALL SPECIMENS			
	CHIMPANZEE SAMPLE		CARNIVORE SAMPLE	
TOOTH MARK TYPE	N	%	N	%
Unmarked	80	63.	18	24.
Type 1	23	18.	13	17.
Type 2	9	07.	9	12.
Type 1&2	15	12.	36	47.
Total	127	100.	76	100.

Percent of specimens calculated by dividing the number of specimens in each tooth mark type category by the total number of specimens in each sample X 100. Unmarked = specimens that do not bear marks; Type 1 = scores and pits; Type 2 = punctures, furrows, and gross gnaw damage; Type 1&2 = specimens with type 1 and type 2 marks. Chi-square= 40.386, d.f = 3, Exact p = .000. There is a significant difference at the .05 level.

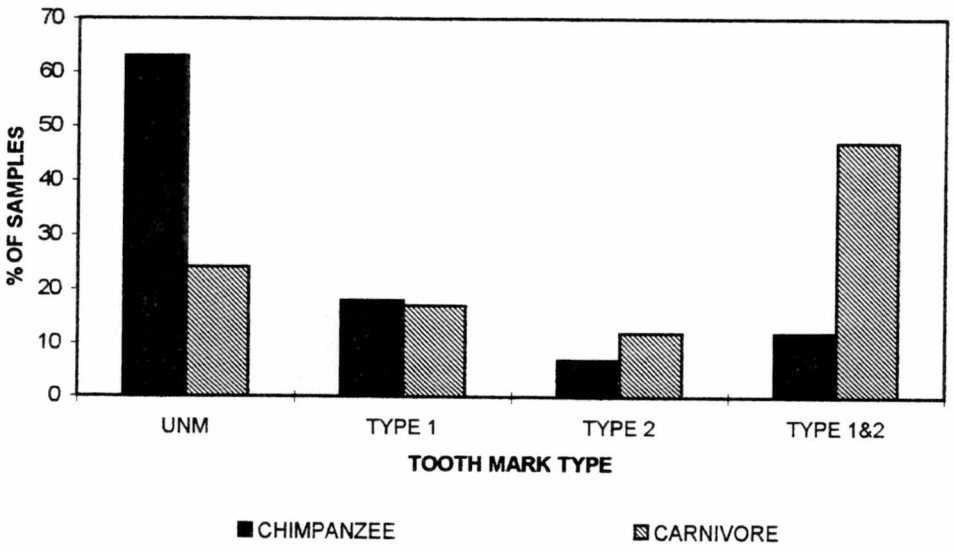


Figure 13. Percent of specimens bearing at least one of a specific mark type or no marks in the chimpanzee sample and carnivore sample. Data shown in Table 15.

Bone Size Groups

Intrasample differences are evident when the incidence of tooth-marked and unmarked specimens are compared by bone size groups. Chi-square tests show significant differences for both the chimpanzee sample and carnivore sample in regards to bone size groups (Table 16 and 17 and Figure 14 and 15). In the chimpanzee sample, differences between size 2 and size 3 bones are attributed to the incidence of unmarked, type 1, and type 1 and 2 specimens. Of size group 2 specimens, 71% are unmarked, 14% exhibit type 1 marks, and 8% bear both type 1 and type 2 marks. In contrast, 39% of the size 3 specimens are unmarked, 32% display type 1 marks, and 23% have both type 1 and type 2 marks. For the carnivore sample, the greatest differences between bone size groups is in the incidence of unmarked specimens and specimens with both type 1 and type 2 marks. Of the size group 2 specimens, 50% are unmarked and 24% bear both type 1 and type 2 marks, while only 11% of the size 3 specimens are unmarked and 58% exhibit both type 1 and type 2 marks.

Skeletal Element Groups

Intrasample differences are also apparent when the incidence of tooth-marked and unmarked specimens are compared by skeletal element group. Chi-square tests show significant differences between skeletal element groups in both the chimpanzee sample and carnivore sample (Table 18 and 19 and Figure 16 and 17). In the chimpanzee sample, the differences between skeletal element groups are attributed to the disproportionate incidence of tooth-marked and unmarked specimens for the compact bone group relative

Table 16. The number and percent of specimens bearing at least one of a specific mark type or no marks by bone size group in the chimpanzee sample.

	CHIMPANZEE SAMPLE BONE SIZE GROUPS			
	SIZE GROUP 2		SIZE GROUP 3	
TOOTH MARK TYPE	N	%	N	%
Unmarked	68	71.	12	39.
Type 1	13	14.	10	32.
Type 2	7	07.	2	06.
Type 1&2	8	08.	7	23.
Total	96	100.	31	100.

Percent of specimens calculated by dividing the number of specimens in each tooth mark type category by the total number of specimens in each size group X 100. Unmarked = specimens that do not bear marks; Type 1 = scores and pits; Type 2 = punctures, furrows, and gross gnaw damage; Type 1&2 = specimens with type 1 and type 2 marks. Chi-square = 12.422, d.f = 3, Exact p = .004. There is a significant difference at the .05 level.

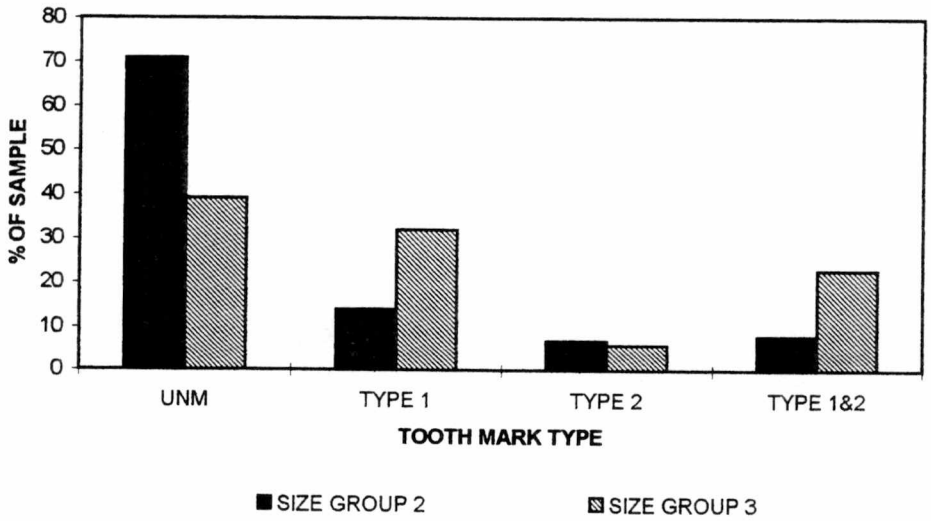


Figure 14. Percent of specimens bearing at least one of a specific mark type or no marks by bone size group in the chimpanzee sample. Data are shown in Table 16.

Table 17. The number and percent of specimens bearing at least one of a specific mark type or no marks by bone size group in the carnivore sample.

	CARNIVORE SAMPLE BONE SIZE GROUPS			
	SIZE GROUP 2		SIZE GROUP 3	
TOOTH MARK TYPE	N	%	N	%
Unmarked	12	50.	6	11.
Type 1	3	13.	10	19.
Type 2	3	13.	6	12.
Type 1&2	6	24.	30	58.
Total	24	100.	52	100.

Percent of specimens calculated by dividing the number of specimens in each tooth mark type category by the total number of specimens in each size group X 100. Unmarked = specimens that do not bear marks; Type 1 = scores and pits; Type 2 = punctures, furrows, and gross gnaw damage; Type 1&2 = specimens with type 1 and type 2 marks. Chi-square = 14.409, d.f = 3, Exact p = .002. There is a significant difference at the .05 level.

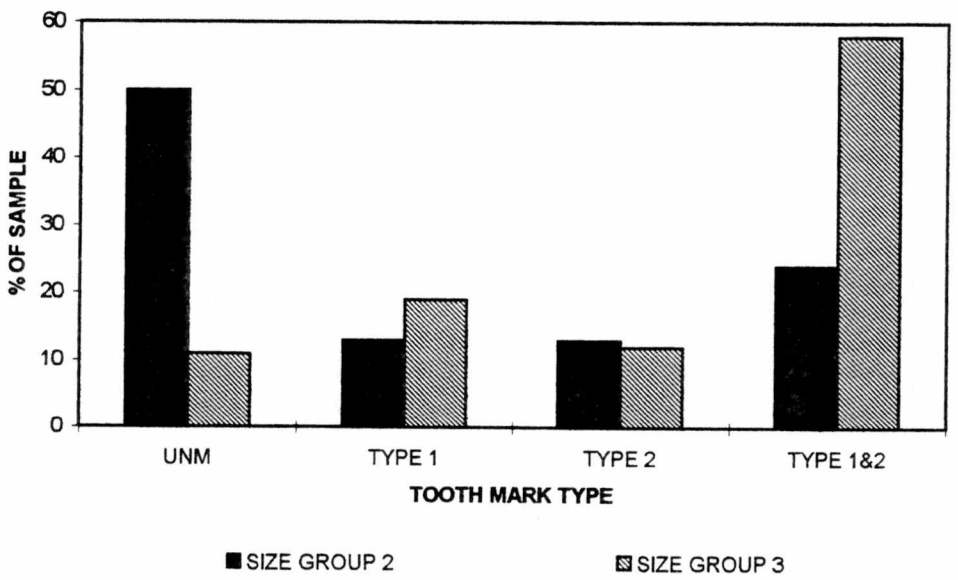


Figure 15. Percent of specimens bearing at least one of a specific mark type or no marks by bone size group in the carnivore sample. Data shown in Table 17.

Table 18. The number and percent of specimens bearing at least one of a specific mark type or no marks by skeletal element group in the chimpanzee sample.

	CHIMPANZEE SAMPLE SKELETAL ELEMENT GROUPS					
	FLAT BONES		COMPACT BONES		LONG BONES	
TOOTH MARK TYPE	N	%	N	%	N	%
Unmarked	8	47.	43	91.	29	46.
Type 1	4	24.	2	04.	17	27.
Type 2	3	17.	2	04.	4	06.
Type 1&2	2	12.	0	00.	13	21.
Total	17	100.	47	100.	63	100.

Percent of specimens calculated by dividing the number of specimens in each tooth mark type category by the total number of specimens in each skeletal element group X 100. Unmarked = specimens that do not bear marks; Type 1 = scores and pits; Type 2 = punctures, furrows, and gross gnaw damage; Type 1&2 = specimens with both type 1 and type 2 marks. Chi-square = 30.578, d.f = 6, Exact p = .000. There is a significant difference at the .05 level.

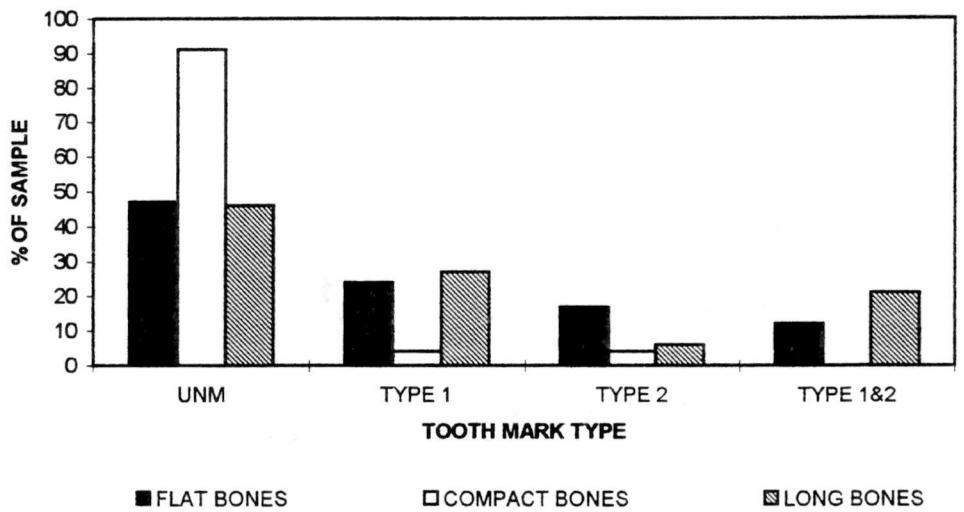


Figure 16. Percent of specimens bearing at least one of a specific mark type or no marks by skeletal element group in the chimpanzee sample. Data shown in Table 18.

Table 19. The number and percent of specimens bearing at least one of a specific mark type or no marks by skeletal element group in the carnivore sample.

	CARNIVORE SAMPLE SKELETAL ELEMENT GROUPS					
	FLAT BONES		COMPACT BONES		LONG BONES	
TOOTH MARK TYPE	N	%	N	%	N	%
Unmarked	0	00.	10	77.	8	15.
Type 1	0	00.	3	23.	10	18.
Type 2	1	13.	0	00.	8	15.
Type 1&2	7	87.	0	00.	29	52.
Total	8	100.	13	100.	55	100.

Percent of specimens calculated by dividing the number of specimens in each tooth mark type category by the total number of specimens in each skeletal element group X 100. Unmarked = specimens that do not bear marks; Type 1 = scores and pits; Type 2 = punctures, furrows, and gross gnaw damage; Type 1&2 = specimens with both type 1 and type 2 marks. Chi-square = 32.162, d.f = 6, Exact p = .000. There is a significant difference at the .05 level.

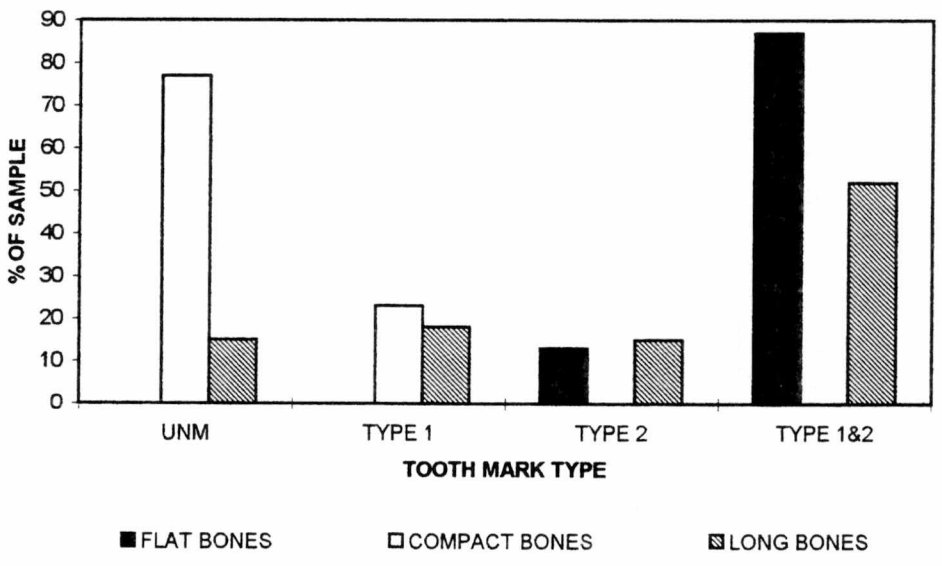


Figure 17. Percent of specimens bearing at least one of a specific mark type or no marks by skeletal element group in the carnivore sample. Data shown in Table 19.

to the flat and long bone groups. The flat and long bone groups are characterized by a roughly equal percentage of unmarked and marked specimens, whereas 92% of the compact bone specimens are unmarked and only 8% are tooth-marked. The carnivore sample shows a similar disproportionate distribution of tooth-marked and unmarked specimens between skeletal element groups. The compact bone group is most commonly unmarked (77%), followed by the long bone group (15%), and then the flat bone group with no unmarked specimens.

