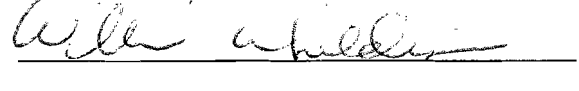
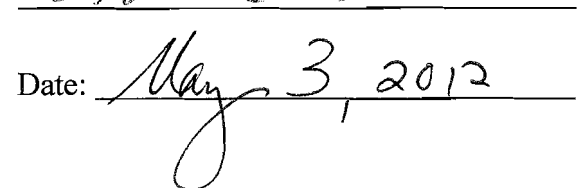


ANALYSIS OF EXPERIMENTAL WOOD CHIPPER TRAUMA ON BONE

by

Kenneth Domenick
A Thesis
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Master of Science
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Spring Semester 2012
George Mason University
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DEDICATION

This is dedicated to my wife Andrea, who has put up with all of the “disgusting” smells associated with this thesis and listening to me talk about the “weirdness” of the cases. This is also dedicated to my parents, Mike and Cherl Domenick, who from a young age, have encouraged and supported me to get all of the “smarts” and “sheep’s hide” that I can. Cheers!

ACKNOWLEDGEMENTS

I would like to thank the many friends, relatives, and supporters who have made this happen. I will not begin to try to name them all for fear that would forget one and they would not want to help me later because I forgot to mention them-most especially those who took days out of their lives to read this thesis and give me feedback and suggestions.

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LIST OF ABBREVIATIONS

American Academy of Forensic Science	AAFS
Blunt Force Trauma	BFT
High Velocity Projectile	HVP
Knife Cut Wound.....	KCW
Knife Stab wound	KSW
Sharp Force Trauma.....	SFT
Scanning Electron Microscope	SEM
Deoxyribonucleic Acid	DNA

ABSTRACT

Analysis of Experimental Wood Chipper Trauma on Bone

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George Mason University, 2012

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In the literature and research relating to human corpse dismemberment and mutilation, there are few studies focusing on wood chipper induced trauma. Most of what is known about wood chipper trauma is based on a handful of documented cases in which wood chippers were used for dismemberment. In pop culture media such as movies, television, and the internet, body disposal via wood chipper is portrayed as a quick and effective method of getting rid of a body and eliminating evidence while avoiding detection. This thesis addresses these shortcomings by providing thorough case reviews and a preliminary study on wood chipper induced trauma. Several case studies are analyzed in which wood chippers were used in criminal cases to dispose of bodies. From these we learn that when wood chippers are used to dispose of human remains and that small potentially difficult to recover bone fragments are produced. Furthermore, a laboratory experiment was designed to test the trauma produced when domestic pig (*Sus scrofa*) limbs were inserted into a home model wood chipper. Results show that bone fragment sizes range from 45 mm to less than 1 mm. Many of the larger fragments have one or

two cuts with those cuts creating fragments with consistent diameters. This wood chipper also produced bone alterations including square, V-shaped, and W-shaped kerfs that were dissimilar to other types of sharp force trauma. Some of these defects may be class characteristics associated with this model of wood chipper while others may be individual characteristics due to wear-related defects of the specific wood chipper used. This thesis will assist the forensic community by providing information regarding trauma that can be expected to be observed following dismemberment via wood chipper thereby facilitating event reconstruction, victim identification, and conviction of perpetrators.

CHAPTER ONE- INTRODUCTION

In 1986, Richard Crafts murdered, froze, and dismembered his wife, Helle. A short time after the investigation into the disappearance of Helle began, a team of investigators, with the assistance of forensic scientists, began to recover human remains from a site believed to be where Richard had disposed of Helle's body. The investigators believed that the remains were those of Helle, and based on eyewitness testimony, believed the remains were dismembered using a chain saw and commercial wood chipper.

This case highlights a knowledge gap in the scientific community. How might one determine whether human remains were indeed dismembered using a wood chipper in an attempt to dispose of the evidence and cover up illegal activities or destroy features that could lead to the identification of the deceased? Recent scientific and medical literature contains a plethora of research on various types of skeletal trauma including blunt force (Weatley, 2008, Moraitis & Spiliopoulou, 2006, Wieberg & Wescott, 2008, Ta'ala, Berg, & Haden, 2006, Jacobsen, Bech, & Lynnerup, 2009) high velocity projectile (DeFreminville, Prat, Rongieras, & Voiglio, 2010, Langley, 2007, Quatrehomme & Iscan, 1999, Ubelaker, 1996, Symes & Francisco, 1993) thermal (Campbell & Fairgrieve, 2011, Ubelaker, 2009, Blau & Briggs, 2011), and various sharp force traumas such as knife mark (Shaw et al., 2011, Freas, 2010,) and saw marks

(Symes, Chapman, Rainwater, Cabo, & Myster, 2010) as well as mixtures of the above (Ambade & Godbole, 2003, Fischer, Kleeman, & Troger, 1994, Komar & Lathrop, 2012, Marciniak, 2009,). Even more rarely encountered types of trauma such as blast trauma (Christensen, Smith, Ramos, Shegogue, & Whiteworth, 2011, Trimbel & Clasper, 2001, Hull, Bowyer, Cooper & Crane, 1994, Hull, 1992, Crabtree, 2006) have received some attention in recent published literature. Notably, however, there is little research in reference to wood chipper induced trauma. What is known about wood chipper trauma is primarily based on two case reviews and a few published studies. These studies, however, did not focus on tool marks or fracture patterns on bone, but on the size of fragments produced during the dismemberment.

This thesis catalogues trauma on bone, specifically the resulting tool marks and fracture patterns caused by wood chippers through case study reviews, background research on wood chipper trauma, how wood chippers work, and an experimental test using domestic pig (*Sus scrofa*) limbs. The results of this study may assist forensic scientists and investigators by detailing various wood chipper traumas and skeletal alterations so that a wood chipper may potentially be identified as the source of trauma in cases where the source may be unknown.

Media Coverage

The media is ubiquitous in today's society and the internet is a common tool used for research. A Google query on "how to dispose of human remains quickly without detection" yielded approximately 8,400,000 sites. When "wood chipper" is added to that query, 5670 web sites were found. On the internet, using a wood chipper appears to be

known as an effective and quick method to cover up a crime and dispose of unwanted remains and evidence. What's more, wood chippers are easily accessible at the local hardware store, department store, or home improvement center for rental or purchase at relatively little cost.

The fascination with the wood chipper disposal method is continually fueled by other pop culture media of today. In an entertainment media article discussing the top ten ways to get rid of bodies in movies, the number one method was a wood chipper (Sonnixsen, 2010). The most well-known movie in which a wood chipper was used to dispose of human remains was Joel and Ethan Coens' *Fargo* (1996). In the movie, the financially troubled Jerry Lundegaard hires two criminals, Carl and Gaear from Fargo, North Dakota, to kidnap his wife Jean for ransom money in order to take care of his financial obligations. While en route to the hideout, a state trooper and two teenaged kids are killed by the kidnappers, launching an investigation by the local sheriff. A change in plans for the pickup of the ransom money leaves Jerry's father-in-law, who is paying the ransom, as well as the mechanic at the car lot where Jerry and his father-in-law work, dead. Carl ends up with \$1 million instead of the arranged \$80,000 after the murders. Carl buries all but the original amount of ransom money along the side of the road and returns to the hide out. Upon his return he finds that Gaear has killed Jean. Following a dispute, Gaear kills Carl with an ax and is in the act of putting his body through a wood chipper when the sheriff arrives at the hideout and shoots him as he tries to flee. The Coehn brothers reveal in the special feature DVD that partial inspiration for the movie did indeed come from the murder case of Helle Crafts (*IMDB*).

A lesser known movie, *The Wood Chipper Massacre*, also features remains being disposed of with a wood chipper (1989). Three kids are being watched by their dictator aunt while their father is away on business. During her stay, the aunt gets into a fight with one of the kids and is killed. The kids dismember her, put her in a freezer, then later take her out and put her through a wood chipper. Later in the movie, the aunt's son comes looking for her and he too is pushed into the wood chipper by one of the teenagers. In this movie, the kids get away with both murders (Woodchipper Massacre).

The wood chipper disposal method is still portrayed today in a variety of television crime series with episodes of *Bones* (2006), *CSI* (2004), and *CSI-Miami* (2009) each featuring victims being dismembered with a wood chipper. Even the Australian TV crime series *The Strip* (2008) and Linda LaPlantes' *Trial and Retribution* (2002), airing in the UK, have episodes featuring a body being disposed of with a wood chipper. These popular TV series lend validity to the possibility that victims can be disposed of with wood chippers and the perpetrators can sometimes get away with their crimes. In these crime scene shows, it is portrayed that through detailed and thorough investigations, along with keen forensic analysis, details of the crimes were still discovered and the perpetrator's crimes were uncovered. In real life, this may not be the case. Speaking with Detective M. Grimsley, of the Loudon County VA. Sheriff's department (personal communication, 25 February 2012), it is possible that many people dispose of remains using a wood chipper more often than is known because what is left after chipping would likely be difficult to find, especially if the dump site were not known.

Scientific Studies on Wood Chipper Trauma

Following the Helle Crafts murder case and the media spike in the wood chipper disposal method, one might expect the research on wood chipper trauma to increase in an attempt to assist forensic scientists in future cases that may involve wood chippers. This, however, is not the case. Only a handful of subsequent studies dealing with wood chipper trauma in the forensic field were conducted. Dr. John A. Williams presented his findings at the annual meeting of the American Academy of Forensic Science (AAFS) on size fragmentation of mechanical chippers versus shredders settings on a wood chipper and observations of which function made the chips based on size of bone fragments recovered (Williams, 2007). The Centers for Disease Control and Prevention published a report in *The Journal of the American Medical Association*, reporting the number of fatal and non-fatal wood chipper workforce accidents between 1992 and 2002 (Struttmann, 2004). In the *Journal of Forensic Identification*, Beers and Allen (2007) reported on the identification processes taken when a worker was accidentally pulled through a commercial wood chipper. This study focused on cataloguing the remains recovered and using intact fingerprints from the remains to make a positive identification of the individual. Little information on the trauma to bones was reported in this publication. Finally, during the murder investigation of Helle Crafts, Dr. Henry Lee conducted a study to confirm that the size of the bone fragments recovered were consistent with the size of bone fragments of a pig carcass which was inserted into a wood chipper similar to the one used by Richard to dispose of Helle.