TOOTH MARK MORPHOLOGY

Tooth Score Morphology

The results of the macroscopic and light microscopic analyses indicate that chimpanzee incisal tooth scores are distinguishable from African carnivore tooth scores on bone. Chimpanzee incisal tooth scores appear as linear impressions with small sideways deviations oriented perpendicular to the long axis of the bone. They are characterized by a relatively uniform width and depth and by a flat base. They may occur on bones singly or as sets of 2 or 3 parallel marks. In contrast, carnivore tooth scores are elongate grooves with small sideways undulations that are oriented oblique to the long axis of the bone. The width and depth of carnivore tooth scores vary considerably along the length of the mark. The width of the mark can decrease by as much as 80% of the maximum width (Shipman,1983). The base of the mark is generally rounded. Carnivore tooth scores may occur on the bone singly but more commonly occur as clusters of intersecting marks

located near the ends of the bone. Stereomicrographs of chimpanzee and carnivore tooth scores at 7X magnification are shown in Figure 18.

Although sample sizes are small, the results suggest that scanning electron microscopy provides little if any value over macroscopic and light microscopic techniques in differentiating chimpanzee and African carnivore tooth scores. In fact, SEM only seemed to overpower the image obliterating the distinctive morphological characteristics with each increase in magnification. Comparisons of chimpanzee and African carnivore tooth scores at 20X, 50X, and 90X magnifications are shown in Figures 19, 20, and 21.

Tooth Score Widths

The data presented here show that maximum and minimum tooth score widths are not useful criteria for distinguishing individual agents. The results of the Manova analysis show that there is a significant difference between both the $\log_{10}$- transformed maximum and minimum tooth mark widths and individual species (Table 20 and 21). However, the Tukey HSD post hoc test on the $\log_{10}$- transformed minimum and maximum tooth mark widths only shows significant differences for the African wild dog. For minimum width, the mean African wild dog tooth score width is significantly narrower than the mean African lion tooth score width. For maximum width, the mean African wild dog tooth score width is significantly narrower than mean chimpanzee, African lion, and striped hyena tooth score widths but not the cheetah. Although the Manova shows statistical significance, it should be noted that the ranges of maximum and minimum tooth score widths overlap extensively.

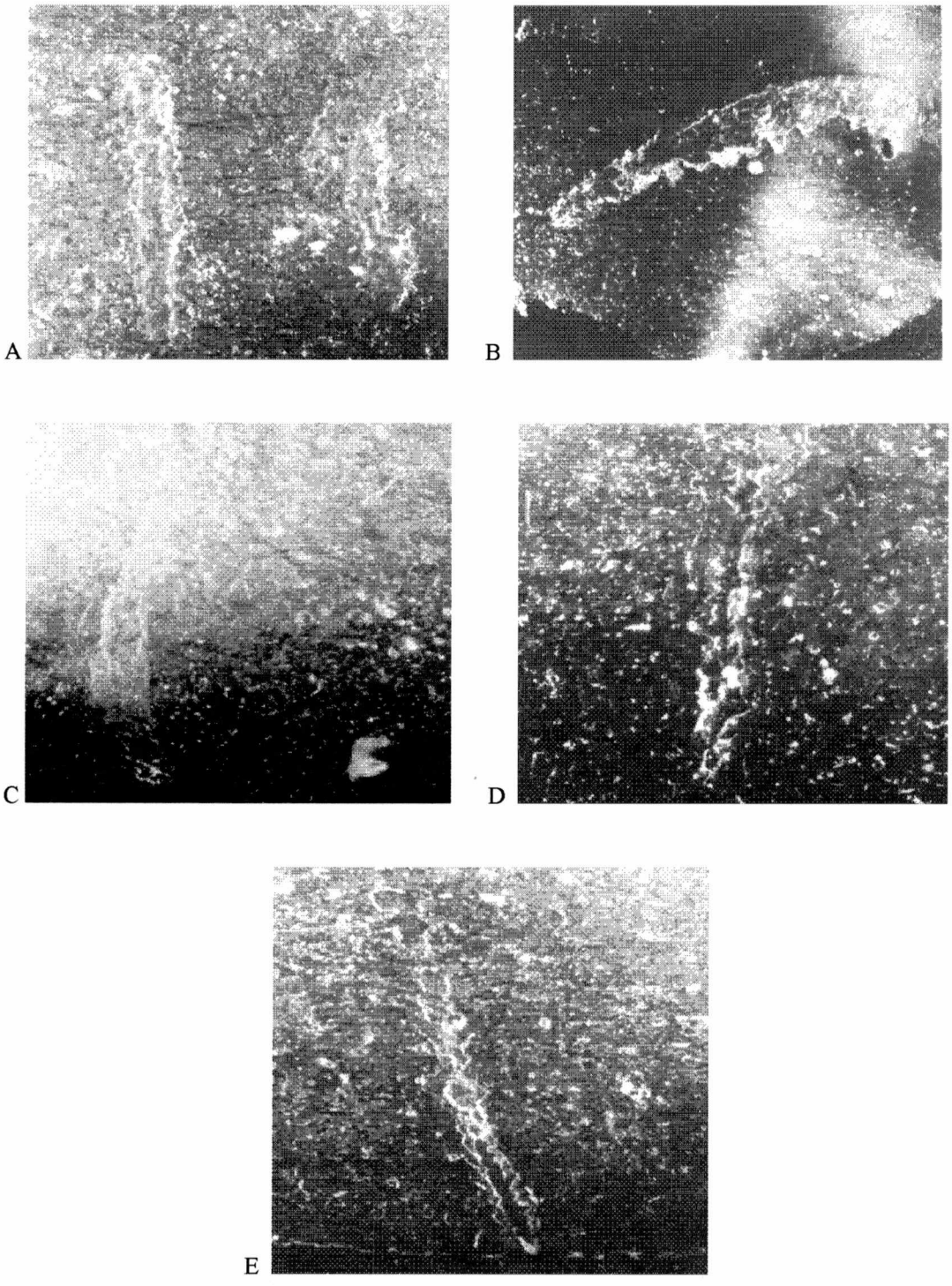


Figure 18. Stereomicroscopy photographs of chimpanzee and African carnivore tooth scores at 7X magnification. A. Chimpanzee incisal tooth score on pig femur. B. African lion tooth score on pig femur. C. Striped hyena tooth score on pig humerus. D. African wild dog tooth score on pig femur. E. Cheetah tooth score on pig femur.

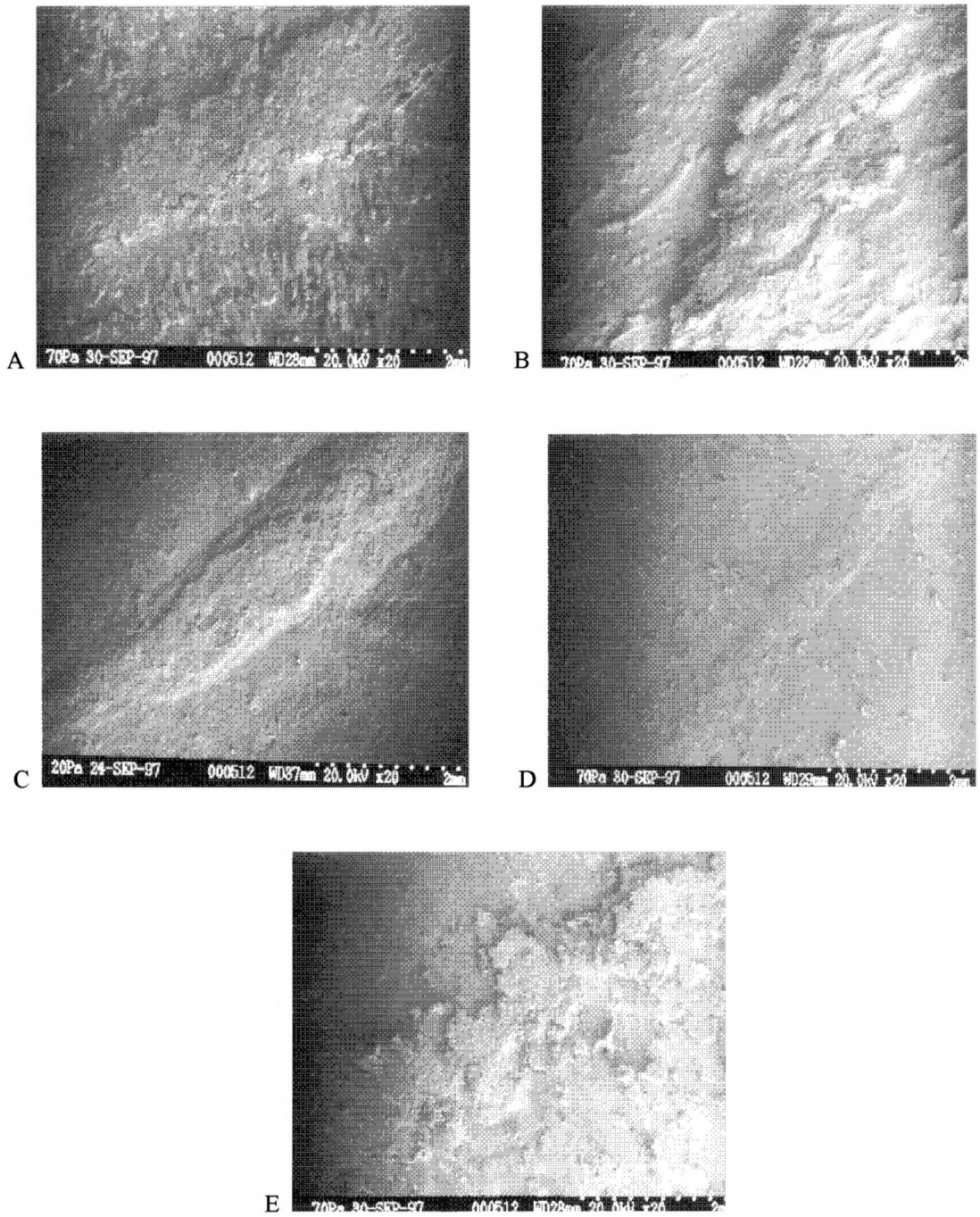


Figure 19. SEM micrographs of chimpanzee and African carnivore tooth scores at 20X magnification. A. Chimpanzee incisal tooth score on pig femur. B. African lion tooth score on pig femur. C. Striped hyena tooth score on pig humerus. D. African wild dog tooth score on pig femur. E. Cheetah tooth score on pig femur.

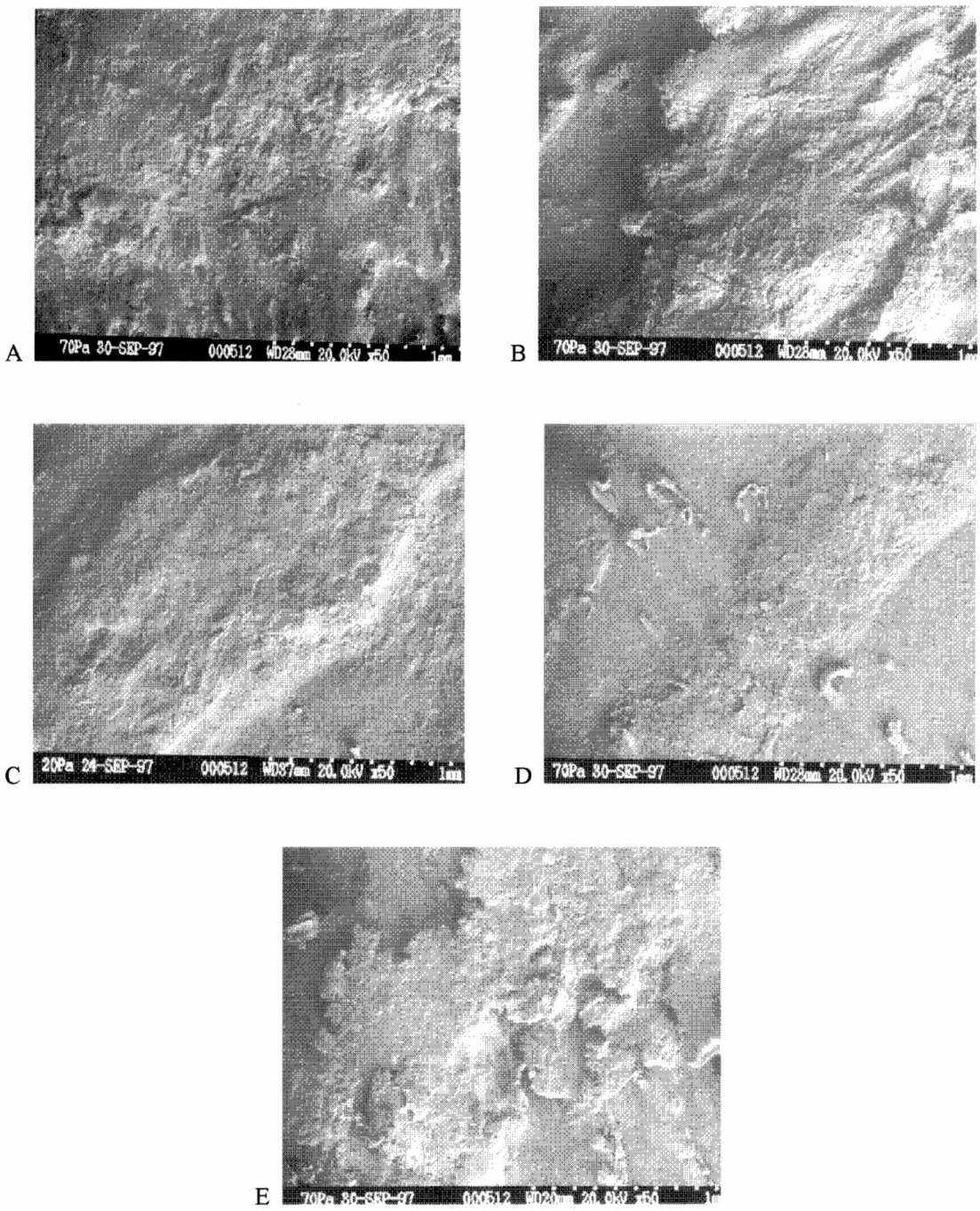


Figure 20. SEM micrographs of chimpanzee and African carnivore tooth scores at 50X magnification. A. Chimpanzee incisal tooth score on pig femur. B. African lion tooth score on pig femur. C. Striped hyena tooth score on pig humerus. D. African wild dog tooth score on pig femur. E. Cheetah tooth score on pig femur.