This lack of research in relation to wood chipper trauma as a means of dismemberment and disposal is a strong contributing factor for the undertaking of this

thesis. The next few chapters will provide detailed additional background information including case studies, wood chipper function, and skeletal trauma studies in order to contextualize the experiments conducted.

CHAPTER TWO- WOOD CHIPPER CASE STUDIES

Case studies are used in the forensic field to focus on a specific event and provide a detailed analysis of that event and the evidence surrounding it. Case studies can be explanatory or descriptive in nature. Explanatory studies are used to find underlying principles or the cause of something, while descriptive case studies provide detailed summaries of past or current cases. In either instance, case studies serve to exchange information between fellow forensic investigators to strengthen the community's understanding of certain events or principles. Several case studies in which wood chippers were used, or were suspected of having been used, in the dismemberment and disposal of remains and evidence are summarized below.

Helle Crafts

In the late summer of 1986, Helle Crafts retained the services of a divorce lawyer to start divorce proceedings against her husband, Richard. Both Richard and Helle worked for the airlines, Richard as a pilot and Helle as a flight attendant. Richard also worked part time at the local police department as a constable. In October of 1986, Helle announced to Richard that she was filing for divorce. On November 10th, Richard ordered a dump truck from the local dealer and requested a pintle hook, a hitch used to pull heavy machinery, be installed. Richard also inquired about a large wood chipper, and on November 14th reserved one from the local rental store which would be available

on the 18th. Due to complications with the dump truck, it was not ready for pickup on the scheduled day, forcing Richard to pay additional money to hold the wood chipper (Lee & O'niel, 2002 Herzog, 2001).

On November 13th, Richard purchased a large chest freezer which he picked up on the 17th, never giving the sales person his name, only "Mr. Cash". When the power would unexpectedly go out a few days later, Richard claimed that the purchase of this freezer was to replace the freezer that family currently owned that the power outage caused to malfunction. The same day he purchased the freezer, he dove to New York to purchase a flat shovel and a pair of fire proof gloves.

Helle Crafts was last seen on November 18th, 1986 when she was dropped off at home by a friend after returning from a trip to Hamburg, Germany. The family's nanny arrived at home around 2 a.m. the next morning and a few hours later the power unexpectedly went out after a storm. The nanny took the Crafts' children to a family member living a few hours away while Richard remained at home. This was interesting to the family and others because Richard had a backup generator that would accommodate situations like this and Richard had trained for this type of emergency during his service in the military. Power was returned by mid-morning although Richard claimed that the power was still off at mid-afternoon (Lee & O'niel, 2002, Herzog, 2001).

On November 20th, after still having issues with the dump truck, Crafts rented a Ford U-Haul truck to tow the wood chipper. The nanny and children had returned by this time. Crafts was seen driving the U-Haul and wood chipper around town that day. That night, the nanny remained at home while Richard worked his 10 p.m. to 2 a.m. shift at the

police station. At 7 p.m. a witness saw a U-Haul with a wood chipper behind it chipping “wood” over a bridge. The witness distinctly remembered the day because it was snowing, and the 20th through the 21st were the only days it had snowed in awhile or would snow for a few weeks. When Richard returned the wood chipper on the 21st, the sales associate at the rental store noticed a couple of piles of wood chips and plastic or cloth bags with something in them, as well as a Stihl chainsaw in the back of the U-Haul (Lee & O’niel, 2002 Herzog, 2001).

When asked regarding the whereabouts of Helle, Richard would tell friends and family she was in Denmark with her sick mother, or that she left him and the children, or even that they would see her when they arrived at their destination. After two weeks of not hearing from Helle, many of Helle’s friends became worried and began phoning the police asking them to investigate. Over a month after Helle was last seen, the investigation finally began. Searches were conducted of the home and a property that the couple owned outside of town as well as their vehicles. Small traces of blood were discovered at the home. During the investigation, it was discovered that Richard had rented the U-Haul and wood chipper, and that one eyewitness had seen the truck and chipper on the bridge. A search was conducted at that location as well (Lee & O’niel, 2002 Herzog, 2001).

Among the evidence recovered during the investigation near the bridge were 69 human bone fragments, two teeth, and a piece of skull. The Stihl chainsaw Richard had recently purchased was recovered from the river. Hairs were recovered from the ground and from the chainsaw. Mail addressed to Helle was recovered from the bank as well,

and this was significant because Richard claimed that no mail had arrived for her since before she returned from Germany. Dental records were examined and the teeth were confirmed as having belonged to Helle. DNA analysis was conducted on hairs recovered and confirmed that the hair was Helle's (Lee & O'niel, 2002 Herzog, 2001).

Following the arrest of Richard for the murder of his wife, Dr. Henry C. Lee, one of the forensic investigators in the murder case, conducted an experiment. His experiment was designed to answer questions that could be asked by the defense at trial concerning the size of bone fragments recovered at the river bank. In his experiment, he and his associates put a 47 pound pig through a wood chipper similar to the one used to dispose of the remains of Helle. They found that the particle size, shape and pattern of the test subject fragments were consistent with the size, shape and pattern of evidence fragments recovered (Lee & O'niel, 2002 Herzog, 2001).

It appears that Richard planned the murder and disposal of Helle's body well, but not perfectly. He rented a wood chipper, which he suspected would do an effective job of getting rid of the remains, and disposed of the remains in an area which would make finding evidence difficult. He purchased equipment to prepare the body for disposal: a chainsaw for dismemberment, a freezer to store the remains until the opportune moment, and the dump truck to pull the wood chipper to a secluded spot to dispose of the chipped remains.

He failed, however, to take a few things into account. First, Helle's friends became concerned and initiated investigations revealing that Richard's accounts of Helle's whereabouts were inaccurate. Some would explain his stories as a cover-up for

the ensuing divorce, but the stories were so numerous that there were differences each time he told it. Second, the unexpected delays with the dump truck forced him to have to use a U-Haul to haul the wood chipper which was much more conspicuous. Third, the snow storm arrived at an inopportune time making the timing of events much more unforgettable to witnesses. Fourth, Richard over-estimated his friendships at the police department. He assumed that because the police knew him, they would not suspect him as having anything to do with the disappearance of Helle. Lastly, he underestimated the strength of forensic science.

Robert William Pickton

Prostitutes began disappearing in 1988 around British Columbia. Due largely to their line of work and their lack of social ties and limited family relationships, their disappearance often went unnoticed for long periods of time and no investigations into their disappearance were initially conducted. When families of the women eventually began to become concerned after long periods without contact, missing persons reports were initiated, but no investigations were conducted.

Around this time, there were two reports of women having been brutally assaulted at the farm of Robert William “Willie” Pickton, a pig farmer near Vancouver (Cameron, 2010, Culbert, 2007, Krauss, 2002). Reports were filed, but again no investigations were conducted because of the line of work of the women. After additional reports noted items belonging to missing women had been seen at the farm, Pickton became a suspect and investigations began at his farm in February 2002 into a charge unrelated to the disappearance of the women.

During the searches at the pig farm, investigators uncovered the head, hands and feet of three women including skin and identifying features, two partial lower jaw bones with teeth from two different women, 14 hand bones that appeared to have been cut with a knife, and a heel and rib bone that DNA matched to a partial skull found years earlier in a swamp near the farm (Culbert, 2007). In all, various remains of six different women were recovered during the initial investigation. It was alleged that after women were killed, their bodies were dismembered, inserted into the wood chipper on the farm, and the remains fed to the pigs, made into sausage produced at the farm, or consumed by Robert himself to get rid of evidence. An undisclosed number of bone fragments were also recovered from the wood chipper. DNA, dental records, and fingerprints were used to identify the recovered remains and bone fragments, as well as other remains found at the farm.

Willie Pickton chose victims that he thought would not be missed by anyone and believed that his crimes would never come to light. Evidence of his activities and of the victims' identities, however, was still recovered years after the crimes were committed.

Other Criminal Cases

At least two other criminal cases have involved, or have been suspected of involving, wood chippers to dispose of remains, but with fewer available details. In August of 1994, Michele Roger murdered her boyfriend David A. Richmond, burned his remains, and upon discovering that the remains were not sufficiently destroyed, put what was left through a wood chipper. It was reported to investigators that the remains were then mixed with concrete and disposed of. These concrete blocks have not been

discovered and there were no bone fragments or other remains discovered to examine (Stutzman, 1998, Taylor, 1994, Sanford, 1993).

More recently, 10-year-old Zahra Baker disappeared from her home in Hickory, N.C. During the investigation, cadaver dogs “hit” on the wood chipper and a few piles of chipped wood as possibly containing human remains. Later, dismembered remains were recovered that were confirmed as Zahra’s, including bone fragments. Few additional details have been released as the case is very recent, court proceedings are still pending, and investigations into the case are still ongoing (DeNies & Ferran, 2010, Schabner & Ferran, 2010).

These cases demonstrate that wood chippers continue to be used as a method for dismemberment and disposal of remains. Additional research on the subject of trauma created by wood chippers may be very beneficial in identifying fragments recovered during criminal investigations and reconstructing events surrounding these crimes.

CHAPTER THREE- SHARP FORCE TRAUMA

Sharp force trauma is any trauma inflicted with a pointed or edged object (Kimmerle & Baraybar, 2008). Examples of tools that can produce sharp force trauma include knives, axes, saws, swords and screwdrivers. Sharp force trauma can be categorized into three main groups: knife stab wounds, knife cut wounds, and saw marks (Symes et al., 2002).

Knife blades are described as having at least one beveled, or sharpened, edge. Weapons that fall into this category include knives, axes, hatchets, and swords (Symes et al. 2002). Saws are defined as “a strip of metal with teeth cut into at least one edge of the blade used in reciprocating or continuous motion to cut dense material” (Symes, 1996).