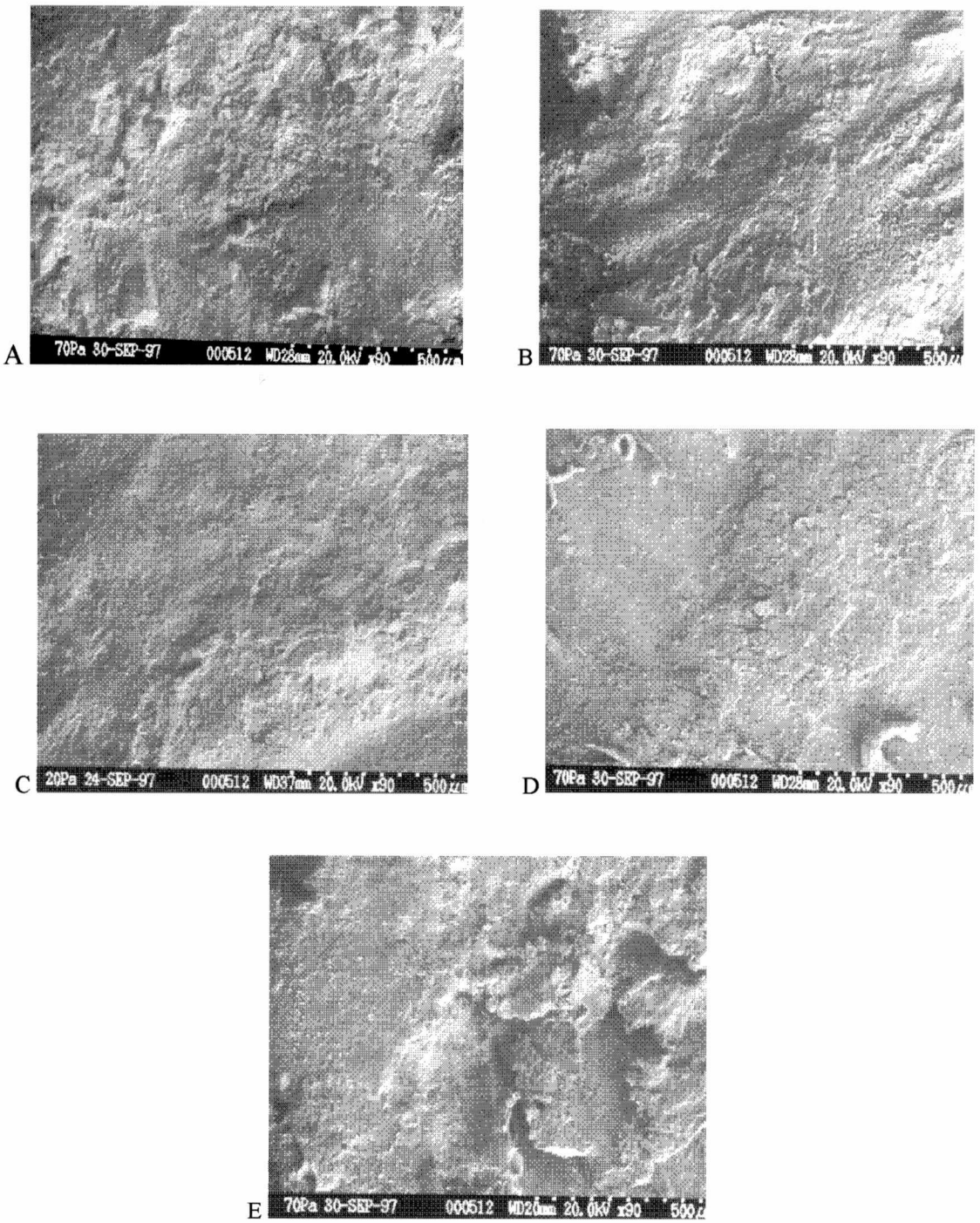


Figure 21. SEM micrographs of chimpanzee and African carnivore tooth scores at 90X magnification. A. Chimpanzee incisal tooth score on pig femur. B. African lion tooth score on pig femur. C. Striped hyena tooth score on pig humerus. D. African wild dog tooth score on pig femur. E. Cheetah tooth score on pig femur.

Table 20. Descriptive statistics for maximum and minimum tooth mark widths by species. Results of the Manova test are reported in Table 21.

	Species	N	Mean Width (mm)	Range	Standard Deviation	Variance
MAXIMUM	Chimpanzee	52	1.18	0.3-4.0	0.79	0.61
	African lion	53	1.22	0.4-2.9	0.59	0.35
	Striped hyena	18	1.19	0.3-2.6	0.56	0.32
	African wild dog	36	0.82	0.2-3.8	0.68	0.46
	Cheetah	15	0.85	0.6-1.2	0.18	0.03
MINIMUM	Chimpanzee	52	0.52	0.2-2.2	0.38	0.15
	African lion	53	0.67	0.1-2.0	0.40	0.16
	Striped hyena	18	0.60	0.2-1.3	0.32	0.10
	African wild dog	36	0.48	0.1-2.1	0.42	0.17
	Cheetah	15	0.56	0.35-1.05	0.18	0.03

Table 21. Results of the Manova multivariate test. The overall Manova test shows a significant relationship between the log_{10}-transformed tooth mark widths and species at alpha .05. Multivariate F value (Wilks' Lambda) = 3.641, d.f = 8, Exact p = .000. The univariate tests of between-subjects effects are both significant at the .05 level. The log minimum tooth mark width F value = 3.078, d.f = 4, p = .018. The log maximum tooth mark width F value = 4.792, d.f = 4, p = .001. Shown below are the results of the Tukey HSD multiple comparisons test on the log_{10}-transformed minimum and maximum tooth mark widths by species. 1.00 = chimpanzee; 2.00 = African lion; 3.00 = Striped hyena; 4.00 = African wild dog; 5.00 = cheetah. * = mean difference is significant at the .05 level.

Dependent Variable	(I) Species	(J) Species	Mean Difference (I-J)	Std. Error	Sig.	Lower Bound	Upper Bound
LOGMIN	1.00	2.00	-.1194	.052	.149	-.2617	2.294E-02
		3.00	-9.22E-02	.073	.715	-.2916	.1072
		4.00	5.906E-02	.058	.847	-9.91E-02	.2172
		5.00	-.1040	.078	.674	-.3177	.1097
	2.00	1.00	.1194	.052	.149	-2.29E-02	.2617
		3.00	2.720E-02	.073	.996	-.1717	.2261
		4.00	.1785*	.058	.017	2.096E-02	.3360
		5.00	1.538E-02	.078	1.000	-.1979	.2287
	3.00	1.00	9.220E-02	.073	.715	-.1072	.2916
		2.00	-2.72E-02	.073	.996	-.2261	.1717
		4.00	.1513	.077	.286	-5.93E-02	.3618
		5.00	-1.18E-02	.093	1.000	-.2668	.2431
	4.00	1.00	-5.91E-02	.058	.847	-.2172	9.905E-02
		2.00	-.1785*	.058	.017	-.3360	-2.10E-02
		3.00	-.1513	.077	.286	-.3618	5.926E-02
		5.00	-.1631	.082	.273	-.3872	6.103E-02
	5.00	1.00	.1040	.078	.674	-.1097	.3177
		2.00	-1.54E-02	.078	1.000	-.2287	.1979
		3.00	1.182E-02	.093	1.000	-.2431	.2668
		4.00	.1631	.082	.273	-6.10E-02	.3872
LOGMAX	1.00	2.00	-3.78E-02	.048	.936	-.1694	9.381E-02
		3.00	-3.29E-02	.068	.989	-.2172	.1515
		4.00	.1776*	.054	.008	3.138E-02	.3237
		5.00	7.178E-02	.072	.860	-.1258	.2694
	2.00	1.00	3.778E-02	.048	.936	-9.38E-02	.1694
		3.00	4.915E-03	.067	1.000	-.1790	.1888
		4.00	.2153*	.053	.001	6.973E-02	.3609
		5.00	.1096	.072	.552	-8.76E-02	.3067
	3.00	1.00	3.287E-02	.068	.989	-.1515	.2172
		2.00	-4.91E-03	.067	1.000	-.1888	.1790
		4.00	.2104*	.071	.026	1.581E-02	.4050
		5.00	.1046	.086	.745	-.1310	.3403
	4.00	1.00	-.1776*	.054	.008	-.3237	-3.14E-02
		2.00	-.2153*	.053	.001	-.3609	-6.97E-02
		3.00	-.2104*	.071	.026	-.4050	-1.58E-02
		5.00	-.1058	.076	.632	-.3130	.1014
	5.00	1.00	-7.18E-02	.072	.860	-.2694	.1258
		2.00	-.1096	.072	.552	-.3067	8.760E-02
		3.00	-.1046	.086	.745	-.3403	.1310
		4.00	.1058	.076	.632	-.1014	.3130

Tooth Pit Morphology

The data presented here show that there is a significant difference between the area of tooth pits and species (Table 22 and Figure 22). The largest mean areas of tooth pits are attributed to the striped hyena and African lion, followed by the African wild dog and cheetah, and then the chimpanzee with the smallest mean area. When the area of tooth pits is stratified by bone type, the striped hyena and African wild dog inflicted larger tooth pits on cancellous bone, while the African lion and chimpanzee inflicted the larger tooth pits on cortical bone (Table 23 and Figure 23).

When the arcsin-transformed ratio of the minor axis to major axis are compared, the Kruskal-Wallis test shows that there is no significant difference between species (Table 24 and Figure 24). Tooth pits in the striped hyena and African lion sample are the most variable, followed by the chimpanzee and cheetah, and then the African wild dog. Tooth pits in the striped hyena sample exhibit the longest major and minor axes lengths, while the chimpanzee sample has the shortest mean major and minor axes lengths (Table 25 and 26 and Figure 25 and 26). In respect to bone type, the striped hyena and African wild dog inflicted the longest major and minor axes lengths on cancellous bone, while the chimpanzee and African lion inflicted the longest axes lengths on cortical bone.

Table 22. The number and mean area of tooth pits by sample. Kruskal-Wallis test (Chi-square Approximation) chi-square = 32.857, d.f = 4, Monte Carlo p = .000. There is a significant difference at the .05 level.

		AREA (mm)	
Sample	N	Mean	+/- 1 s.d.
Chimpanzee	18	4.07	1.66
African lion	34	11.23	6.79
Striped hyena	4	18.23	9.15
African wild dog	15	5.73	3.18
Cheetah	9	5.25	3.61

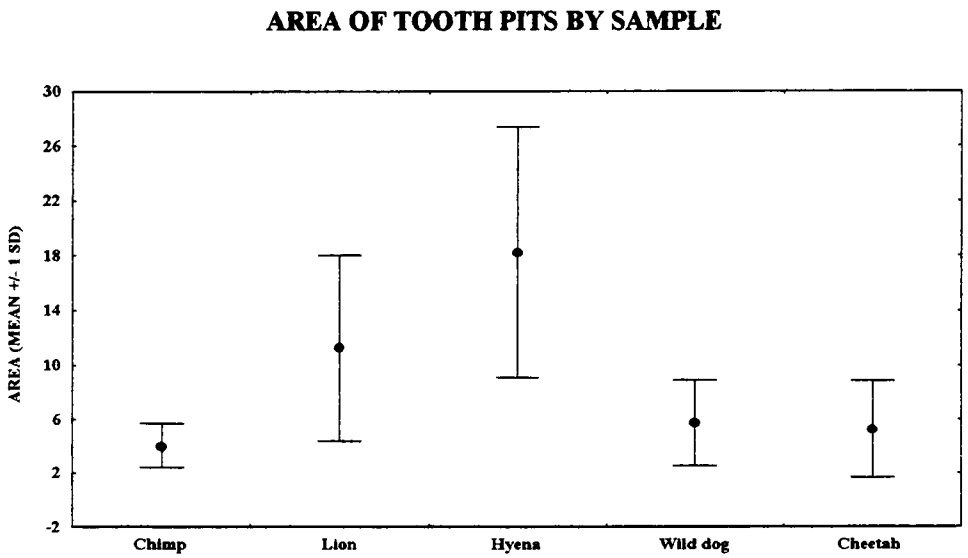


Figure 22. The mean area of tooth pits by sample. Data shown in Table 22.

Table 23. Mean area of tooth pits stratified by bone type.

	AREA (mm)					
	Cancellous Bone			Cortical Bone		
Sample	N	Mean	+/- 1 s.d.	N	Mean	+/- 1 s.d.
Chimpanzee	12	3.67	1.5	6	4.89	1.81
African lion	15	9.40	4.63	19	12.68	7.93
Striped hyena	2	22.21	5.93	2	14.25	12.35
African wild dog	6	7.42	3.13	9	4.61	2.84
Cheetah	9	5.25	3.61	0	-	-

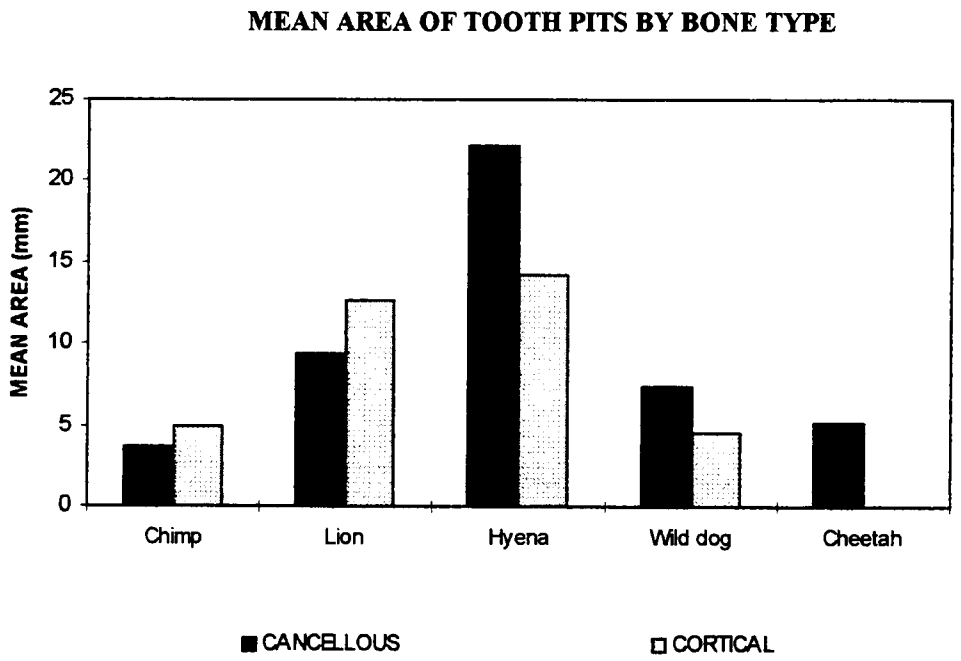


Figure 23 . Mean area of tooth pits stratified by bone type. Data shown in Table 23.

Table 24. The mean ratio of the minor axis to major axis by sample. Kruskal-Wallis test (Chi-square approximation) on arcsin transformed ratios: Chi-square= 5.398, d.f.= 4, Monte Carlo p = .247. There is no significant difference at the .05 level.

		MINOR/MAJOR AXIS RATIO (mm)	
Sample	N	Mean	+ / - 1 s.d.
Chimpanzee	18	.78	.10
African lion	34	.76	.13
Striped hyena	4	.71	.16
African wild dog	15	.70	.06
Cheetah	9	.77	.12

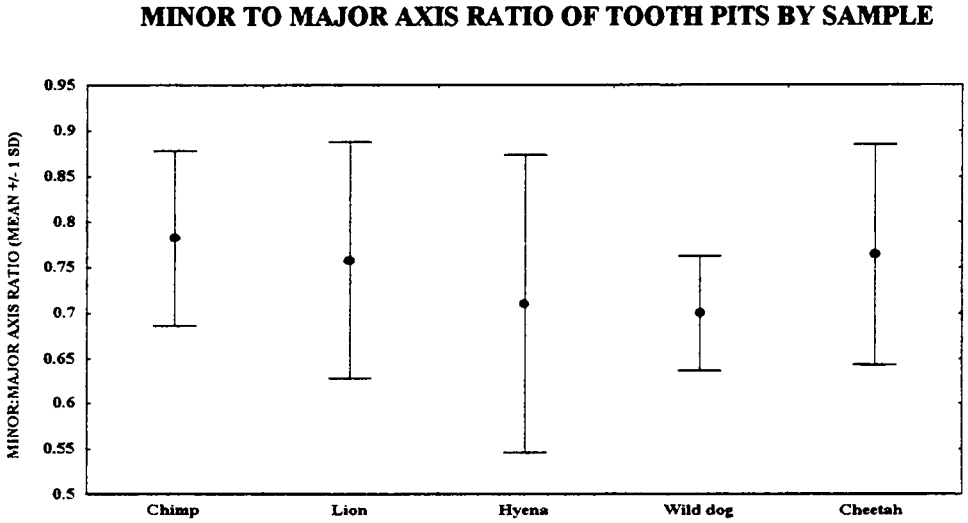


Figure 24. The mean ratio of the minor to major axis. Data shown in Table 24.