When a bone is cut with a knife or saw, the tool will often leave a kerf, striations, or both. A kerf is the walls and floor of a cut and is produced when a cut is incomplete, i.e., when the bone is not bisected, or when the cut is a “false start”. Striations are a series of ridges, furrows, or linear marks, left by tools as they pass through bone (Galloway, 19990. Kerfs tend to be the most informative trauma left on bones in identifying the tool that created them and are very distinguishable between knife cut wounds, knife stab wounds, and saw marks (Symes et al., 2002). If the bone is bisected, only striations will be observed and will not be as distinctive as the tool that created them.

Knife Stab Wounds

Knife stab wounds are formed when a sharp object strikes a bone. These objects can be knives, screwdrivers, ice picks, or other like classes of weapons. When these weapons strike bone, they will puncture, nick, or gouge a bone (see Figure 1). These wounds are categorized by their depth being greater than their width. Knife stab wounds may have an elongated, triangular, or V-shaped cross section (Kimmerle & Baraybar, 2008) or may form a cone-shaped defect in the bone (Ferllini, 2012). This type of wound will have minimal to no wastage, defined as fragments of the bone separated from the main section of the bone (see Figure 2) (Ferllini, 2012, Croft & Ferllini, 2007). Protrusions can also be observed on bone edges when puncture wounds occur as tools pass through a bone. Protrusions are wastage particles of the bone that do not completely separate from the bone (Croft & Ferllini, 2007).

Striations on the kerf wall of knife stab wounds can be parallel or perpendicular to the kerf floor depending on direction of blow. Striations from knife stab wounds may be visible with the naked eye, or may be microscopic in nature (Reichs, 1998). Some knife stab wounds will also exhibit hinge fractures, where part of the bone will fracture and not separate from the original bone (see Figure 2) (Ferllini, 2012). Hinge fractures differ from protrusions in the size of the separated bone particles as well as the manner in which they are created.

Depending on the weapon, knife stab wounds can also produce transverse, longitudinal or oblique fractures (Croft & Ferllini, 2007). Transverse fractures are fractures running along the short axis of the bone. Longitudinal fractures run along the long axis of the bone. Oblique fractures run diagonally along the short axis of the bone.

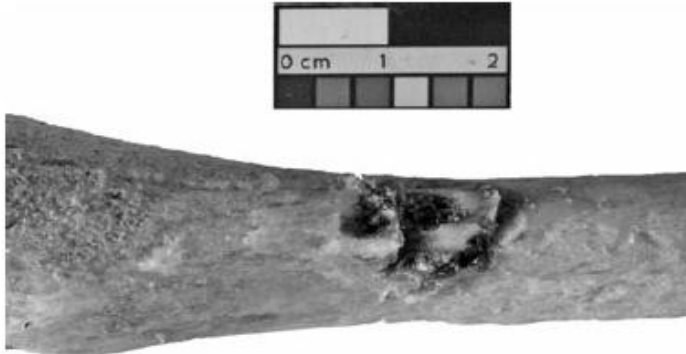


Figure 1 Knife stab wound (from Ferllini, 2012)

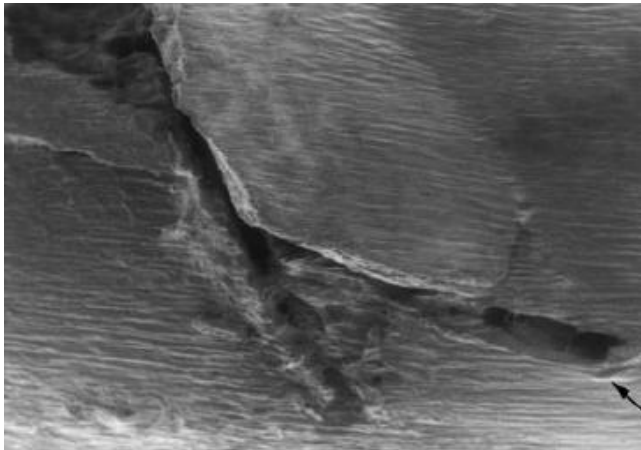


Figure 2 Knife stab wound with hinge fracture and wastage (from Ferllini, 2012).

Knife Cut Wounds

Knife cut wounds, or incised wounds, are any wounds that are made by a blade in which the length of the wound is greater than its depth, and their appearance is significantly different from a knife stab wound (Symes et al., 2002). Knife cut wounds are made when a sharp edged tool passes over the surface of the bone, leaving a mark. These wounds can be made by various actions such as stabbing, chopping, hacking, or slashing. Knife cut wounds will leave a V-shaped kerf floor (see Figure 4) (Symes et al. 2010). Knife cut wounds will rarely bisect the bone; therefore kerfs will usually be present. Knife cut wounds will have striations on the kerf wall perpendicular to the kerf floor. If a knife made the mark, the striations will usually be microscopic in nature. If a larger, more massive weapon made the wound, striations could be visible to the naked eye (Reichs, 1998).

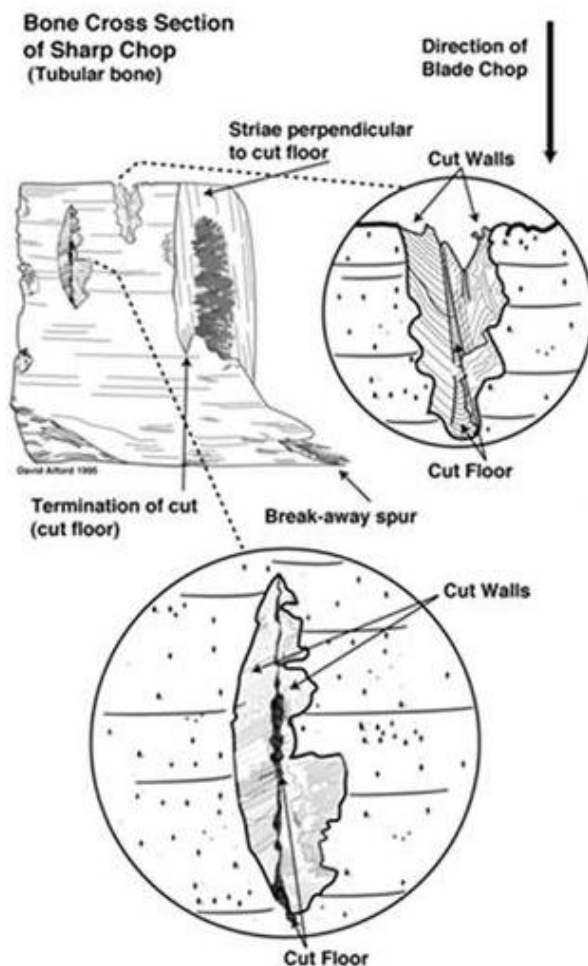


Figure 3 Sharp chop wound and trauma associated (from Symes, 2010).

A variety of studies have been conducted examining different types of tools that make knife cut wounds, such as hatchets, axes, cleavers, machete, and knives (Tucker et al. 2001, Humphrey and Hutchinson, 2001, Lynn and Fairgrieve, 2009a, 2009b, Alunni-Perret et al., 2005). Observations of the trauma created have been observed macroscopically and microscopically, including scanning electron microscopy (SEM). From these studies, four classes of trauma have been used to categorize bone alterations:

(1) clean cut, or no alterations other than the cut wound, (2) chattering, or a series of small fragments or “chips” (3) crushing, where small to medium pieces of bone are pushed in directly by the weapon in the direction of the blow and (4) fracture, or medium to large pieces of bone broken by the weapon in the path of the blow. Studies also discuss the different types of weapons that will generate these classes of trauma in varying amounts.

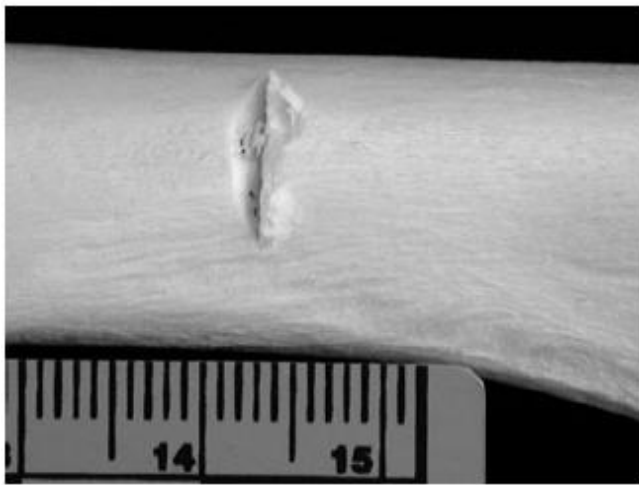


Figure 4 Knife cut wound (from Lynn & Fairgrieve, 2009a).

Saw Marks

Saws, although having some similarities to knives, work differently in their cutting pattern and therefore leave different alterations on bones. Saws chisel, or shave, material away as the blade passes over the surface being cut and leave square kerf floors (Symes et al., 2010). When bone is bisected, breakaway spurs, or projections of the bone

at the floor of the terminal cut, where the bone fractures, have been observed. Likewise, on the opposite side of the bone will be a notch, which is the “mirror image” of the spur.

Striations will often be visible to the naked eye on both kerf walls, and additional detail can usually be seen microscopically. These striations will be parallel to the kerf floor (Reichs, 1998). Striations can also be seen on the kerf floor. Note that knives with a serrated edge can leave marks on bones that are similar in some ways to marks left by saws (Kimmerle & Baraybar, 2008). The key difference is that with serrated knives, one kerf wall will be smooth and polished while the other will have striations similar to the blade (Reichs, 1998).