Table 25. Mean length of the major axis stratified by bone type.

	MAJOR AXIS (mm)					
	Cancellous Bone			Cortical Bone		
Sample	N	Mean	+/- 1 s.d.	N	Mean	+/- 1 s.d.
Chimpanzee	12	1.63	.38	6	1.93	.41
African lion	15	2.69	.68	19	3.05	1.04
Striped hyena	2	4.49	.04	2	3.09	1.11
African wild dog	6	2.41	.58	9	1.88	.50
Cheetah	9	1.96	.68	0	-	-

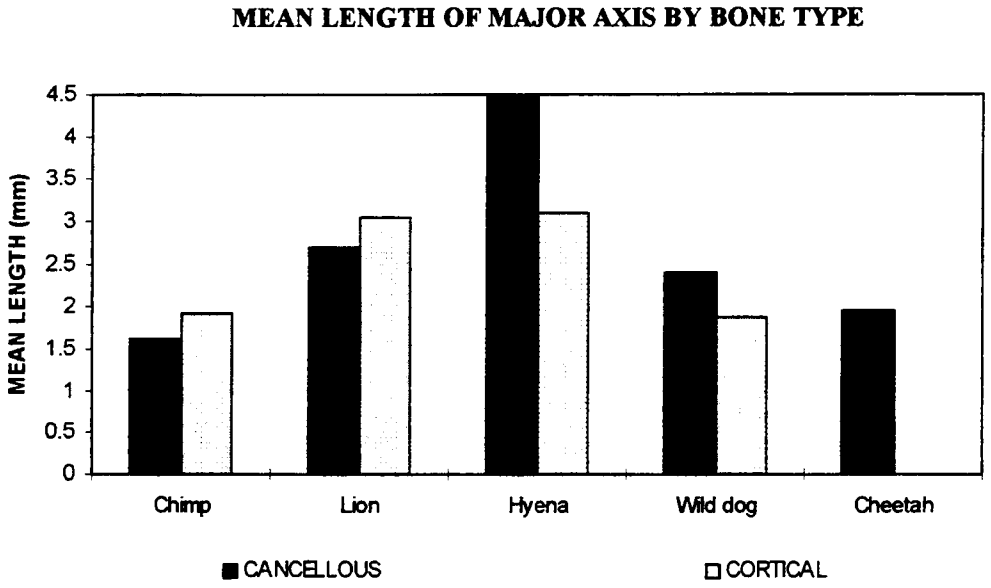


Figure 25. Mean length of the major axis of tooth pits stratified by bone type. Data shown in Table 25.

Table 26. Mean length of the minor axis stratified by bone type.

	MINOR AXIS (mm)					
	Cancellous Bone			Cortical Bone		
Sample	N	Mean	+/- 1 s.d.	N	Mean	+/- 1 s.d.
Chimpanzee	12	1.29	.30	6	1.46	.31
African lion	15	1.98	.53	19	2.29	.73
Striped hyena	2	2.94	.76	2	2.48	1.5
African wild dog	6	1.75	.44	9	1.29	.41
Cheetah	9	1.47	.47	0	-	-

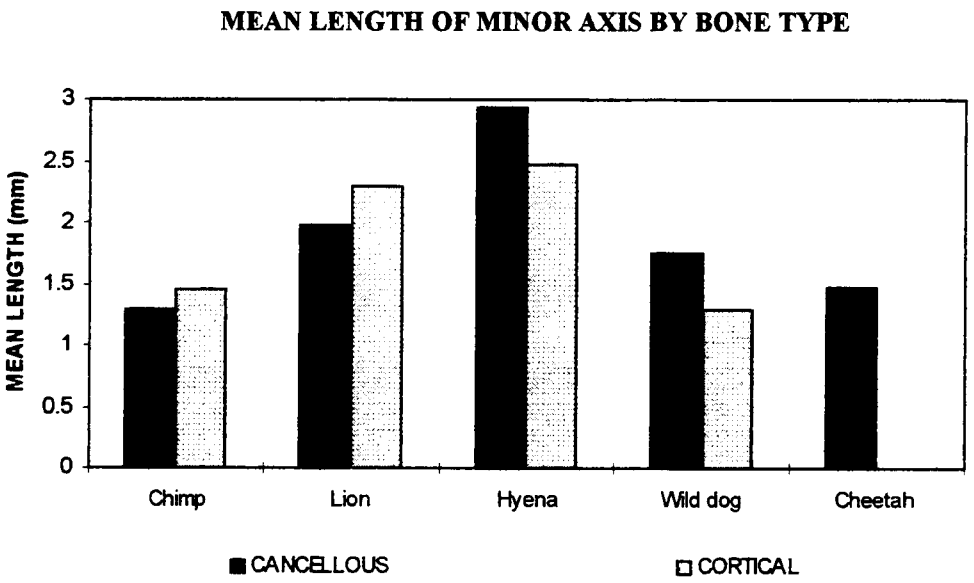


Figure 26. Mean length of the minor axis of tooth pits stratified by bone type. Data shown in Table 26.

Chapter V

Discussion

In this chapter, assemblage-level analyses are examined in relation to various energetic, mechanical, and behavioral principles. Specimen-level analyses (tooth score morphology and widths) are discussed in relation to current methodological debates and other methodological issues. The tooth pit morphology analysis is examined in relation to Selvaggio's study of the size and shape of extant carnivore tooth pits. The results of each analysis are summarized and discussed separately.

ASSEMBLAGE-LEVEL

Tooth Mark Densities

The significantly lower density of tooth marks in the chimpanzee sample compared to the carnivore sample is attributed to the incomplete consumption of soft tissue by the chimpanzees. In the chimpanzee sample, more than half of the specimens exhibit no tooth marks, while the number of marks on tooth-marked specimens range from one to five. Chimpanzees tend to mark all specimens with equal intensity and show no preference for any particular skeletal element, bone size, or bone portion.

The uniformly low tooth mark densities can be explained in part by the low level of interest in the bones exhibited by the chimpanzees. As detailed in Chapter III, the level of interest is measured as the amount of time each chimpanzee group at the four zoological

parks spent gnawing or manipulating the bones. While the level of interest varied between the groups, for all groups the percentage of time spent not gnawing or manipulating the bones (no interaction) exceeded the amount of time spent gnawing (Table 27 and Figure 27). The Little Rock Zoo chimpanzees spent the longest mean percentage of time gnawing (32.1%), followed by the Knoxville Zoo chimpanzees (22.2%), the St. Louis Zoo chimpanzees (6.8%), and then the Jackson Zoo chimpanzees who spent no time gnawing on the bones. The low level of interest displayed by the chimpanzees in the bones is markedly different from that of their wild counterparts who are known to completely devour their prey. Wild chimpanzees eat all parts of the carcass, including the skin, viscera, bone, hair, and even teeth (Teleki, 1975). The remnants of a carcass generally only consist of a few small bone fragments and scraps of skin (Takahata et al., 1984 and Stanford, 1996).

The difference between the bone mastication behavior of captive chimpanzees and that of wild chimpanzees can partly be explained by differences in motivation. For captive chimpanzees, gnawing appears to be more a reflection of boredom and object-centered play than a propensity to consume bone. Unlike their free-ranging counterparts, captive chimpanzees are rarely if ever hungry. The feeding habits of captive animals appear to influence the extent of bone gnawing (Capaldo, 1995; Haynes, 1981). Hungry animals tend to gnaw bone with greater intensity and as a result produce more conspicuous damage than "well-fed or over-fed" captive animals (Miller, 1969:21). In addition, chimpanzees are highly social animals that rely heavily on the transmission of learned behavior. Given that captive chimpanzees have never learned to recognize meat or bone as

Table 27. The mean and mean percentage of total mean time each chimpanzee group engaged in gnawing, manipulating, and no interaction with the bones.

CHIMPANZEE GROUP	GNAWING	OBJECT MANIPULATION	NO INTERACTON
Knoxville Zoo			
Mean	13.08	12.1	33.8
Mean %	22.2	20.5	57.3
Little Rock Zoo			
Mean	19.7	11.2	30.4
Mean %	32.1	18.3	49.6
St. Louis Zoo			
Mean	4.5	13.4	47.8
Mean %	6.8	20.4	72.8
Jackson Zoo			
Mean	0	0	46.5
Mean %	0	0	100.0

The number of feeding experiments per group: Knoxville Zoo (n=5), Little Rock Zoo (n=4), St. Louis (n=3), Jackson Zoo (n=4). Mean and mean percentage of time presented in minutes.

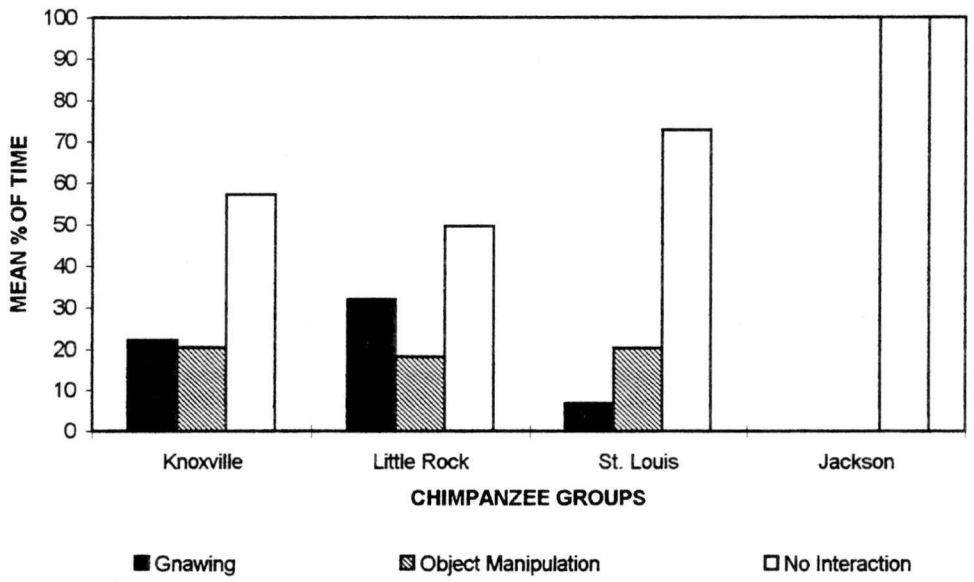


Figure 27. Mean percentage of total mean time each chimpanzee group engaged in gnawing, manipulating, and no interaction with the bones. Data shown in Table 27.

a potential food source, it is not surprising that they displayed so little interest in the bones.

In the carnivore sample, significant intrasample differences are apparent when tooth mark densities are compared by bone size groups and skeletal element groups but not long bone groups or long bone portions. The carnivore sample exhibits significantly higher tooth mark densities on size group 3 bones compared to size group 2 bones. Differences between the two size groups are attributed to the greater amount of flesh and marrow present on size 3 (pig) bones compared to size 2 (sheep) bones. Even after butchering, size 3 bones still retained significantly more flesh than size 2 bones. Capaldo (1995) reports that size 3 bones have higher wet marrow weights than size 2 bones.

With respect to skeletal element groups, carnivores inflict significantly more tooth marks on flat bones and long bones compared to compact bones. Two explanations are presented to account for the disproportionate distribution of tooth mark densities between skeletal element groups. First, the low tooth mark densities on compact bones may be due to the method of presentation. Many of the compact bones were presented to the carnivores as articulated carpal/metacarpal/ first phalanges and tarsal/metatarsal/first phalanges units. In an actualistic study of skeletal element survival, Marean and others (1992) report that tarsals survive spotted hyena ravaging much better when presented as a unit than when unattached. Due to the tight ligamental binding of the metatarsal joint, hyenas appeared to have greater difficulty consuming the distal limb unit.

The distributional differences of tooth mark densities between skeletal element groups may also result from density and nutritional differences in skeletal elements. When

presented with a variety of skeletal elements, spotted hyenas are known to choose the greasiest and least dense element first (Marean and Spencer,1991; Marean et al.,1992; Blumenschine and Marean, 1993). Bones chosen first for consumption are often more severely damaged than those chosen later in the consumption sequence. Because of their greasy and soft makeup, pelves (flat bones) are consumed first, followed by long bones, and then compact bones.

Although not statistically significant, the carnivore sample is also characterized by a disproportionate distribution of tooth mark densities between long bone groups. Proximal long bones have the highest tooth mark densities, followed by the intermediate long bones, and then the distal long bones with the lowest tooth mark densities. The distributional differences appear to result from differences in the amount of marrow in long bones. Blumenschine and Madrigal (1993) report that the non-cursorial warthog and sheep show a marked proximal long bone dominance in marrow weights compared to intermediate and distal long bones. In addition, the distal long bones in the carnivore sample are all size group 2 bones. As previously mentioned, size group 3 bones have higher marrow weights than size 2 bones.

In the carnivore sample, tooth mark densities are fairly uniform for long bone portions. Based on density and energetic factors, the greasiest and least dense epiphyseal portion should exhibit the highest tooth mark densities, followed by the near-epiphyseal portion, and then the midshaft portion. The uniformity of the sample appears to be a product of the tooth mark tallying methodology. As described in Chapter III, gross gnaw damage was counted as one mark, irrespective of the size of the area of damage. Gross

gnaw damage tends to be concentrated on the epiphyseal and near-epiphyseal portions of the bone. Thus, this methodology is not useful in determining the extent of gnawing on long bone portions.

Incidence of Tooth Marks

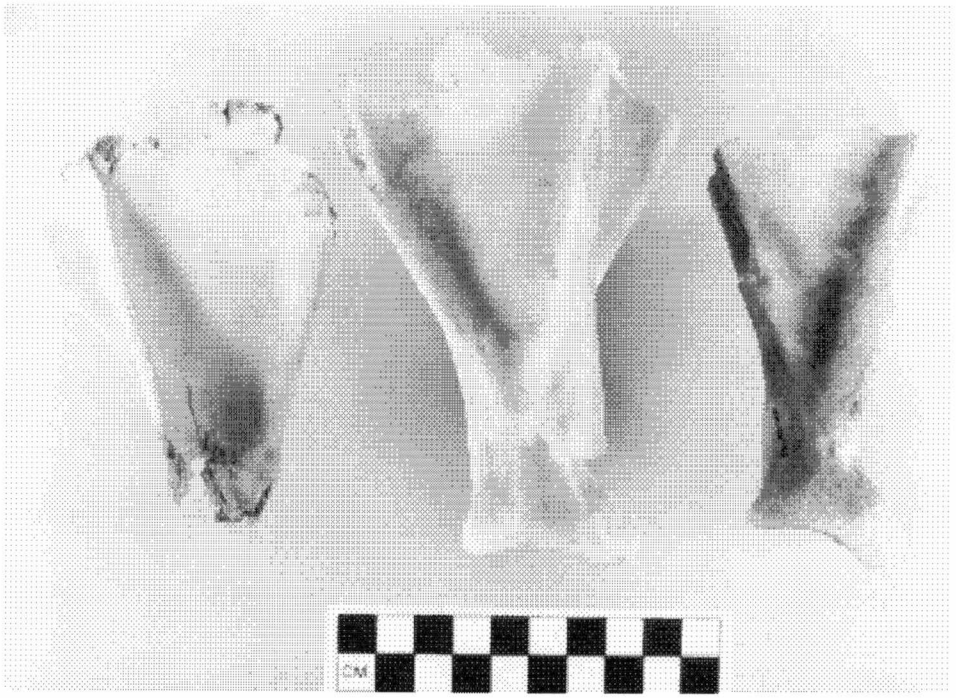
In general, the incidence of tooth-marked specimens in the chimpanzee sample is considerably lower than the incidence of tooth-marked specimens in the carnivore sample. In the chimpanzee sample, only 37% of the specimens are tooth-marked, whereas 76% of the specimens in the carnivore sample are tooth-marked. In regards to tooth mark types, the carnivore sample has a higher proportion of specimens bearing type 2 (punctures, furrows, and gross gnaw damage) marks and specimens exhibiting both type 1 and type 2 marks compared to the chimpanzee sample. However, the chimpanzee sample has a slightly higher percentage of specimens bearing type 1 (scores and pits) marks than the carnivore sample. Of type 2 damages, the proportion of fractured specimens is markedly different between the two samples. For long bones only, the percentage of fractured specimens is substantially lower in the chimpanzee sample compared to the carnivore sample. Only 5% of the long bones in the chimpanzee sample are fractured, while 70% of the long bones in the carnivore sample are fractured (Table 28).

Although rare, chimpanzees can fracture bones with their teeth that closely resemble bones fractured by carnivores. As illustrated in Figure 28, the chimpanzee- and carnivore-fractured scapulae are characterized by what Binford (1981) calls crenulated edges. Crenulated edges are produced when a tooth penetrates and removes an area along

Table 28. Number of individual specimens by long bone segment, size group, and sample. Long bone segments are divided into epiphyseal fragments (EPF), near epiphyseal fragments (NEF), midshaft fragments (MSF), and complete (CO) long bones. Complete long bones denote specimens that were not fragmented. Below the solid line is a break down of the carnivore sample by species.

		Long Bone Portions					
Sample	Size Group	EPF	NEF	MSF	CO	Total	Total %
Chimpanzee	2	2	0	0	32	34	54.
	3	1	0	0	28	29	46.
Chimpanzee total		3	0	0	60	63	
Total %		05.	0.	0.	95.		
Carnivore	2	1	0	3	5	9	7.
	3	42	17	21	32	112	93.
Total		43	17	24	37	121	
Total %		36.	14.	20.	30.		
African lion	2	0	0	3	0	3	04.
	3	40	16	15	9	80	96.
Lion total		40	16	18	9	83	
Total %		48.	19.	22.	11.		
Striped hyena	2	1	0	0	4	5	29.
	3	2	1	6	3	12	71.
Hyena total		3	1	6	7	17	
Total %		18.	06.	35.	41.		
African wild dog	2	0	0	0	1	1	08.
	3	0	0	0	11	11	92.
Wild dog total		0	0	0	12	12	
Total %		0.	0.	0.	100.		
Cheetah	2	0	0	0	0	0	0.
	3	0	0	0	9	9	100.
Cheetah total		0	0	0	9	9	
Total %		0.	0.	0.	100.		

A



B

Figure 28. A. Sheep scapulae gnawed by a striped hyena (left), African wild dog (center), and chimpanzee (right). B. Sheep metacarpals gnawed by a striped hyena (left) and chimpanzee (right).

the edge of the bone equal to the size of the tooth. The chimpanzee-fractured metacarpal displays mashed edges. Mashed edges are produced when an animal gnaws on one end of the bone while resting the opposite end of the bone on the ground (Binford, 1981). Instead of resting the bone on the ground, chimpanzees tend to hold one end of the bone in their hand while gnawing on the opposite end. Nunamiut Eskimos are also known to produce mashed edges when they gnaw on bones of young animals (Binford, 1981). The striped hyena-fractured metacarpal is described as channeled. This type of fracture is characterized by a channel running parallel to the longitudinal axis of the bone (Binford, 1981).

Chimpanzees can also produce spiral fractures (Figure 29). A captive, male chimpanzee was observed to crack open a pig femur by striking it numerous times against the ground. After having broken the bone, he repeatedly dipped a piece of straw into the marrow cavity and then licked the end of the straw. A similar behavior has been observed among wild chimpanzees. Boesch and Boesch (1989) report that Tai chimpanzees use tools (sticks) to extract marrow from the bones they have broken with their teeth.

In the chimpanzee sample, intrasample differences are evident when the incidence of tooth-marked and unmarked specimens are compared by bone size groups and skeletal element groups. In regard to bone size groups, the chimpanzee sample has a much higher proportion of unmarked size 2 specimens compared to unmarked size 3 specimens. For skeletal element groups, the chimpanzee sample has a higher proportion of unmarked compact bones compared to unmarked flat and long bones. The high percentage of unmarked size 2 bones and unmarked compact bones may be attributed to the method of

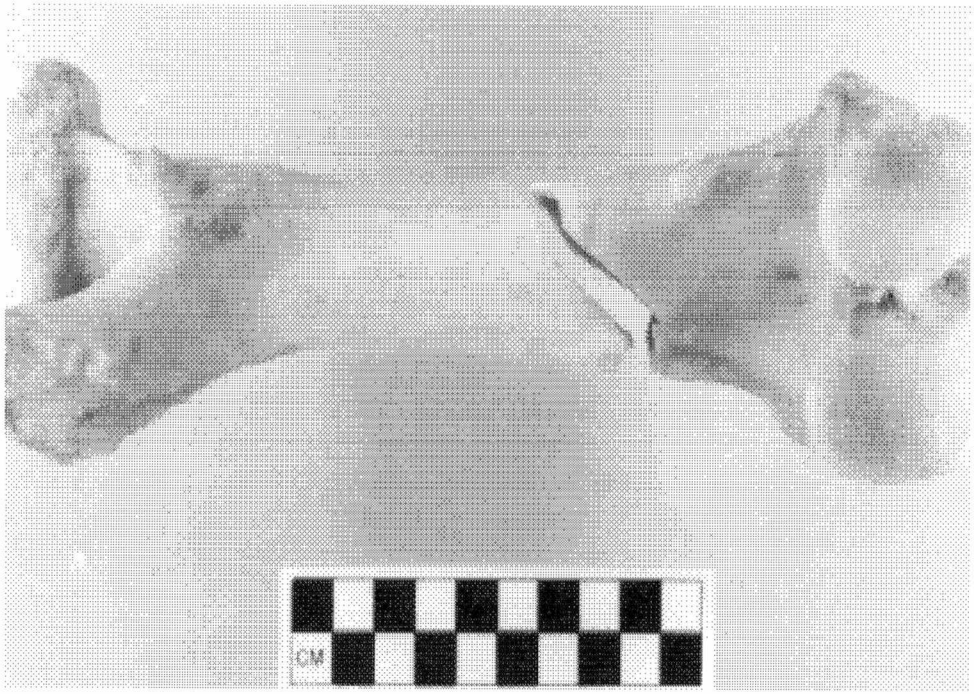


Figure 29. Spiral fracture produced by a chimpanzee on a pig femur.

presentation. As described for carnivores in the previous section, carpal and tarsal bones are more commonly tooth-marked when unattached than when attached to the metacarpal or metatarsal. In the chimpanzee sample, 49% of the size 2 specimens are composed of compact bones. Thus, the high proportion of unmarked size 2 specimens may result from the large number of compact bones in that size group.

Like in the chimpanzee sample, intrasample differences are apparent in the carnivore sample when the incidence of tooth-marked and unmarked specimens are compared by bone size groups and skeletal element groups. For bone size groups, the carnivore sample exhibits a higher proportion of tooth-marked size 3 specimens compared to size 2 specimens. As detailed in the previous section, the differences in size 3 versus size 2 bones can be explained by the greater amount of flesh and marrow present on size 3 bones compared to size 2 bones. Blumenschine (1988) proposes another explanation to account for the lower proportion of tooth-marked size 2 specimens. According to Blumenschine, size1 and size 2 long bones are less resistant to breakage than size 3 specimens which tends to reduce the amount of gnawing and associated tooth-marking necessary for the carnivore to break the bone. Hence, size 1 and size 2 fragments are expected to exhibit a lower proportion of tooth marks compared to size 3 fragments. The results of this analysis, however, do not support Blumenschine's findings. While size 2 specimens do display a lower proportion of tooth marks, size 2 (44%) specimens are also significantly less fragmented than size 3 (80%) specimens (Table 28). Thus, energetic factors seem to provide a better explanation for the observed differences between size groups.

In regards to skeletal element groups, the carnivore sample exhibits a higher percentage of tooth-marked flat and long bones compared to compact bones. The observed differences result from density and energetic differences in skeletal elements. As described for tooth mark densities, the greasiest and least dense elements tend to display a higher proportion of tooth marks. Thus, flat bones display the highest proportion of tooth marks, long bones are intermediate, and compact bones exhibit the lowest proportion of tooth marks.

TOOTH MARK MORPHOLOGY

Tooth Score Morphology

Macroscopic and light microscopic characteristics of tooth scores are diagnostic of the modifying agent. The most conspicuous signature criterion indicative of hominoid bone mastication is the morphology of the incisal tooth scores. A signature criterion is a "constant and unique criterion that discriminates one agent or set of agents from another" (Binford 1981:26). The broad, spatulate morphology of chimpanzee incisors produce tooth scores on bone that are characterized by a relatively uniform width and depth and a flat base. Chimpanzee tooth scores result from either turning the bone against the incisors or pulling the incisors over the surface of the bone. They can occur singly or as sets of two or three parallel marks oriented perpendicular to the long axis of the bone. They also tend to be located more often on the midshaft portion of a long bone. Incisal tooth scores may have been produced with the intent to remove periosteum from the surface of the bone as White (1992) has suggested for hominid bone consumption.

In contrast, carnivore tooth scores are characterized by a rounded base and highly variable width and depth. Carnivore tooth scores can occur singly but more commonly occur as clusters of intersecting marks oriented oblique to the long axis of the bone. Carnivore tooth scores tend to be concentrated on the near-epiphyseal portion of the bone. They are the result of the teeth slipping down the surface of the bone while the carnivore gnaws on the epiphysis.

Although Shipman (1981) and Shipman and Rose (1983) maintain that scanning electron microscopy is a necessary requirement for distinguishing different surface modifications on bone, the results of this study do not support their contentions. Although sample sizes are small, scanning electron microscopy did not prove useful in distinguishing chimpanzee and carnivore tooth scores. As others have noted (Shipman, 1981; Shipman and Rose, 1983; Cook, 1986; Olsen,1988), SEM does offer several advantages over the standard light microscope, including its superior resolution, greater depth of field, and its ability to examine specimens at higher magnifications. In this study, however, the high magnification capabilities of the SEM tended to obscure the diagnostic differences between chimpanzee and carnivore tooth scores. Other disadvantages of the SEM include its high operating costs, its time-consuming nature, and the resultant limitations these factors impose on assemblage-level analyses of surface modifications (Blumenschine 1995; Blumenschine et al., 1996).

Tooth Score Widths

Tooth score width is not a useful criterion for distinguishing individual agents. The multivariate analysis only shows significant differences for the African wild dog. For minimum width, the African wild dog mean tooth score width is significantly narrower than that of the African lion. While for maximum width, the African wild dog mean tooth score width is significantly narrower than that of all species (chimpanzee, striped hyena, and African lion) except the cheetah. The ranges of both maximum and minimum tooth score widths overlap extensively.

The purpose of this analysis was to apply statistical procedures to Haynes's (1981) observation that species of carnivores are distinguishable by the width and length of their tooth marks. As described in Chapter III, only widths were examined due to the difficulty in attaining reliable length measurements with an ocular micrometer at 20x magnifications. Regardless of whether widths or widths and lengths are included in the analysis, I feel the results of any tooth score width analysis will be of negligible usefulness in attributing these marks to modifying agent. Haynes (1981) acknowledges that tooth mark lengths and widths can vary by bone density (cancellous versus cortical) and the shape of the bone being marked. In addition, tooth score widths can vary by tooth type. While only incisal tooth scores were measured in the chimpanzee sample, tooth scores in the carnivore sample could have resulted from any one of the four tooth types (incisors, canines, premolars, or molars).

Tooth Pit Morphology

The results of this analysis are discussed in relation to Selvaggio's (1994a) study of the size and shape of extant carnivore tooth pits. The results of this analysis show that there is a significant difference between the area of tooth pits and species. Striped hyena tooth pits exhibit the largest mean area, followed by the African lion, African wild dog, cheetah, and then the chimpanzee with the smallest mean area. When tooth pit area is examined by bone type, an unexpected pattern emerges. As expected, the striped hyena and African wild dog do inflict larger tooth pits on cancellous bone compared to cortical bone. The African lion and chimpanzee, however, inflict larger tooth pits on cortical bone than on cancellous bone.

With respect to the area of tooth pits on cancellous bone, the results of this analysis exhibit a similar pattern as that reported by Selvaggio for identical or comparable species. The striped hyena sample exhibits the largest mean area (22.2) on cancellous bone, followed by the African lion (9.4), the African wild dog (7.4), the cheetah (5.3), and then the chimpanzee with the smallest mean tooth pit area (3.7). In Selvaggio's study, the spotted hyena has the largest mean area (21.5), followed by the African lion (17.9), and then the cheetah (3.2). In this analysis, the distribution of the area of tooth pits is the same for cortical bone as reported for cancellous bone. Selvaggio, however, reports a different distribution for cortical bone. The African lion sample exhibits the largest mean area on cortical bone, followed by the spotted hyena, and then the cheetah.

The results show that there is no significant difference between the minor to major axis ratio and individual species. When the minor axis length and major axis length are

compared by bone type, axes lengths between species display a similar pattern as reported for the area of tooth pits. For minor axis and major axis length on cancellous bone, the striped hyena sample displays the longest mean length, followed by the African lion, African wild dog, cheetah, and then the chimpanzee with the shortest mean length. On cortical bone, the chimpanzee inflicts longer major and minor axes lengths than the African wild dog but not the African lion or striped hyena. In Selvaggio's study, the distribution of major and minor axes lengths are the same for all analyses except for the distribution of minor axis lengths on cancellous bone. For major axis length on cortical and cancellous bone and minor axis length on cortical bone, the African lion sample exhibits the longest mean axis length, the spotted hyena displays an intermediate length, and the cheetah inflicts the shortest mean length. For the length of the minor axis on cancellous bone, however, the spotted hyena inflicts the longest mean length, followed by the African lion, and then the cheetah.

The purpose of this analysis was to compare the results of my technique (digital imaging and computer-generated measurements) with those obtained by Selvaggio (1994a) using video-imaging and computer-generated measurements. The differences in our results are attributed largely to the current inability to control for tooth type. Additional factors may be the small sample sizes and imprecise definitions of tooth pits. Given improvements, I feel digital imaging can be useful in identifying species or at least family from their tooth marks on bone.

Chapter VI

Conclusions

The most distinctive criteria for distinguishing chimpanzee and carnivore tooth modifications on bone are summarized as follows:

1. The chimpanzee-generated bone assemblage is characterized by a high incidence of unmarked specimens. The number of tooth marks on tooth-marked specimens generally range from one to five marks. Tooth mark densities are uniformly low for all skeletal elements, bone sizes, and long bone portions. Most chimpanzee damage is minor, consisting of tooth pits and scores; more severe damages such as furrowing and fracturing are extremely rare.

   Conversely, the carnivore-generated bone assemblage is characterized by a relatively high incidence of tooth-marked specimens. The number of tooth marks on tooth-marked specimens range from six to fifteen marks. Tooth mark densities are highest for size 3 bones and flat bones (scapula and pelvis). Carnivore damage is severe, having a high incidence of specimens exhibiting punctures, furrows, and fractures.