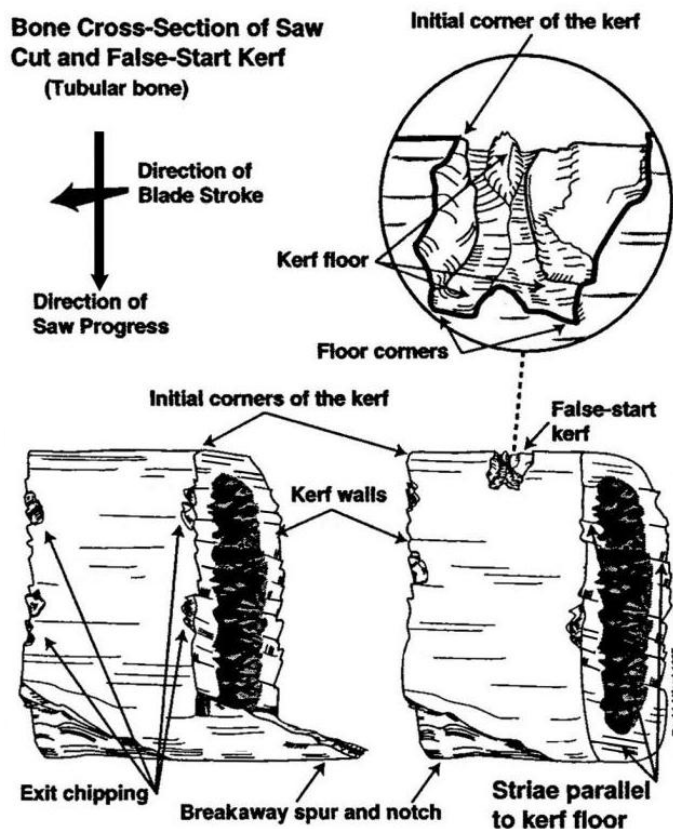


Figure 5 Saw cut diagram with spur and notch (from Symes, 2010)

Sharp-Blunt Injuries

Sharp-blunt injuries occur when more massive cutting tools such as axes, hatchets, and machetes are used to cut bone (Kimmerle & Baraybar, 2008). Because of the mass of the weapon and the force at which it strikes, blunt force trauma is often observed in connection with the sharp trauma. Sharp-blunt wounds are characterized as having smooth surface entrance wounds with fragmented or separated exit defects. These defects are also larger and can have linear or other fractures emerging from the point of impact (Kimmerle & Baraybar, 2008, Lynn & Fairgrieve, 2009a). These types of

wounds also have large amounts of wastage formed by chipping or spalling (Reichs, 1998). The kerfs of sharp-blunt trauma typically have rougher edges than with knife wounds, may be more square as opposed to being linear, and have more chattering (Alunni-Perret et al., 2005). When axes and hatchets are used, flaking may occur on the acute angle of the cut with no flaking on the obtuse side (Lynn & Fairgrieve, 2009a).

Fractures are often produced in association with sharp-blunt injuries. Fractures are characterized as incomplete or complete, and can be caused by direct or indirect trauma (Galloway, 1999). Fractures may be comminuted, when two or more fragments are generated, or simple, when the bone breaks in just one place. Typically, fractures observed following sharp-blunt trauma are complete, comminuted fractures.

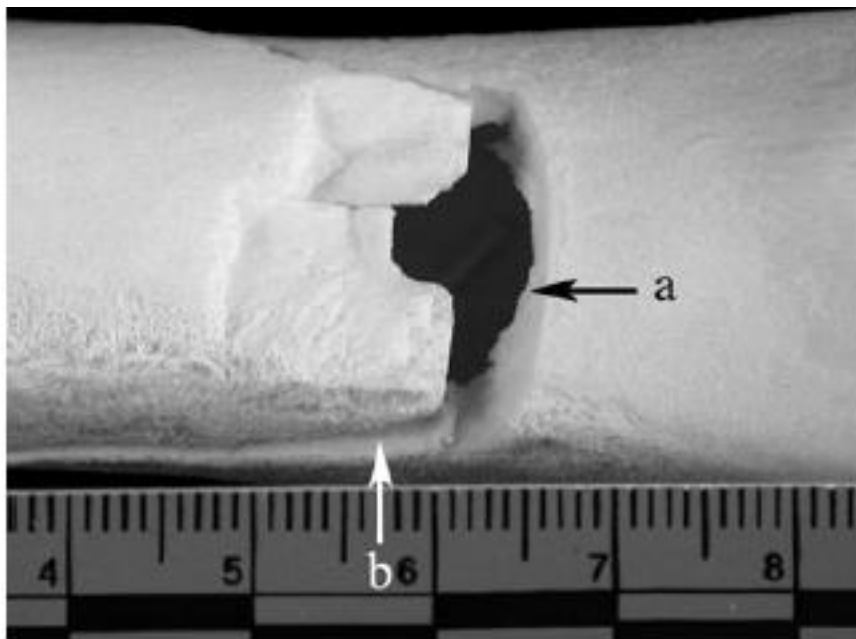


Figure 6 Sharp-Blunt injury, a is the cut wound and b is the fracture (from Lynn & Fairgrieve, 2009b).

Table 1 Comparison of sharp force trauma characteristics

Type of trauma	Weapons associated with trauma	Description of trauma	Source
<i>Knife stab wound</i>	Knife, box cutters, screwdriver,	• V-shaped kerf • Elongated or triangular kerf • Shaving from back of knife • Minimal wastage • Striations perpendicular to kerf floor • Protrusions • Hinge fractures	Symes et al., 2010 Kimmerle & Baraybar, 2008 Symes et al., 2002 Croft & Ferllini, 2007 Reichs, 1998 Ferllini, 2012
<i>Knife cut wound</i>	Ax, hatchet, sword, knife	• Long bones bisection • Chattering • Transverse and longitudinal fractures • No observable striations to visible striations • V-shaped kerf	Lynn & Fairgrieve, 2009a Tucker et al., 2001 Reichs, 1998 Symes et al., 2010
<i>Saw</i>	Saw, serrated knife	• Breakaway spurs and notches • Square kerf • Striations parallel to kerf floor • Large amounts of wastage	Symes et al., 2010 Reichs, 1998.
<i>Sharp-blunt</i>	Ax, hatchet, sword,	• Smooth entrance with fragmented exits • Linear fractures form point of origin • Large amounts of wastage • V-shaped kerf to square, but rough • Flaking • Various types of fracturing	Kimmerle & Baraybar, 2008 Reichs, 1998 Alunni-Perret et al., 2005 Lynn & Fairgrieve, 2009a

Mutilation and Dismemberment

Human mutilation is defined as the act of depriving an individual of a limb, member, or other important part of the body, deprivation of an organ, or severe disfigurement and it covers the term dismemberment (Hakkanen-Nyholm, H., Weizmann-Henilus, G., Salenius, S., Lindberg, N., & Repo-Tiihonen, 2009). Sharp force trauma is prevalent in victims of dismemberment and mutilation because when the perpetrator of a crime desires to dispose of remains, and the intent to do so is making them smaller, they will use weapons that are convenient such as axes, hatchets, or large kitchen knives. With the exception of saws, which will leave only sharp force trauma, weapons used to dismember remains will often leave sharp and blunt force trauma (Kimmerle & Baraybar, 2008).

Cases of mutilation and dismemberment are not common. In Germany, one in 500 criminal cases involves mutilation or dismemberment (Konopka, Bolechala, and Strona, 2006). Twenty-three cases of dismemberment were reported in Poland between 1968 and 2005 (Konopka, Strona, Bolechala, and Kunz, 2006). Over a seven year period in the Konya province Turkey, seven of 3940 deaths involved dismemberment, and of those seven, only one was the result of a homicide (Dogang, Demirci, Deniz, and Erkol, 2010). Over a 60 year period in Sweden, 22 deaths had criminal dismemberment or mutilation aspects to them (Rajs, Lundstrom, Broberg, Lidberg, & Lindquist, 1998). Less than 1% of cases investigated in New South Wales, Australia exhibited dismemberment (Soars, 2011). No direct studies on mutilation and dismemberment in the United States were located; however, it is claimed that dismemberment cases have been on the rise

(McKeown and Bennett, 1995) and serial killers who dismembered their victims were mentioned in a recent study (Promish & Lester, 1999). One forensic anthropologist (Symes, 1992) reported that he was consulted on nine dismemberment cases between 1998 and 1992.

Both detection avoidance and psychological reasons have been proposed for why dismemberment and mutilation occur and although this thesis is not focused on the psychological aspects of dismemberment, they merit mentioning to help explain why a criminal would dismember or mutilate a body. Reasons proposed for dismemberment and mutilation have included: defensive mutilation, aggressive mutilation, offensive mutilation, and necromaniac mutilation.

Defensive mutilation is when the perpetrator is trying to remove the body, cover up the crime, or prevent identification of the deceased. Aggressive mutilation is when the assailant shows aggression for the victim before or after the attack. Offensive mutilation is dismemberment that accompanies lust murders or necrosadistic murders. Necromaniac mutilation refers to mutilation for obtaining a trophy or a fetish (Konopka, Bolechala, & Strona, 2006). In addition to psychological reasons, dismemberment has been documented in cases of torture, execution, and for medical reasons (Kimmerle & Baraybar, 2008).

The two most common methods of dismemberment are limb bisection and joint disarticulation (Reichs, 1998). In the limb bisection method, limbs are severed at or around the joints instead of in the joint. For example, limbs would be severed above the wrist to remove the hands and above the ankles to remove the feet as opposed to at the

wrist or ankle joint. Femurs would be severed below the femoral head instead at the acetabulum to remove the legs. In the joint disarticulation method, limbs are separated at or within the points of articulation; for example, in the knee or elbow joint, the shoulder, or pelvic girdle (Reichs, 1998). This method is not seen very frequently as it requires more knowledge of anatomy or butchering and is more time consuming.

Using a wood chipper for dismemberment is an example of extreme defensive mutilation in that it serves to facilitate disposal of the body and preventing, or hampering, identification. Remains to be inserted into a wood chipper for further dismemberment could be initially dismembered following either method, or not at all if a large enough wood chipper were to be employed.

Wood Chipper Trauma

Wood chipper trauma has not yet been described in literature, but it is hypothesized that alterations produced by wood chippers will resemble sharp force trauma produced by knives or axes and hatchets. Because wood chippers use rotating blades at high speed, it is anticipated there may be some differences as well, and that they may also resemble sharp-blunt trauma. In addition to other well-documented types of sharp force trauma, other alterations created by a wood chipper may include flaking, or fragments of bone breaking away from the site of impact (Lynn & Fairgrieve, 2009a). Peeling or shaving may also be observed, which is lifting of fragments away from the bone while remaining at the site of origin (Kimmerle & Baraybar, 2008). There may also be striations on the kerf surfaces created by the blade or other components of the wood

chipper. Fractures associated with sharp-blunt trauma such as incomplete or greenstick may also be observed.

CHAPTER FOUR- WOOD CHIPPERS

Wood chippers are machines used to turn leaves, grass, and branches into smaller more manageable pieces and clean up vegetative material from yards. Wood chippers come in home models and commercial models. Home models are designed for light amounts of work such as leaves and grass and can also handle smaller branches up to about four or five inches in diameter (see Figure 7 and Figure 8). Large capacity chippers, or sometimes referred to as commercial chippers, are designed to take tree trunks up to approximately twelve inches and shred them into small pieces (see Figure 9 and Figure 10). Chippers may be characterized by their chipping reduction ratio. The chipping reduction ratio refers to the volume of material prior to and after chipping.

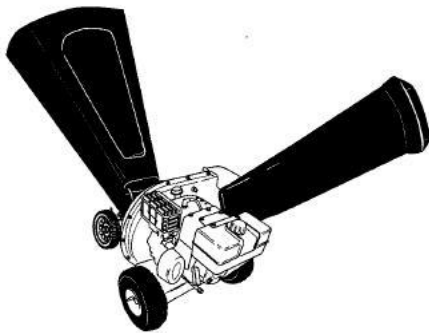


Figure 8 Home model wood chipper

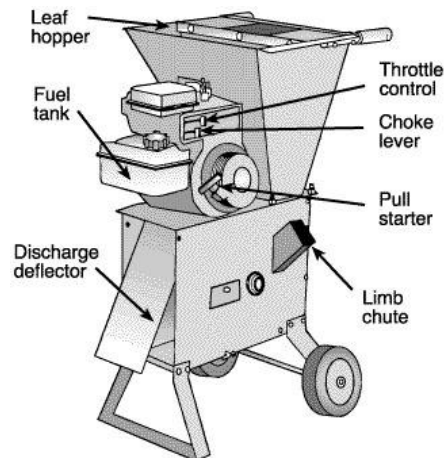


Figure 7 Home model wood chipper diagram

Wood Chipper Operation

Although wood chippers come in different makes, models, designs, and sizes, they all work in essentially the same manner. Inside a metal enclosure, blades are attached to a fly wheel, also called an impeller, which is spun by the motor at high speeds ranging between 1700 RPM and 3750 RPM (Sears and Roebuck, 1998). The motor is attached to an input-chute or hopper into which material to be chipped or shredded is inserted. This chute or hopper then brings the material in contact with the blades and the blades chop it into small pieces. Chipped pieces are ejected from the chipper through a discharge chute. Material can be collected in a truck or bag to be taken away, chipped into a pile to be used as mulch, or dispersed over a large area to decompose more easily (see Figure 10). Once chipped, the material falls through the opening in the fly wheel or falls between the flywheel and the frame of the wood chipper and is scooped up by one of a set of four lifters. Material is moved around the chipper housing by centripetal force and carried by the lifters to be expelled out of the opening in the front. These lifters are also attached to the flywheel but on the opposite side in reference to the chipping blade. The lifters remove material perpendicular to the way they were inserted.

One wood chipper that operates somewhat differently is a commercial drum shredder. These chippers are larger in size and instead of having their cutting blades perpendicular to the hopper/input chute; they run parallel to the hopper/input chute. Material inserted to the hopper/input chute is pulled through and expelled in a straight line. With other types of chippers, material is inserted into the chipper perpendicular to

the cutting blade and expelled perpendicular to the way in which it was inserted (see Figure 10).



Figure 9 Commercial wood chipper

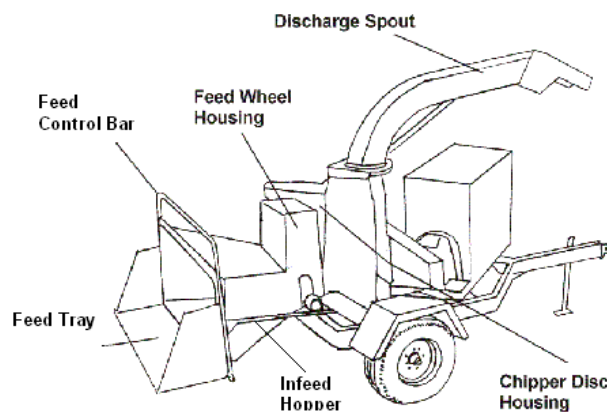


Figure 10 Commercial wood chipper diagram

Wood Chipper Safety and Changes in Design

As mentioned previously, a report was released summarizing wood chipper deaths occurring in the workforce between 1992 and 2002 (Struttmann, 2004). Since 2002,

further data has been collected and 39 individuals have been killed in wood chipper related accidents (U.S. Department of Labor, 2003, 2004, 2005, 2006, 2007, 2008, 2009, & 2010). Most of the wood chippers involved in these accidents were commercial chippers large enough to pull their victims through if an article of clothing or other material were to get caught, but some cases did involve home mode wood chippers. In fatal cases involving home models, the main cause of death was blood loss. During this time, the Centers for Disease Control and Prevention issued safety guidelines in an attempt to decrease the number of fatalities. Some of these suggestions included:

- All safety devices and controls, such as emergency shut-off devices, are tested and verified to be functioning properly before the chipper is used.
- Workers are trained in safe work procedures, including operating wood chipper safety devices and safety controls.
- At least two workers are in close contact with each other when operating the chipper.
- Workers wear close-fitting clothing, gloves without cuffs, trousers without cuffs and skid-resistant foot wear.
- Workers feeding material are positioned at the side of the machine to allow quick operation of the emergency shut-off device and minimize risk of entanglement in branches.
- Workers load small raked-up material such as twigs and leaves directly into the chip truck or in trash cans or bags instead of feeding it into the chipper (NIOSH, 1999).

These safety guidelines were designed to decrease the number of work force fatalities. This report also discussed some safety features that have been added to help

prevent accidents. Some improvements have included a safety stop bar which will disengage the chipping blades when pulled, a reverse function on the chipping blades, and smaller in-feed hopper openings (NIOSH, 1999).

CHAPTER FIVE- MATERIALS AND METHODS

Materials and Methods

Four fore limbs and one rear limb from domestic pig, *Sus scrofa*, were used in this study. The limbs were obtained from a local butcher who had saved them for an undisclosed reason which did not occur, making them available for study. Limbs were bisected by the butcher with a ban saw through the bone. During the butchering process, limbs are bisected below the mid joint of each leg with the remainder of the leg being saved for ham. The hind limb obtained included the femur, tibia, and fibula with no part of the foot or ankle being included in the sample (see Figure 11). The fore limbs included the carpals, metacarpals, phalanges, and a few inches of the distil radius and ulna, but no part of the humerus (see Figure 11). There are ethical as well as practical issues in using human cadavers for scientific research, especially in traumatic or destructive research. Therefore, pigs are often used as proxies for humans in such studies. Anatomically, pigs are closely related to humans in regards to bone structure and skin morphology making them well-suited for this study.

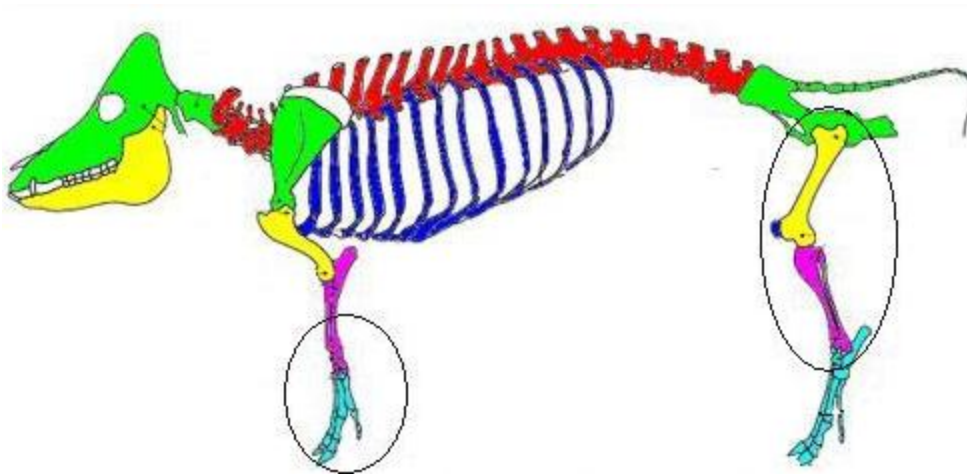


Figure 11 Pig skeleton with limb portions used circled

A Craftsman model 247.775880 wood chipper was used (see Figure 7). This is a light-capacity home model and is similar to models that are readily accessible by purchase or rental at a local home improvement or hardware store and most likely to be used in a criminal context. The chipping blade of this model is attached to a fly wheel located inside a central hopper (see Figure 12). The blade has a beveled angle of the blade being approximately 45 degrees according to the protractor (see Figure 13). The blade is attached to the fly wheel above an opening where chipped material can fall through after chipping occurs (see Figure 14). Measurements of various components were taken using a digital micrometer. The blade is 7.41 mm thick. The distance between the end of the hopper and the outer edge of the blade is 7.95 mm (see Figure 15). The distance between the end of the hopper and the fly wheel is 12.7 mm. The flywheel is 4.25 mm thick. The lifter blades are 6.35 mm in diameter with the ends having a

quarter circle shape removed from the top and bottom. The spacing between the lifter blades is 15.88 mm.