2. The most conspicuous diagnostic criterion of hominoid bone mastication is the morphology of incisal tooth scores. Chimpanzee incisal tooth scores are characterized by a uniform width and depth and a flat base. They most often occur singly but also as sets of two or three parallel marks oriented perpendicular to the long axis of the bone. They tend to be located on the mid-shaft portion of a long bone.

> In contrast, carnivore tooth scores exhibit a highly variable width and depth and generally have a rounded base. They most often occur as clusters of intersecting marks oriented oblique to the long axis of the bone. They tend to be concentrated on the near-epiphyseal portion of a long bone.

While this study demonstrates that extant hominoids are capable of imparting damage types (tooth scores, tooth pits, tooth punctures, and even fractures with crenulated and mashed edges) on bone identical to those inflicted by carnivores, there are appreciable differences in the extent and severity of mastication damage. The disparity in consumption damage produced by chimpanzees and carnivores is in accordance with Binford's (1981:148) prediction that "it is highly unlikely that a normal hominid pattern of consumption would include gnawing to the extent that it would mimic the consequences of the classic carnivore's behavior."

The ability to recognize carnivore tooth mark mimicking of hominid tooth marks is crucial to interpretations of the primacy of hominid versus carnivore roles in modifying archaeological bone assemblages. The misidentification of hominid tooth marks could falsely inflate the frequency of carnivore tooth marks and thus lead to an erroneous conclusion that carnivores rather than hominids were the primary agents of bone modification.

Hominid tooth marks could also serve as a new diagnostic of hominid involvement with a faunal assemblage and provide perhaps the most direct line of evidence for early hominid meat-eating. Hominid tooth marks may prove particularly useful when more conspicuous indicators (stone tools or cut marks) of hominid involvement are absent from

an archaeological site. Of notable interest, is the potential use of hominid tooth marks as an indicator of hominid involvement with animal remains prior to the advent of the Oldowan stone tool technology roughly 2.5 million years ago (Potts, 1993).

FUTURE DIRECTIONS

Future research hopes to enlarge sample sizes through working with free-ranging rather than captive chimpanzees and carnivores. While captivity provides a controlled setting, the predictability of food and lack of intra- and interspecific competition alters the natural feeding behavior of the animals. Van Valkenburgh (1996) even suggests that carnivores use their teeth differently in a noncompetitive captive situation as opposed to a natural environment.

The ability to identify species from their tooth marks on bone could be useful to zooarchaeologists in their efforts to reconstruct site formation processes and the order in which hominids and carnivores modified bones. Because of the rarity of carnivores in the archaeological record, the ability to identify family or species of carnivore from their tooth marks could provide evidence of their presence even when their skeletal remains are absent. It could also be useful for inferring extinct carnivore behavior. I feel that digital imaging analysis can be a beneficial technique for discerning individual species from their tooth marks given significantly larger sample sizes and the ability to control for tooth type. Future research is this area will focus on enlarging sample sizes, controlling for tooth type, employing multivariate statistical techniques, and adding more quantitative characteristics such as maximum radian, minimum radian, p-round (degree of circularity), and perimeter.

In addition to tooth pits, this technique will be used to quantify the morphology of chimpanzee and carnivore tooth scores.

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Appendices

Appendix 1. List of Abbreviations

CA	carpal
CO	complete bone
DS	distal epiphysis
EPF	epiphyseal fragment
FE	femur
FI	fibula
FU	furrow
GG	gross gnaw damage
HU	humerus
LBF	long bone fragment
MC	metacarpal
MS	midshaft
MSF	midshaft fragment
MT	metatarsal
NE	near-epiphysis
NEF	near-epiphyseal fragment
PE	pelvis
PI	pit
PHL	phalange
PU	puncture
PX	proximal epiphysis
RA	radius
SC	scapula
SCR	score
SPEC#	specimen number
SPEC.SZ	specimen size
SKE	skeletal element
SZ	size
TA	tarsal
TI	tibia
UL	ulna

Appendix 2. Data table for the number of tooth marks by bone size, skeletal element, long bone fragmentation, specimen size, and long bone portion.

SPEC#	SZ	SKE	LBF	SPEC.SZ	PX	DS	NE	MS	SUM
PTKZ1-1	2	SC	0	0	0	0	0	0	8
PTKZ1-2	2	MT	CO	10	0	3	0	2	5
PTKZ1-3	2	FE	CO	10	14	13	4	6	37
PTKZ1-4	2	RA	CO	10	0	0	0	7	7
PTKZ1-5	2	UL	CO	10	0	0	0	1	1
PTKZ1-7	2	TA	0	0	0	0	0	0	0
PTKZ1-8	2	TA	0	0	0	0	0	0	0
PTKZ1-9	2	TA	0	0	0	0	0	0	1
PTKZ1-10	2	TA	0	0	0	0	0	0	1
PTKZ1-11	2	PE	0	0	0	0	0	0	0
PTKZ2-1	2	UL	CO	10	0	0	0	0	0
PTKZ2-2	2	RA	CO	10	0	0	0	0	0
PTKZ2-3	2	FE	CO	10	1	0	0	0	1
PTKZ2-4	2	TI	CO	10	2	0	1	0	3
PTKZ2-5	2	MC	CO	10	0	0	0	0	0
PTKZ2-6	3	FE	CO	10	0	0	1	1	2
PTKZ2-7	2	SC	0	0	0	0	0	0	3
PTKZ2-8	2	CA	0	0	0	0	0	0	0
PTKZ2-9	2	CA	0	0	0	0	0	0	0
PTKZ2-10	2	CA	0	0	0	0	0	0	0
PTKZ2-11	2	CA	0	0	0	0	0	0	0
PTKZ2-12	2	CA	0	0	0	0	0	0	0
PTKZ3-1	3	HU	CO	10	2	0	0	0	2
PTKZ3-2	3	UL	CO	10	0	1	0	0	1
PTKZ3-3	3	RA	CO	10	0	0	0	0	0
PTKZ3-4	3	FE	CO	10	1	5	0	0	6
PTKZ3-5	3	RA	CO	10	0	0	0	0	0
PTKZ3-6	3	UL	CO	10	0	1	0	0	1
PTKZ3-7	3	UL	CO	10	0	0	0	0	0
PTKZ3-8	3	RA	CO	10	0	2	0	0	2
PTKZ4-1	3	UL	CO	10	1	0	0	1	2
PTKZ4-2	3	FE	CO	10	0	4	0	0	4
PTKZ4-3	3	HU	CO	10	0	0	0	0	0
PTKZ4-4	3	FE	CO	10	2	0	1	0	3
PTKZ4-5	3	UL	CO	10	0	0	0	0	0

SPEC#	SZ	SKE	BP	SPEC.SZ	PX	DS	NE	MS	SUM
PTKZ4-6	3	RA	CO	10	0	1	0	0	1
PTKZ4-7	3	RA	CO	10	0	0	0	0	0
PTKZ5-1	3	PE	0	0	0	0	0	0	0
PTKZ5-2	3	HU	CO	10	1	0	0	0	1
PTKZ5-3	3	RA	CO	10	0	3	0	0	3
PTKZ5-4	3	UL	CO	10	0	0	0	0	0
PTKZ5-5	3	FE	CO	10	0	0	0	0	0
PTKZ5-6	3	HU	CO	10	2	0	0	0	2
PTLR1-1	2	MC	CO	10	0	1	0	0	1
PTLR1-2	2	UL	CO	10	0	0	0	0	0
PTLR1-3	2	RA	CO	10	0	0	0	0	0
PTLR1-4	2	SC	0	0	0	0	0	0	7
PTLR1-5	2	SC	0	0	0	0	0	0	1
PTLR1-6	3	FE	CO	10	0	0	0	1	1
PTLR1-7	3	PE	0	0	0	0	0	0	1
PTLR1-8	2	CA	0	0	0	0	0	0	0
PTLR1-9	2	CA	0	0	0	0	0	0	1
PTLR1-10	2	CA	0	0	0	0	0	0	0
PTLR1-11	2	CA	0	0	0	0	0	0	0
PTLR1-12	2	CA	0	0	0	0	0	0	0
PTLR2-1	2	UL	CO	10	0	0	0	0	0
PTLR2-1	2	RA	CO	10	0	0	0	0	0
PTLR2-3	2	UL	CO	10	0	0	3	0	3
PTLR2-4	2	RA	CO	10	0	0	0	0	0
PTLR2-5	2	MC	EPF	10	0	0	0	1	1
PTLR2-6	2	MC	EPF	10	0	0	0	9	9
PTLR2-7	2	PE	0	0	0	0	0	0	4
PTLR2-8	2	PE	0	0	0	0	0	0	0
PTLR2-9	3	FE	CO	10	0	2	0	0	2
PTLR2-11	2	CA	0	0	0	0	0	0	0
PTLR2-12	2	CA	0	0	0	0	0	0	0
PTLR2-13	2	CA	0	0	0	0	0	0	0
PTLR2-14	2	CA	0	0	0	0	0	0	0
PTLR2-15	2	CA	0	0	0	0	0	0	0
PTLR2-16	2	CA	0	0	0	0	0	0	0
PTLR2-17	2	CA	0	0	0	0	0	0	0
PTLR2-18	2	CA	0	0	0	0	0	0	0
PTLR2-19	2	CA	0	0	0	0	0	0	0

SPEC#	SZ	SKE	LBF	SPEC.SZ	PX	DS	NE	MS	SUM
PTLR2-20	2	CA	0	0	0	0	0	0	0
PTLR3-1	3	FE	CO	10	2	0	0	0	2
PTLR3-2	3	FE	CO	10	0	0	0	0	0
PTLR3-3	2	MT	CO	10	0	0	0	0	0
PTLR3-4	2	MT	CO	10	0	0	0	3	3
PTLR3-5	2	MT	CO	10	0	0	0	0	0
PTLR3-6a	2	SC	0	0	0	0	0	0	12
PTLR3-6b	2	SC	0	0	0	0	0	0	0
PTLR3-6c	2	SC	0	0	0	0	0	0	0
PTLR3-6d	2	SC	0	0	0	0	0	0	0
PTLR3-6e	2	SC	0	0	0	0	0	0	0
PTLR3-6h	2	SC	0	0	0	0	0	0	0
PTLR3-10	2	TA	0	0	0	0	0	0	0
PTLR3-11	2	TA	0	0	0	0	0	0	0
PTLR3-12	2	TA	0	0	0	0	0	0	0
PTLR3-13	2	TA	0	0	0	0	0	0	0
PTLR3-14	2	TA	0	0	0	0	0	0	0
PTLR3-15	2	TA	0	0	0	0	0	0	0
PTLR3-16	2	TA	0	0	0	0	0	0	0
PTLR3-17	2	TA	0	0	0	0	0	0	0
PTLR3-18	2	TA	0	0	0	0	0	0	0
PTLR3-19	2	PHL	0	0	0	0	0	0	0
PTLR3-20	2	PHL	0	0	0	0	0	0	0
PTLR3-21	2	PHL	0	0	0	0	0	0	0
PTLR3-22	2	PHL	0	0	0	0	0	0	1
PTLR3-23	2	PHL	0	0	0	0	0	0	0
PTLR3-24	2	PHL	0	0	0	0	0	0	0
PTLR3-25	2	TA	0	0	0	0	0	0	0
PTLR3-28	2	TA	0	0	0	0	0	0	0
PTLR3-29	2	TA	0	0	0	0	0	0	0
PTLR3-30	2	TA	0	0	0	0	0	0	0
PTLR4-1	3	FE	EPF	10	0	0	2	6	8
PTLR4-2	2	SC	0	0	0	0	0	0	5
PTLR4-3	2	MC	CO	10	0	0	6	0	6
PTLR4-4	2	UL	CO	10	0	0	0	0	0
PTLR4-5	2	RA	CO	10	0	0	0	0	0
PTLR4-6	2	PE	0	0	0	0	0	0	0

SPEC#	SZ	SKE	LBF	SPEC.SZ	PX	DS	NE	MS	SUM
PTLR4-7	3	FE	CO	10	0	2	0	0	2
PTLR4-9	2	CA	0	0	0	0	0	0	0
PTLR4-10	2	CA	0	0	0	0	0	0	0
PTLR4-11	2	CA	0	0	0	0	0	0	0
PTLR4-12	2	CA	0	0	0	0	0	0	0
PTLR4-13	2	CA	0	0	0	0	0	0	0
PTSL1-1	2	TI	CO	10	0	0	0	0	0
PTSL1-2	2	TI	CO	10	0	0	0	0	0
PTSL1-3	2	SC	0	0	0	0	0	0	0
PTSL1-4	2	PE	0	0	0	0	0	0	2
PTSL1-5	2	FE	CO	10	3	7	0	0	10
PTSL1-6	2	TI	CO	10	0	0	0	4	4
PTSL2-1	2	PE	0	0	0	0	0	0	0
PTSL2-2	2	PE	0	0	0	0	0	0	0
PTSL2-3	2	FE	CO	10	0	0	0	0	0
PTSL2-4	2	FE	CO	10	0	0	0	0	0
PTSL2-5	3	FE	CO	10	0	0	0	0	0
PTSL2-6	2	TI	CO	10	0	0	0	0	0
PTSL3-1	2	FE	CO	10	0	2	0	0	2
PTSL3-2	2	TI	CO	10	0	0	0	0	0
PTSL3-3	2	TI	CO	10	0	0	0	2	2
PTSL3-4	2	SC	CO	10	0	0	0	0	0
PTSL3-5	3	FE	CO	10	0	0	0	0	0
PLSL1-1	3	UL	SHF	10	0	0	13	0	13
PLSL1-2	3	RA	CO	10	0	9	3	0	12
PLSL1-3a	3	FE	SHF	10	0	0	10	1	11
PLSL1-3b	3	FE	EPF	2	0	1	0	0	1
PLSL1-4	3	RA	EPF	8	0	0	0	1	1
PLSL1-5a	3	HU	EPF	10	0	8	2	3	13
PLSL1-5b	3	HU	EPF	4	8	0	0	0	8
PLSL1-5c	3	HU	EPF	4	1	0	0	0	1
PLSL1-5d	3	HU	MSF	7	0	0	0	0	0
PLSL1-6a	3	FE	EPF	6	10	0	0	0	10
PLSL1-6b	3	FE	EPF	10	0	9	14	3	26
PLSL1-8	3	UL	CO	10	1	17	0	2	20
PLKZ1-1	3	FE	CO	10	4	0	0	0	4
PLKZ1-2a	3	UL	SHF	8	0	0	2	9	11
PLKZ1-2b	3	UL	EPF	3	0	0	0	0	0