Figure 12 Chipper opening



Blade 7.41 mm

Fly wheel 4.25 mm

Figure 13 Chipping blade and flywheel

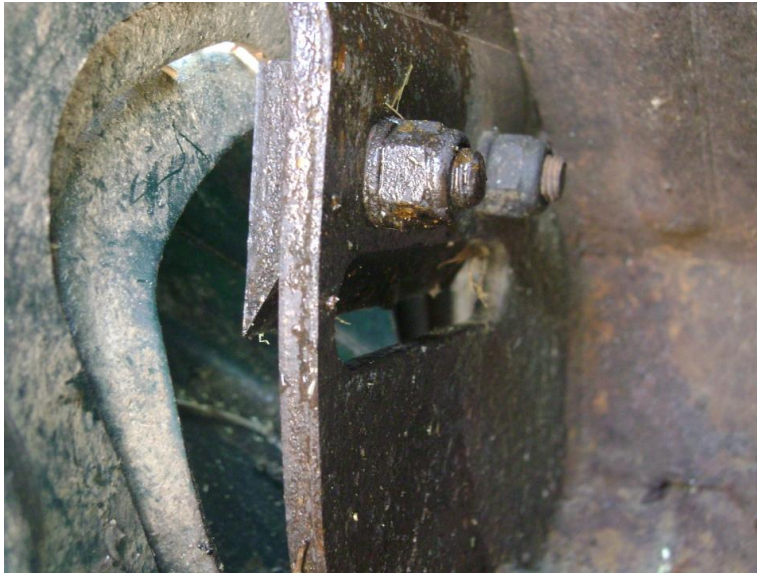


Figure 14 Chipping blade, flywheel, and opening

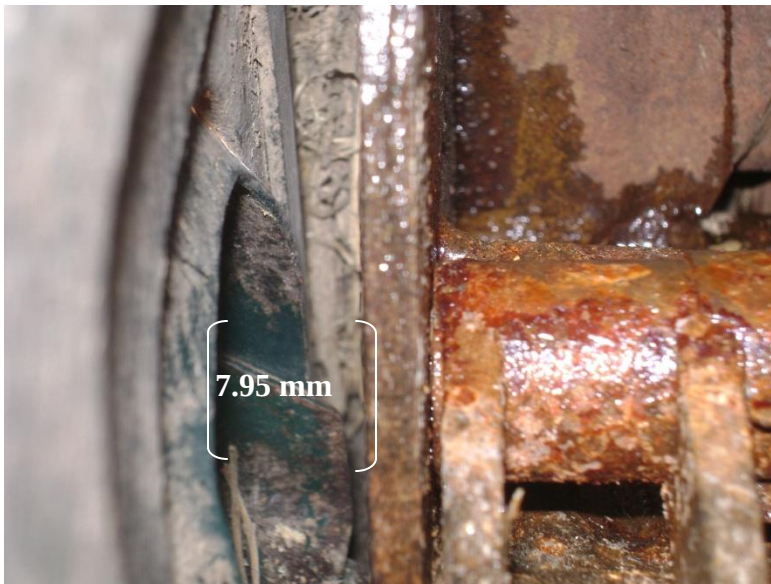


Figure 15 Spacing between flywheel and input chute



Figure 16 Lifters



Figure 17 Wood chipper with collection receptacle

After the specimens were obtained from the butcher, they were photograph, weighed and any alterations made by the butcher were noted. A collection receptacle in the form of a five gallon plastic bucket with a lid containing a hole large enough to fit over the discharge chute was attached to the wood chipper using a ratchet strap (see Figure 17). Limbs were then inserted one at a time into the input chute of the chipper keeping hands clear of the blades. If a limb did not feed through the chipper completely, a stick was used to push the remainder through. After each limb, the receptacle was cleaned out and all chipped material was placed in a clean receptacle that has been previously massed. The mass of the chipped material was measured.

Chipped remains were photographed and then grossly processed by hand to remove as much flesh and muscle as possible in preparation for maceration. Large bone fragments were removed from the chipped material as well as large pieces of muscle and skin that did not contain bone fragments. Bone fragments were saved and muscle and skin were discarded after observations were made. Material still containing bones was washed with water and bone fragments that were easily removed collected in a sieve. Any muscle that had bone fragments that could not be easily removed was macerated to facilitate isolation of bone fragments.

The bones were macerated using a “hot water bath” maceration method following Lee, Luedtke, Allison, Arber, Merriwether, & Steadman (2010). This method involves placing material in water just below 90° C for approximately 24-48 hours. The chipped material was placed in a stainless steel stock pot and the hot water bath was achieved using a hot plate. The remains were macerated for 24 hours. Following maceration, bone

fragments were separated from muscle and other tissue by hand. Smaller fragments were soaked in water allowing for the bone fragments to sink to the bottom and the lighter material to float to the top, allowing for easier removal. Bones were spread out on brown paper and allowed to air dry for minimum of 48 hours and then placed into a brown paper bag to store for further analysis. Limbs were maintained separate through the entire chipping, maceration, and storage process.

A sieve was used to separate fragments by size. The sieves were number 6, 20, 40, and 100 according to U.S. Department of Standards, with openings of 11.6 mm, 5.85 mm, 2.82, and 1.69 mm, respectively. The sieve numbers were converted to size categories for this study with size one being fragments larger than sieve 6, size two being larger than number 20 but smaller than 6, size three being larger than number 40 but smaller than number 20, size four being larger than number 100 but smaller than number 40, and size five being smaller than number 100. Fragments in each category were weighed.

All size one, two and three bone fragments were separated from other bone fragments and closely observed for tool marks produced by the wood chipper. Any non-bone material, such as hoof material, was removed and not observed. Fragments from size four and size five were not observed for tool marks or other trauma.

Fragments were then separated according to whether they had distinguishable through-cuts, (or fragments where the bone was cut completely through). Fragments having these through-cuts were further separated into fragments with one through-cut and fragments with two through-cuts.



Figure 18 Bone fragment with two through-cuts

Fragments (whether having through-cuts or not) were further segregated according to whether they had observable tool marks, fractures, or other characteristics, and fragments lacking tool marks. Fragments lacking any cuts, marks or other characteristics were set aside from further tool mark analysis.

Sliding calipers were used to measure the thickness of fragments with through-cuts to the nearest .00 mm. The masses of bone fragments with each type of alteration were taken to determine the percent of bone fragments with each type of alteration.

CHAPTER SIX- RESULTS

Bone Fragment: Size

Table 2 shows the initial mass of samples before chipping, the mass of material recovered after chipping, the percentage recovered (calculated as mass after chipping over initial mass) as well as bone mass following maceration. Table 3 shows the masses of bone fragments from each size category. On average, 96% of the original mass was recovered following chipping with an average of 189 grams of bone fragments per limb. Of the 189 grams of bone fragments, 22.8g are size one (see Figure 19), 77.2g are size 2 (see Figure 20), 56.2g are size 3 (see Figure 21), 23.8g are size 4 (see Figure 22) and 8.8g are size 5 (see Figure 23).

Table 2 Mass changes following chipping and maceration

	Initial mass	Mass after chipping	Percentage recovered	Bone mass after maceration
<i>Limb 1</i>	927g	920g	99.2	153g
<i>Limb 2</i>	1175g	1126g	95.8	185g
<i>Limb 3</i>	1063g	1025g	96.4	160g
<i>Limb 4</i>	1010g	996g	98.6	156g
<i>Limb 5</i>	1811g	1680g	92.7	291g
<i>Average</i>	1197g	1194g	96.0	189g

Table 3 Weight of recovered bone in each size category by limb

	<i>Category 1</i>	<i>Category 2</i>	<i>Category 3</i>	<i>Category 4</i>	<i>Category 5</i>
<i>Limb 1</i>	18.0g	66.0g	47.0g	14.0g	8.0g
<i>Limb 2</i>	17.0g	78.0g	55.0g	26.0g	9.0g
<i>Limb 3</i>	48.0g	70.0g	27.0g	11.0g	4.0g
<i>Limb 4</i>	18.0g	81.0g	40.0g	12.0g	4.0g
<i>Limb 5</i>	13.0g	91.0g	112.0g	56.0g	19.0g
<i>Averages</i>	22.8g	77.2g	56.2g	23.8g	8.8g



Figure 19 Size one bone fragments



Figure 20 Size two bone fragments

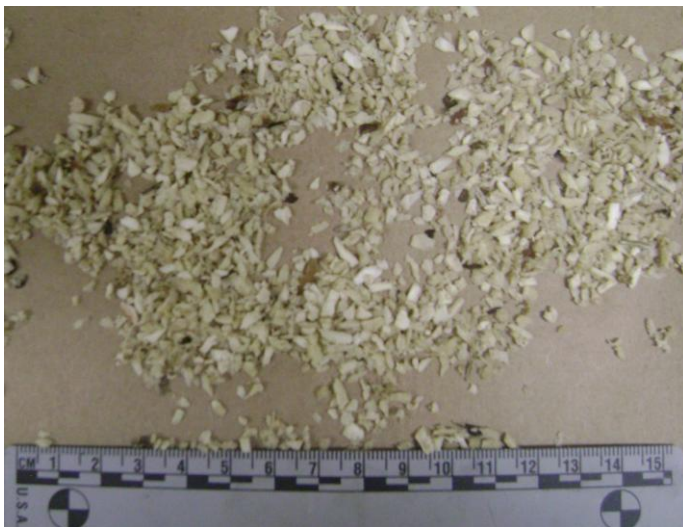


Figure 21 Size three bone fragments

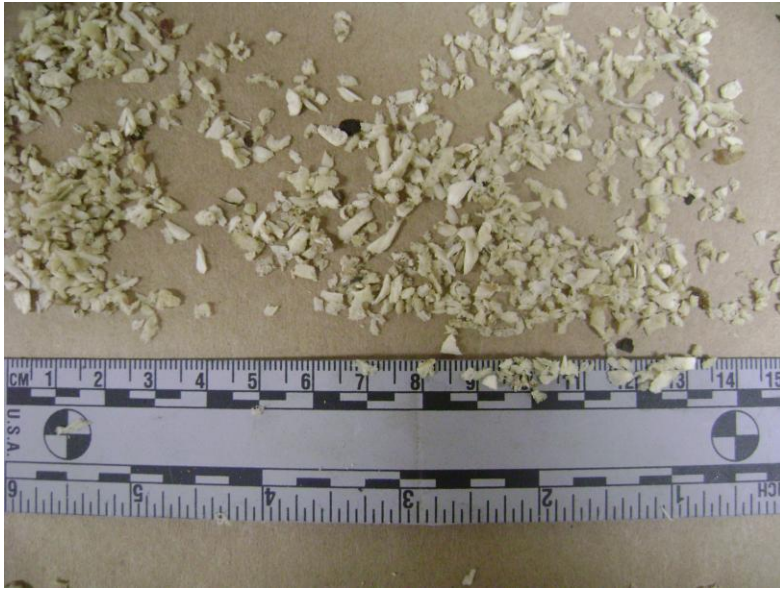


Figure 22 Size four bone fragments



Figure 23 Size five bone fragments

As a percent of total recovered bone weight, 13.41% of all fragments created by the wood chipper in this study are size one, 42.52% are size two, 28.32% are size three, 11.41% are size four, and 4.34% of all fragments are size five (see Table 4 and Figure 24). 55% of bone fragments are of size one and size two combined, which are the size of fragments that are probably most likely to be recovered in a criminal investigation. The smaller fragments may be more difficult to recover or less frequently recovered during investigation. The presence of these fragments in large quantities, however, can still lead investigators to likely conclusions concerning the involvement of wood chippers. The largest percentage of bone fragments fall into size categories two and three combined, together comprising 70.84% of the sample by weight. Size five, the smallest bone particles, account for just 4.34% of all bone fragments. These fragments had the appearance and quality of sand. Without careful observation, these particles could easily be mistaken for material other than bone.