SPEC#	SZ	SKE	LBF	SPEC.SZ	PX	DS	NE	MS	SUM
PLKZ1-2c	3	UL	MSF	2	0	0	0	6	6
PLKZ1-2d	3	UL	MSF	3	0	0	0	2	2
PLKZ1-2e	3	UL	NEF	2	0	0	2	0	2
PLKZ1-2f	3	UL	NEF	2	0	0	3	0	3
PLKZ1-2g	3	UL	MSF	2	0	0	0	2	2
PLKZ1-3a	2	PE	0	0	0	0	0	0	11
PLKZ1-3b	2	PE	0	0	0	0	0	0	0
PLKZ1-4a	3	RA	NEF	5	0	0	2	0	2
PLKZ1-4c	3	RA	MSF	3	0	0	0	3	3
PLKZ1-4d	3	RA	MSF	4	0	0	0	2	2
PLKZ1-4e	3	RA	EPF	2	0	0	0	0	0
PLKZ1-4f	3	RA	EPF	2	0	0	0	0	0
PLKZ1-4g	3	RA	NEF	2	0	0	0	0	0
PLKZ1-4h	3	RA	NEF	2	0	0	1	0	1
PLKZ1-4i	3	RA	EPF	3	1	0	0	0	1
PLKZ1-4j	3	RA	MSF	2	0	0	0	0	0
PLKZ1-4l	3	RA	EPF	2	0	0	0	0	0
PLKZ1-5a	3	FE	MSF	9	0	0	0	5	5
PLKZ1-5f	3	FE	NEF	2	0	0	1	0	1
PLKZ1-6a	3	UL	SHF	9	0	0	5	1	6
PLKZ1-6b	3	UL	MSF	6	0	0	0	0	0
PLKZ1-6c	3	UL	NEF	2	0	0	1	0	1
PLKZ1-6d	3	UL	EPF	2	1	0	0	0	1
PLKZ1-7a	2	MC	MSF	7	0	0	0	2	2
PLKZ1-7b	2	MC	MSF	3	0	0	0	0	0
PLKZ1-7c	2	MC	MSF	2	0	0	0	0	0
PLKZ1-8a	3	RA	EPF	3	0	0	0	0	0
PLKZ1-8b	3	RA	EPF	2	0	0	0	0	0
PLKZ2-1a	3	PE	0	0	0	0	0	0	15
PLKZ2-1b	3	PE	0	0	0	0	0	0	0
PLKZ2-1c	3	PE	0	0	0	0	0	0	0
PLKZ2-1d	3	PE	0	0	0	0	0	0	0
PLKZ2-1e	3	PE	0	0	0	0	0	0	1
PLKZ2-1f	3	PE	0	0	0	0	0	0	0
PLKZ2-2a	3	FE	EPF	10	0	4	6	0	10
PLKZ2-2b	3	FE	NEF	4	0	0	0	0	0
PLKZ2-2c	3	FE	EPF	4	0	0	0	0	0
PLKZ2-2d	3	FE	NEF	2	0	0	1	0	1
PLKZ2-2f	3	FE	NEF	2	0	0	0	0	0

SPEC#	SZ	SKE	LBF	SPEC.SZ	PX	DS	NE	MS	SUM
PLKZ2-2g	3	FE	NEF	2	0	0	1	0	1
PLKZ2-3a	3	HU	EPF	10	0	4	9	0	13
PLKZ2-3b	3	HU	EPF	3	1	0	0	0	1
PLKZ2-3c	3	HU	EPF	3	1	0	0	0	1
PLKZ2-3e	3	HU	NEF	3	0	0	0	0	0
PLKZ2-3f	3	HU	NEF	2	0	0	0	0	0
PLKZ2-4	3	SC	0	0	0	0	0	0	17
PLKZ2-5	3	UL	CO	10	3	3	9	0	15
PLKZ2-6a	3	RA	EPF	7	0	0	0	0	0
PLKZ2-6b	3	RA	EPF	3	0	10	0	0	10
PLKZ2-6c	3	RA	SHF	5	0	0	2	0	2
PLKZ2-7	3	FE	CO	10	5	6	6	0	17
PLKZ3-1	3	HU	CO	10	16	10	1	0	27
PLKZ3-2a	3	FE	SHF	10	0	0	13	2	15
PLKZ3-2c	3	FE	EPF	2	1	0	0	0	1
PLKZ3-2i	3	FE	EPF	3	0	0	0	0	0
PLKZ3-2j	3	FE	EPF	4	0	0	0	0	0
PLKZ3-2k	3	FE	EPF	2	0	1	0	0	1
PLKZ3-2l	3	FE	NEF	2	0	0	0	0	0
PLKZ3-2m	3	FE	EPF	2	0	0	0	0	0
PLKZ3-2n	3	FE	EPF	2	1	0	0	0	1
PLKZ3-2p	3	FE	EPF	2	0	0	0	0	0
PLKZ3-2r	3	FE	EPF	2	0	1	0	0	1
PLKZ3-2s	3	FE	EPF	3	0	1	0	0	1
PLKZ3-2t	3	FE	EPF	2	0	2	0	0	2
PLKZ3-2u	3	FE	EPF	3	3	0	0	0	3
PLKZ3-2v	3	FE	NEF	3	0	0	3	0	3
PLKZ3-2w	3	FE	NEF	2	0	0	5	0	5
PLKZ3-2x	3	FE	EPF	2	1	0	0	0	1
PLKZ3-2y	3	FE	EPF	4	8	0	0	0	8
PLKZ3-2z	3	FE	EPF	4	0	2	0	0	2
PLKZ3-3	3	FE	CO	10	6	4	5	0	15
PLKZ3-4a	3	HU	EPF	10	0	2	11	0	13
PLKZ3-4d	3	HU	EPF	3	2	0	0	0	2
PLKZ3-4e	3	HU	EPF	3	0	0	0	0	0
PLKZ3-4f	3	HU	EPF	2	0	0	0	0	0
PLKZ3-5	3	UL	CO	10	0	0	8	0	8
PLKZ3-6	3	RA	CO	10	0	3	7	0	10
HHKZ1-1	2	SC	0	0	0	0	0	0	8

SPEC#	SZ	SKE	LBF	SPEC.SZ	PX	DS	NE	MS	SUM
HHKZ1-2	2	MC	EPF	10	0	0	0	3	3
HHKZ1-3	2	UL	CO	10	1	0	1	0	2
HHKZ1-4	2	RA	CO	10	2	0	0	0	2
HHKZ1-5	2	FE	CO	10	1	5	1	0	7
HHKZ1-6	2	CA	0	0	0	0	0	0	0
HHKZ1-7	2	CA	0	0	0	0	0	0	0
HHKZ1-9	2	CA	0	0	0	0	0	0	0
HHKZ1-10	2	CA	0	0	0	0	0	0	0
HHKZ1-11	2	CA	0	0	0	0	0	0	0
HHKZ2-1a	3	FE	EPF	4	0	0	0	0	0
HHKZ2-1b	3	FE	EPF	7	0	0	1	0	1
HHKZ2-1c	3	FE	MSF	4	0	0	0	1	1
HHKZ2-1d	3	FE	MSF	4	0	0	0	1	1
HHKZ2-1e	3	FE	MSF	6	0	0	0	7	7
HHKZ2-1f	3	FE	MSF	4	0	0	0	2	2
HHKZ2-1g	3	FE	MSF	4	0	0	0	0	0
HHKZ2-1h	3	FE	MSF	3	0	0	0	0	0
HHKZ2-1j	3	FE	NEF	3	0	0	0	0	0
HHKZ2-2	2	PE	0	0	0	0	0	0	3
HHKZ2-3	2	TA	0	0	0	0	0	0	1
HHKZ2-4	2	TA	0	0	0	0	0	0	0
HHKZ2-5	2	TA	0	0	0	0	0	0	2
HHKZ2-6	2	TA	0	0	0	0	0	0	1
HHKZ2-8	2	MT	CO	10	0	0	0	0	0
HHKZ3-1	3	HU	CO	10	1	0	0	0	1
HHKZ3-2	3	HU	CO	10	4	0	2	0	6
HHKZ3-3	3	HU	CO	10	1	0	27	0	28
LPKZ1-1a	2	SC	0	0	0	0	0	0	12
LPKZ1-1b	2	SC	0	0	0	0	0	0	0
LPKZ1-1c	2	SC	0	0	0	0	0	0	1
LPKZ1-1d	2	SC	0	0	0	0	0	0	0
LPKZ1-2	2	TA	0	0	0	0	0	0	0
LPKZ1-3	2	TA	0	0	0	0	0	0	0
LPKZ1-6	2	TA	0	0	0	0	0	0	0
LPKZ1-7	2	TA	0	0	0	0	0	0	0
LPKZ1-9	3	FE	CO	10	1	2	2	6	11
LPKZ1-11	2	MT	CO	10	0	0	0	0	0
LPKZ2-1	3	PE	0	0	0	0	0	0	9

SPEC#	SZ	SKE	LBF	SPEC.SZ	PX	DS	NE	MS	SUM
LPKZ2-2	3	UL	CO	10	1	0	0	7	8
HHKZ1-2	2	MC	EPF	10	0	0	0	3	3
HHKZ1-3	2	UL	CO	10	1	0	1	0	2
HHKZ1-4	2	RA	CO	10	2	0	0	0	2
HHKZ1-5	2	FE	CO	10	1	5	1	0	7
HHKZ1-6	2	CA	0	0	0	0	0	0	0
HHKZ1-7	2	CA	0	0	0	0	0	0	0
HHKZ1-9	2	CA	0	0	0	0	0	0	0
HHKZ1-10	2	CA	0	0	0	0	0	0	0
HHKZ1-11	2	CA	0	0	0	0	0	0	0
HHKZ2-1a	3	FE	EPF	4	0	0	0	0	0
HHKZ2-1b	3	FE	EPF	7	0	0	1	0	1
HHKZ2-1c	3	FE	MSF	4	0	0	0	1	1
HHKZ2-1d	3	FE	MSF	4	0	0	0	1	1
HHKZ2-1e	3	FE	MSF	6	0	0	0	7	7
HHKZ2-1f	3	FE	MSF	4	0	0	0	2	2
HHKZ2-1g	3	FE	MSF	4	0	0	0	0	0
HHKZ2-1h	3	FE	MSF	3	0	0	0	0	0
HHKZ2-1j	3	FE	NEF	3	0	0	0	0	0
HHKZ2-2	2	PE	0	0	0	0	0	0	3
HHKZ2-3	2	TA	0	0	0	0	0	0	1
HHKZ2-4	2	TA	0	0	0	0	0	0	0
HHKZ2-5	2	TA	0	0	0	0	0	0	2
HHKZ2-6	2	TA	0	0	0	0	0	0	1
HHKZ2-8	2	MT	CO	10	0	0	0	0	0
HHKZ3-1	3	HU	CO	10	1	0	0	0	1
HHKZ3-2	3	HU	CO	10	4	0	2	0	6
HHKZ3-3	3	HU	CO	10	1	0	27	0	28
LPKZ1-1a	2	SC	0	0	0	0	0	0	12
LPKZ1-1b	2	SC	0	0	0	0	0	0	0
LPKZ1-1c	2	SC	0	0	0	0	0	0	1
LPKZ1-1d	2	SC	0	0	0	0	0	0	0
LPKZ1-2	2	TA	0	0	0	0	0	0	0
LPKZ1-3	2	TA	0	0	0	0	0	0	0
LPKZ1-6	2	TA	0	0	0	0	0	0	0
LPKZ1-7	2	TA	0	0	0	0	0	0	0
LPKZ1-9	3	FE	CO	10	1	2	2	6	11
LPKZ1-11	2	MT	CO	10	0	0	0	0	0
LPKZ2-1	3	PE	0	0	0	0	0	0	9

SPEC#	SZ	SKE	LBF	SPEC.SZ	PX	DS	NE	MS	SUM
LPKZ2-2	3	UL	CO	10	1	0	0	7	8
LPKZ2-3	3	RA	CO	10	0	1	0	0	1
LPKZ2-4	3	FE	CO	10	6	4	0	0	10
LPKZ3-1	3	HU	CO	10	3	0	0	1	4
LPKZ3-2	3	RA	CO	10	0	1	0	0	1
LPKZ3-3	3	UL	CO	10	0	0	0	0	0
LPKZ3-4	3	PE	0	0	0	0	0	0	32
LPKZ4-1	3	UL	CO	10	2	3	2	0	7
LPKZ4-2	3	RA	CO	10	0	2	2	0	4
LPKZ4-3	3	FE	CO	10	1	0	0	0	1
LPKZ4-4	3	FE	CO	10	2	5	3	0	10
AJJZ1-1	3	FE	CO	10	8	13	2	0	23
AJJZ1-2	3	FE	CO	10	1	1	3	12	17
AJSL1-1	3	UL	CO	10	0	0	0	0	0
AJSL1-2	3	UL	CO	10	0	0	0	0	0
AJSL1-3	3	RA	CO	10	0	0	0	0	0
AJSL1-4	3	RA	CO	10	0	0	0	0	0
AJSL1-5	3	HU	CO	10	1	0	0	0	1
AJSL1-6	3	HU	CO	10	4	0	0	0	4
AJSL1-7	3	HU	CO	10	3	0	0	2	5

Appendix 3. Data table for the number of tooth marks by tooth mark type, bone size, and skeletal element.

SPEC#	SZ	SKE	SCR	PI	PU	FU	GG	SUM
PTKZ1-1	2	SC	3	1	3	0	1	8
PTKZ1-10	2	TA	0	1	0	0	0	1
PTKZ1-11	2	PE	0	0	0	0	0	0
PTKZ1-2	2	MT	2	3	0	0	0	5
PTKZ1-3	2	FE	10	0	20	7	0	37
PTKZ1-4	2	RA	4	3	0	0	0	7
PTKZ1-5	2	UL	1	0	0	0	0	1
PTKZ1-7	2	TA	0	0	0	0	0	0
PTKZ1-8	2	TA	0	0	0	0	0	0
PTKZ1-9	2	TA	0	0	1	0	0	1
PTKZ2-1	2	UL	0	0	0	0	0	0
PTKZ2-10	2	CA	0	0	0	0	0	0
PTKZ2-11	2	CA	0	0	0	0	0	0
PTKZ2-12	2	CA	0	0	0	0	0	0
PTKZ2-2	2	RA	0	0	0	0	0	0
PTKZ2-3	2	FE	1	0	0	0	0	1
PTKZ2-4	2	TI	1	0	2	0	0	3
PTKZ2-5	2	MC	0	0	0	0	0	0
PTKZ2-6	3	FE	2	0	0	0	0	2
PTKZ2-7	2	SC	0	0	2	0	1	3
PTKZ2-8	2	CA	0	0	0	0	0	0
PTKZ2-9	2	CA	0	0	0	0	0	0
PTKZ3-1	3	HU	0	0	2	0	0	2
PTKZ3-2	3	UL	0	1	0	0	0	1
PTKZ3-3	3	RA	0	0	0	0	0	0
PTKZ3-4	3	FE	5	0	1	0	0	6
PTKZ3-5	3	RA	0	0	0	0	0	0
PTKZ3-6	3	UL	0	1	0	0	0	1
PTKZ3-7	3	UL	0	0	0	0	0	0
PTKZ3-8	3	RA	1	1	0	0	0	2
PTKZ4-1	3	UL	1	1	0	0	0	2
PTKZ4-2	3	FE	1	0	3	0	0	4
PTKZ4-3	3	HU	0	0	0	0	0	0
PTKZ4-4	3	FE	1	0	2	0	0	3
PTKZ4-5	3	UL	0	0	0	0	0	0
PTKZ4-6	3	RA	0	1	0	0	0	1

SPEC#	SZ	SKE	SCR	PI	PU	FU	GG	SUM
PTKZ4-7	3	RA	0	0	0	0	0	0
PTKZ5-1	3	PE	0	0	0	0	0	0
PTKZ5-2	3	HU	0	1	0	0	0	1
PTKZ5-3	3	RA	0	2	1	0	0	3
PTKZ5-4	3	UL	0	0	0	0	0	0
PTKZ5-5	3	FE	0	0	0	0	0	0
PTKZ5-6	3	HU	0	2	0	0	0	2
PTLR1-1	2	MC	0	0	1	0	0	1
PTLR1-10	2	CA	0	0	0	0	0	0
PTLR1-11	2	CA	0	0	0	0	0	0
PTLR1-12	2	CA	0	0	0	0	0	0
PTLR1-2	2	UL	0	0	0	0	0	0
PTLR1-3	2	RA	0	0	0	0	0	0
PTLR1-4	2	SC	1	0	4	0	2	7
PTLR1-5	2	SC	0	0	0	0	1	1
PTLR1-6	3	FE	1	0	0	0	0	1
PTLR1-7	3	PE	1	0	0	0	0	1
PTLR1-8	2	CA	0	0	0	0	0	0
PTLR1-9	2	CA	0	0	1	0	0	1
PTLR2-2	2	RA	0	0	0	0	0	0
PTLR2-1	2	UL	0	0	0	0	0	0
PTLR2-11	2	CA	0	0	0	0	0	0
PTLR2-12	2	CA	0	0	0	0	0	0
PTLR2-13	2	CA	0	0	0	0	0	0
PTLR2-14	2	CA	0	0	0	0	0	0
PTLR2-15	2	CA	0	0	0	0	0	0
PTLR2-16	2	CA	0	0	0	0	0	0
PTLR2-17	2	CA	0	0	0	0	0	0
PTLR2-18	2	CA	0	0	0	0	0	0
PTLR2-19	2	CA	0	0	0	0	0	0
PTLR2-20	2	CA	0	0	0	0	0	0
PTLR2-3	2	UL	1	1	1	0	0	3
PTLR2-4	2	RA	0	0	0	0	0	0
PTLR2-5	2	MC	0	0	0	0	1	1
PTLR2-6	2	MC	1	7	0	0	1	9
PTLR2-7	2	PE	0	0	3	0	1	4
PTLR2-8	2	PE	0	0	0	0	0	0
PTLR2-9	3	FE	1	1	0	0	0	2

SPEC#	SZ	SKE	SCR	PI	PU	FU	GG	SUM
PTLR3-1	3	FE	0	0	2	0	0	2
PTLR3-10	2	TA	0	0	0	0	0	0
PTLR3-11	2	TA	0	0	0	0	0	0
PTLR3-12	2	TA	0	0	0	0	0	0
PTLR3-13	2	TA	0	0	0	0	0	0
PTLR3-14	2	TA	0	0	0	0	0	0
PTLR3-15	2	TA	0	0	0	0	0	0
PTLR3-16	2	TA	0	0	0	0	0	0
PTLR3-17	2	TA	0	0	0	0	0	0
PTLR3-18	2	TA	0	0	0	0	0	0
PTLR3-19	2	PHL	0	0	0	0	0	0
PTLR3-2	3	FE	0	0	0	0	0	0
PTLR3-20	2	PHL	0	0	0	0	0	0
PTLR3-21	2	PHL	0	0	0	0	0	0
PTLR3-22	2	PHL	1	0	0	0	0	1
PTLR3-23	2	PHL	0	0	0	0	0	0
PTLR3-24	2	PHL	0	0	0	0	0	0
PTLR3-25	2	TA	0	0	0	0	0	0
PTLR3-28	2	TA	0	0	0	0	0	0
PTLR3-29	2	TA	0	0	0	0	0	0
PTLR3-3	2	MT	0	0	0	0	0	0
PTLR3-4	2	MT	3	0	0	0	0	3
PTLR3-5	2	MT	0	0	0	0	0	0
PTLR3-6a	2	SC	4	8	0	0	0	12
PTLR3-6b	2	SC	0	0	0	0	0	0
PTLR3-6c	2	SC	0	0	0	0	0	0
PTLR3-6d	2	SC	0	0	0	0	0	0
PTLR3-6e	2	SC	0	0	0	0	0	0
PTLR3-6h	2	SC	0	0	0	0	0	0
PTLR4-1	3	FE	2	5	0	0	1	8
PTLR4-10	2	CA	0	0	0	0	0	0
PTLR4-11	2	CA	0	0	0	0	0	0
PTLR4-12	2	CA	0	0	0	0	0	0
PTLR4-13	2	CA	0	0	0	0	0	0
PTLR4-2	2	SC	0	5	0	0	0	5
PTLR4-3	2	MC	1	4	0	0	1	6
PTLR4-4	2	UL	0	0	0	0	0	0
PTLR4-5	2	RA	0	0	0	0	0	0
PTLR4-6	2	PE	0	0	0	0	0	0

SPEC#	SZ	SKE	SCR	PI	PU	FU	GG	SUM
PTLR4-7	3	FE	2	0	0	0	0	2
PTLR4-9	2	CA	0	0	0	0	0	0
PTSL1-1	2	TI	0	0	0	0	0	0
PTSL1-2	2	TI	0	0	0	0	0	0
PTSL1-3	2	SC	0	0	0	0	0	0
PTSL1-4	2	PE	1	1	0	0	0	2
PTSL1-5	2	FE	1	2	7	0	0	10
PTSL1-6	2	TI	4	0	0	0	0	4
PTSL2-1	2	PE	0	0	0	0	0	0
PTSL2-2	2	PE	0	0	0	0	0	0
PTSL2-3	2	FE	0	0	0	0	0	0
PTSL2-4	2	FE	0	0	0	0	0	0
PTSL2-5	3	FE	0	0	0	0	0	0
PTSL2-6	2	TI	0	0	0	0	0	0
PTSL3-1	2	FE	2	0	0	0	0	2
PTSL3-2	2	TI	0	0	0	0	0	0
PTSL3-3	2	TI	0	2	0	0	0	2
PTSL3-4	2	SC	0	0	0	0	0	0
PTSL3-5	3	FE	0	0	0	0	0	0
PLKZ1-1	3	FE	0	0	2	2	0	4
PLKZ1-2a	3	UL	2	7	1	0	1	11
PLKZ1-2b	3	UL	0	0	0	0	0	0
PLKZ1-2c	3	UL	0	6	0	0	0	6
PLKZ1-2d	3	UL	2	0	0	0	0	2
PLKZ1-2e	3	UL	2	0	0	0	0	2
PLKZ1-2f	3	UL	0	3	0	0	0	3
PLKZ1-2g	3	UL	1	1	0	0	0	2
PLKZ1-3a	2	PE	1	8	1	1	0	11
PLKZ1-3b	2	PE	0	0	0	0	0	0
PLKZ1-4a	3	RA	0	2	0	0	0	2
PLKZ1-4c	3	RA	1	2	0	0	0	3
PLKZ1-4d	3	RA	0	2	0	0	0	2
PLKZ1-4e	3	RA	0	0	0	0	0	0
PLKZ1-4f	3	RA	0	0	0	0	0	0
PLKZ1-4g	3	RA	0	0	0	0	0	0
PLKZ1-4h	3	RA	0	1	0	0	0	1
PLKZ1-4i	3	RA	0	1	0	0	0	1
PLKZ1-4j	3	RA	0	0	0	0	0	0
PLKZ1-4l	3	RA	0	0	0	0	0	0

SPEC#	SZ	SKE	SCR	PI	PU	FU	GG	SUM
PLKZ1-5a	3	FE	1	4	0	0	0	5
PLKZ1-5f	3	FE	1	0	0	0	0	1
PLKZ1-6a	3	UL	2	4	0	0	0	6
PLKZ1-6b	3	UL	0	0	0	0	0	0
PLKZ1-6c	3	UL	1	0	0	0	0	1
PLKZ1-6d	3	UL	0	1	0	0	0	1
PLKZ1-7a	2	MC	0	1	0	0	1	2
PLKZ1-7b	2	MC	0	0	0	0	0	0
PLKZ1-7c	2	MC	0	0	0	0	0	0
PLKZ1-8a	3	RA	0	0	0	0	0	0
PLKZ1-8b	3	RA	0	0	0	0	0	0
PLKZ2-1a	3	PE	6	1	5	0	3	15
PLKZ2-1b	3	PE	0	0	0	0	0	0
PLKZ2-1c	3	PE	0	0	0	0	0	0
PLKZ2-1d	3	PE	0	0	0	0	0	0
PLKZ2-1e	3	PE	1	0	0	0	0	1
PLKZ2-1f	3	PE	0	0	0	0	0	0
PLKZ2-2a	3	FE	4	1	3	1	1	10
PLKZ2-2b	3	FE	0	0	0	0	0	0
PLKZ2-2c	3	FE	0	0	0	0	0	0
PLKZ2-2d	3	FE	0	1	0	0	0	1
PLKZ2-2f	3	FE	0	0	0	0	0	0
PLKZ2-2g	3	FE	0	0	1	0	0	1
PLKZ2-3a	3	HU	3	6	3	1	0	13
PLKZ2-3b	3	HU	0	1	0	0	0	1
PLKZ2-3c	3	HU	1	0	0	0	0	1
PLKZ2-3e	3	HU	0	0	0	0	0	0
PLKZ2-3f	3	HU	0	0	0	0	0	0
PLKZ2-4	3	SC	2	11	1	2	1	17
PLKZ2-5	3	UL	6	5	0	3	1	15
PLKZ2-6a	3	RA	0	0	0	0	0	0
PLKZ2-6b	3	RA	1	8	0	1	0	10
PLKZ2-6c	3	RA	0	0	2	0	0	2
PLKZ2-7	3	FE	3	7	5	0	2	17
PLKZ3-1	3	HU	4	9	11	3	0	27
PLKZ3-2a	3	FE	6	0	8	0	1	15
PLKZ3-2c	3	FE	0	1	0	0	0	1
PLKZ3-2i	3	FE	0	0	0	0	0	0
PLKZ3-2j	3	FE	0	0	0	0	0	0

SPEC#	SZ	SKE	SCR	PI	PU	FU	GG	SUM
PLKZ3-2k	3	FE	0	0	0	1	0	1
PLKZ3-2l	3	FE	0	0	0	0	0	0
PLKZ3-2m	3	FE	0	0	0	0	0	0
PLKZ3-2n	3	FE	0	0	1	0	0	1
PLKZ3-2p	3	FE	0	0	0	0	0	0
PLKZ3-2r	3	FE	1	0	0	0	0	1
PLKZ3-2s	3	FE	0	1	0	0	0	1
PLKZ3-2t	3	FE	0	2	0	0	0	2
PLKZ3-2u	3	FE	0	2	1	0	0	3
PLKZ3-2v	3	FE	1	2	0	0	0	3
PLKZ3-2w	3	FE	2	3	0	0	0	5
PLKZ3-2x	3	FE	0	0	0	1	0	1
PLKZ3-2y	3	FE	1	2	5	0	0	8
PLKZ3-2z	3	FE	0	0	0	1	1	2
PLKZ3-3	3	FE	2	4	6	1	2	15
PLKZ3-4a	3	HU	11	0	2	0	0	13
PLKZ3-4d	3	HU	2	0	0	0	0	2
PLKZ3-4e	3	HU	0	0	0	0	0	0
PLKZ3-4f	3	HU	0	0	0	0	0	0
PLKZ3-5	3	UL	1	6	0	0	1	8
PLKZ3-6	3	RA	3	6	0	1	0	10
PLSL1-1	3	UL	2	8	1	0	2	13
PLSL1-2	3	RA	3	5	0	4	0	12
PLSL1-3a	3	FE	4	7	0	0	0	11
PLSL1-3b	3	FE	0	1	0	0	0	1
PLSL1-4	3	RA	0	0	0	0	1	1
PLSL1-5a	3	HU	0	8	2	2	1	13
PLSL1-5b	3	HU	4	0	3	1	0	8
PLSL1-5c	3	HU	0	0	0	1	0	1
PLSL1-5d	3	HU	0	0	0	0	0	0
PLSL1-6a	3	FE	1	0	8	1	0	10
PLSL1-6b	3	FE	12	11	1	0	2	26
PLSL1-8	3	UL	4	12	1	2	1	20
HHKZ1-1	2	SC	0	6	0	0	2	8
HHKZ1-2	2	MC	0	2	0	0	1	3
HHKZ1-3	2	UL	0	0	1	0	1	2
HHKZ1-4	2	RA	0	0	1	0	1	2
HHKZ1-5	2	FE	6	1	1	1	1	10
HHKZ1-6	2	CA	0	0	0	0	0	0

SPEC#	SZ	SKE	SCR	PI	PU	FU	GG	SUM
HHKZ1-7	2	CA	0	0	0	0	0	0
HHKZ1-9	2	CA	0	0	0	0	0	0
HHKZ1-10	2	CA	0	0	0	0	0	0
HHKZ1-11	2	CA	0	0	0	0	0	0
HHKZ2-1a	3	FE	0	0	0	0	0	0
HHKZ2-1b	3	FE	1	0	0	0	0	1
HHKZ2-1c	3	FE	1	0	0	0	0	1
HHKZ2-1d	3	FE	1	0	0	0	0	1
HHKZ2-1e	3	FE	2	5	0	0	0	7
HHKZ2-1f	3	FE	2	0	0	0	0	2
HHKZ2-1g	3	FE	0	0	0	0	0	0
HHKZ2-1h	3	FE	0	0	0	0	0	0
HHKZ2-1j	3	FE	0	0	0	0	0	0
HHKZ2-2	2	PE	0	0	1	0	2	3
HHKZ2-3	2	TA	1	0	0	0	0	1
HHKZ2-4	2	TA	0	0	0	0	0	0
HHKZ2-5	2	TA	2	0	0	0	0	2
HHKZ2-6	2	TA	0	1	0	0	0	1
HHKZ2-8	2	MT	0	0	0	0	0	0
HHKZ3-1	3	HU	0	0	0	0	1	1
HHKZ3-2	3	HU	4	0	1	0	1	6
HHKZ3-3	3	HU	3	24	0	0	1	28
LPKZ1-11	2	MT	0	0	0	0	0	0
LPKZ1-1a	2	SC	3	2	6	0	1	12
LPKZ1-1b	2	SC	0	0	0	0	0	0
LPKZ1-1c	2	SC	1	0	0	0	0	1
LPKZ1-1d	2	SC	0	0	0	0	0	0
LPKZ1-2	2	TA	0	0	0	0	0	0
LPKZ1-3	2	TA	0	0	0	0	0	0
LPKZ1-6	2	TA	0	0	0	0	0	0
LPKZ1-7	2	TA	0	0	0	0	0	0
LPKZ1-9	3	FE	10	1	0	0	0	11
LPKZ2-1	3	PE	6	0	2	0	1	9
LPKZ2-2	3	UL	7	1	0	0	0	8
LPKZ2-3	3	RA	1	0	0	0	0	1
LPKZ2-4	3	FE	1	4	0	5	0	10
LPKZ3-1	3	HU	3	0	0	1	0	4
LPKZ3-2	3	RA	1	0	0	0	0	1
LPKZ3-3	3	UL	0	0	0	0	0	0

SPEC#	SZ	SKE	SCR	PI	PU	FU	GG	SUM
LPKZ3-4	3	PE	7	13	10	0	2	32
LPKZ4-1	3	UL	0	5	0	2	0	7
LPKZ4-2	3	RA	2	2	0	0	0	4
LPKZ4-3	3	FE	0	0	1	0	0	1
LPKZ4-4	3	FE	1	2	3	4	0	10
AJJZ1-1	3	FE	2	12	1	7	1	23
AJJZ1-2	3	FE	15	0	0	0	2	17
AJSL1-5	3	HU	0	0	0	0	1	1
AJSL1-6	3	HU	0	0	4	0	0	4
AJSL1-7	3	HU	2	2	0	1	0	5
AJSL1-3	3	RA	0	0	0	0	0	0
AJSL1-4	3	RA	0	0	0	0	0	0
AJSL1-1	3	UL	0	0	0	0	0	0
AJSL1-2	3	UL	0	0	0	0	0	0

Vita

Kimberly Anne Dingess was born in Huntington, West Virginia on January 23, 1968. She attended the Cabell County public school system in Huntington, West Virginia, graduating from Huntington East High School in the spring of 1986. She received a Bachelor of Arts degree with honors in Anthropology from Marshall University in December of 1992. After a year in the real world, she eagerly entered the graduate program at the University of Tennessee, Knoxville, officially receiving a Master of Arts degree in Anthropology in May of 1998.