Table 4 Percentages of bone fragment in each size category by weight

	Size 1	Size 2	Size 3	Size 4	Size 5
<i>Limb 1</i>	11.76%	43.14%	30.72%	9.15%	5.23%
<i>Limb 2</i>	9.19%	42.16%	29.73%	14.05%	4.86%
<i>Limb 3</i>	30.00%	43.75%	16.88%	6.88%	2.5%
<i>Limb 4</i>	11.61%	52.26%	25.81%	7.74%	2.58%
<i>Limb 5</i>	4.47%	31.27%	38.49%	19.24%	6.53%
<i>Average</i>	13.41%	42.52%	28.32%	11.41%	4.34%

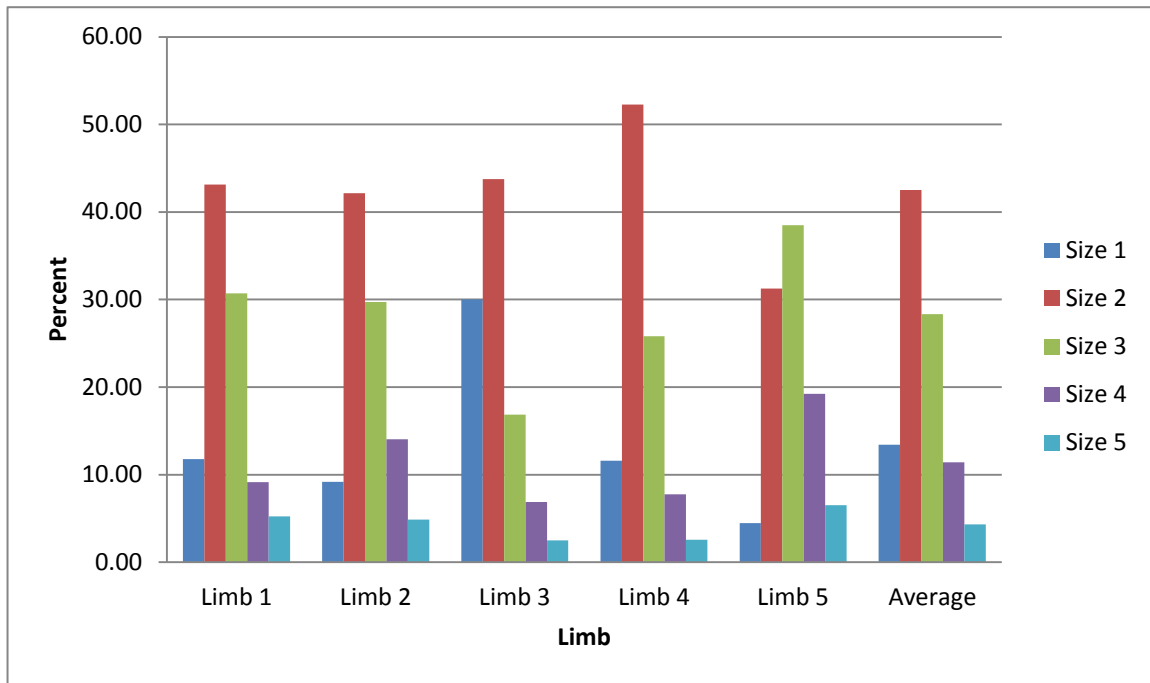


Figure 24 Fragment size percentages by limb

Maximum lengths and widths of the largest ten percent of bone fragments from size one and size two were measured. Bone lengths range from 45.44 mm to 15.6 mm with an average length of 27.96 mm. Widths range from 26.42 mm to 5.72 mm with an average of 15.52 mm. The largest fragment is 43.01 mm long and 26.42 mm wide the smallest is 33.12 mm by 5.72 mm.

Bone Fragments: Through-Cuts

239 bone fragments had at least one through-cut accounting for 23.88% by weight of all bone fragments recovered. Of the 239 fragments with through-cuts, 166, or 14.74% by weight had two through-cuts and the other 73, or 9.13% of total weight had only one cut. The average thickness of fragments with two through-cuts is 6.47 mm with the thickest fragment being 9.89 mm and the thinnest being 3.24 mm. The average thickness

of fragments with one through-cut is 5.9 mm with 8.01 mm being the thickest and 2.89 mm the thinnest (see Table 5 and Table 6).

Table 5 Minimum and maximum widths of bones with through-cuts

	Minimum width	Maximum width	Average
<i>One through-cut</i>	2.89 mm	8.07 mm	5.85 mm
<i>Two through-cuts</i>	3.24 mm	9.89 mm	6.47 mm

Table 6 Number of observed fragments with through cuts

	Number of bone fragments observed	Number of bone fragments observed with at least one through cuts	Number of bone fragments with two cuts	Number of bone fragments with one cut
<i>Limb 1</i>	72	54	36	18
<i>Limb 2</i>	60	45	32	13
<i>Limb 3</i>	76	58	33	25
<i>Limb 4</i>	52	39	31	8
<i>Limb 5</i>	77	43	34	9
<i>Average</i>	67	47	33	14

Bone fragments: Tool Marks

Multiple bone fragments from size category one, two and three had visually observable tool marks. Three bone fragments had square-shaped kerfs (see

Figure 25). The kerf floors did not appear to have any striations, although it did have a “compressed” appearance, as if it was compacted or pressed down. The walls did appear to have some striations when observed microscopically that were perpendicular to the floor, but no specific details of the striations could be distinguished. Specific details that could link the striations to a feature of the wood chipper would likely need to be observed with the aid of a higher powered microscopy such as a SEM. One fragment had three thinner side-by-side square kerfs. The diameters of these three kerfs are each 1.75 mm. The diameters of the kerfs on the other fragments are 2.98 mm and 2.46 mm.



Figure 25 Bone fragment with square kerf

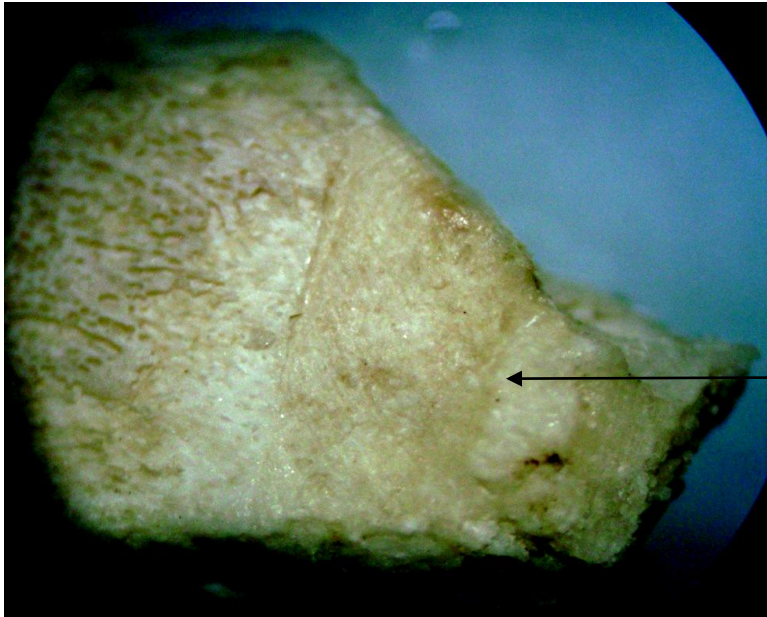


Figure 26 Microscopic view of bone fragment with square kerf

One fragment had two W-shaped kerfs (see

Figure 27). The W-shaped kerf had similarities to the square shaped kerf with a compressed bottom and perpendicular striations on the wall. The diameters of the kerfs were 3.16 mm and 3.43 mm.

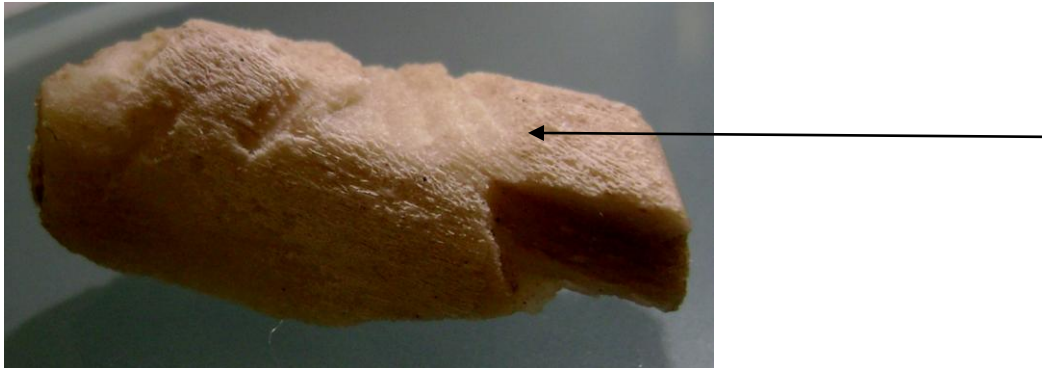


Figure 27 Bone fragment with W-shaped kerf

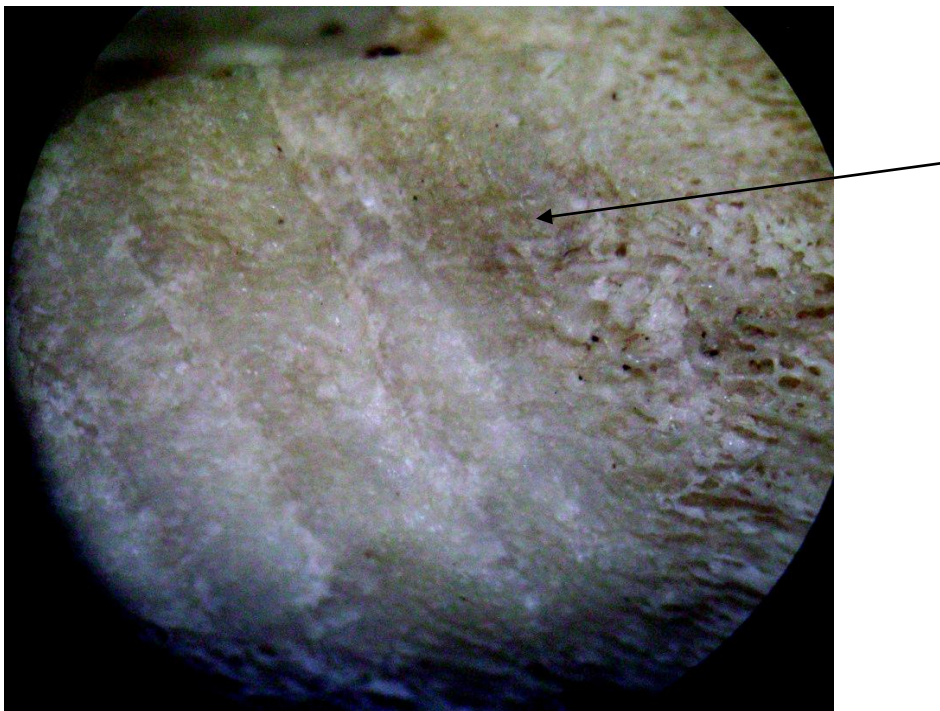


Figure 28 Microscopic view of W-shaped kerf

Twenty four fragments had V-shaped kerfs. The kerfs generally ran the length of the fragments, and therefore the lengths of the kerfs varied depending on the size of the

fragment. Three fragments had gouges and appeared to have deeper kerfs than lengths. Two fragments had gouges and V-shaped kerfs, similar to characteristics observed with knife stab wounds and knife cut wounds. Nine fragments were found with striations similar to striations observed on wood fragments chipped by the same chipper (see Figure 29, Figure 30, Figure 31, and Figure 32 and Table 7).

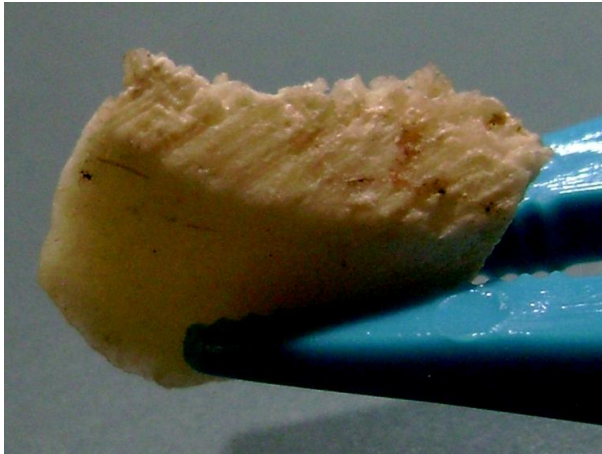


Figure 29 Striations on bone



Figure 30 Striations on bone



Figure 31 Striations on wood chip



Figure 32 Striations on wood chip

Table 7 Number and types of tool marks observed

	Square Kerf	V Kerf	Striations	KSW	KCW
<i>Number of fragments</i>	3	22	9	3	24

Bone Fragments: Other Alterations

Various alterations other than tool marks were observed. Bone fragments from all limbs had extensive amounts of peeling, mostly in fragments analyzed for through-cuts. Flaking, break away spurs and notches, fractures, shaving and chattering were also common (See Table 8).

Table 8 Other alterations observed

	Fracture	Spurs and notches	Peeling	Flaking	Chattering	Shaving
<i>Number of fragments</i>	6	12	54	34	12	22

Other Observations: Non-Bone Trauma

The flesh was the largest fragment remaining after limbs were chipped. The skin for each leg remained, for the most part, intact (see Figure 34). The length of skin fragments are between 88% and 93% of the original length of the legs used. Once chipped, the muscle and bone material resembled in appearance and texture that of ground meat (see Figure 33). There were, however, large remaining pieces of muscle from each limb. The largest piece was 13 g and approximately 13 mm³. Soft tissue

accounted for 84% of the total mass of the specimens after chipping. Although soft tissue decomposes more rapidly than skeletal material, it may still be recovered following wood chipper dismemberment in criminal cases.



Figure 33 Material after chipping



Figure 34 Skin from leg

CHAPTER SEVEN-DISCUSSION

This research will begin to assist forensic scientists and investigators by aiding investigators in the identification of remains that may have been dismembered using a wood chipper. As mentioned prior, previous studies have only documented particle size and the ability to recover DNA. This study, in addition to documenting fragment size also catalogues patterns or marks left on bone fragments.

During the Helle Crafts murder investigation, a piece of skull bone 6.35 mm long was discovered along with 69 other bone fragments, two teeth, part of a finger, a fingernail, and a part of a toenail (Lee & O'neil, 2009). The size of the bone fragments described in that case is consistent with this study. Williams (2007) found that experimentally chipped fragments rarely exceeded 12 mm in length, but this study found that 74 bone fragments from size one and two exceeded 12 mm in length with all but nine of those fragments having widths that also exceeded 12 mm. The engine size or type of cutting blade may account for these differences. Additional research comparing a variety of wood chippers may help clarify this.

Size four and five bone fragments account for 15.75% of the bone fragments recovered in this study. Because of their small size, they were determined to be less informative regarding tool mark study. Size alone may not be indicative of wood chipper

trauma, but the discovery of numerous bone fragments of this size may indicate that a wood chipper was involved in creating them.

Through-cut bone fragments, which were observed frequently, were likely caused as the chipping blade passed through the bone, although it is possible that some through-cuts were created by the flywheel. Many fragments had two through-cuts producing bone fragments of a consistent thickness. This alteration had not previously been described in literature. Single and multiple through-cuts in the same bone created by the same perpetrator have been noted (Konopka, Bolechala, & Strona, 2006), but the thickness of the bone fragment in those cases was much greater than those observed in this study. The through-cuts observed in this study likely require mechanical means and are unlikely to be created by hand. Specific tool marks were not observed on through-cuts, however with the aid of higher microscopy, marks may be observed.

Nine bone fragments had tool marks and striations similar to striations observed on wood chips created by the chipper used for this study. Further analysis of striations on the chipping blade, and comparison to striations on the bone and wood chips, could provide the most beneficial information for linking a wood chipper to the trauma it created.

The V-shaped kerfs were most likely not created by the actual chipping blade. Rather, they were probably created by the bone coming in contact with other metal components of the chipper or hopper that did not carry as much force. The square kerfs could have been created by the fly wheel or the hole in the fly wheel as the bones were passing through the opening. The diameter of the square-kerfs, however, is slightly

smaller than the diameter of the fly wheel (although this difference could be accounted for by some shrinkage as the bone dried). The W-shaped kerf was possibly made by the bone coming in contact with the fly wheel. Close examination of the flywheel reveals several defects (see Figure 35 and Figure 36) which have similar characteristics to the trauma patterns observed in the bone fragment.



Figure 35 Defect in flywheel



Figure 36 Defect in flywheel

Numerous bone fragments exhibit peeling. When examined microscopically, no observable tool marks were noted in association with the peeling. This could have resulted from blunt forces as components of the chipper struck the bone causing flakes of bone to break off. Multiple bone fragments also exhibited characteristics similar to spurs and notching.

Soft tissue accounted for a large portion of the recovered post-chipping remains in this study. Roughly 84% of the total mass prior to chipping was soft tissue. Additional studies focusing on soft tissue trauma may be beneficial.

Approximately 3.5% of the initial material was left in the chipper. This is significant because if it were determined that a wood chipper could have been used in a criminal context, bone and soft tissue will likely remain behind in the chipper to be recovered.

As this is a preliminary study into the trauma that wood chippers create on bone, all questions surrounding wood chipper trauma are not addressed. Further studies will facilitate a better understanding of wood chipper trauma such as whether prior conditions have an effect on trauma (such as freezing or burning), different types of chippers used, the type of bone used, (for example flat versus long bone), and possibly even sizes of victims. Further studies into tool marks created, further size comparisons of different chippers and shredder components, and species bone comparisons would all contribute to the knowledge of how chippers alter bone.

CHAPTER EIGHT- CONCLUSION

Bone fragment size is a reliable indicator that a wood chipper may have been used to dismember remains, and has been demonstrated in several previous studies as well as this one. Using a home model wood chipper, bone fragment sizes ranged from 45.44 mm .01 mm. Most bone fragments, (approximately 70%), were between 12.7 mm and 3.18 mm.

An alteration commonly observed in this study was through-cuts, most likely created by the wood chipper's cutting blade. 27% of all bone fragments by weight had at least one through-cut. Although lacking specific tool marks, these fragments have a fairly consistent diameter of 5.85 mm for fragments with at least one through-cut and 6.47 mm for fragments with two through-cuts. Nine other fragments had striations that may be useful for directly linking bone fragments to a wood chipper blade. These striations were similar to striations created on wood particles chipped in the same chipper. These similarities indicate that the component cutting the bone is likely the same component that cut the wood.

These results provide investigators and forensic scientists with additional information that can be used in the analysis of bone fragments recovered, and determine whether the remains may have been dismembered with a wood chipper. In addition, it is

hoped that these results will dissuade perspective criminals from using wood chippers to dispose of remains by showing that forensic scientists can uncover their illicit activities.

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CURRICULUM VITAE

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