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Real time examination of saw marks on bone produced by three common types of saws: a digital and quantitative method

Abstract

Saw marks are common in cases and autopsies associated with dismemberment and/or mutilation. However, due to difficulties in using current methods to determine types of saws based upon their respective tool marks on/in bones, this topic has not been well researched or published. These difficulties become even greater if determinations are court challenged due to a lack of substantiating quantitative measurements taken during an autopsy or even at the scene in a documented real time manner. Using a quasi-experimental design, the author used three types of saws (a circular saw, a regular saw, and a handsaw) to cut a piece of dry bovine (cow) bone and measured their tool marks separately using a hand-held digital device. The preliminary results indicate the ability to differentiate the three types of saw marks based upon eight quantifiable criteria. The findings from this study suggest real time quantitative measurements may be available for saw marks during both the processing of an autopsy as well as in the field.

Keywords: forensic sciences, forensic medicine, forensic pathology, autopsy, saw marks, kerf characteristics, tool-mark examination, crime scene investigation, forensic anthropology

Volume 2 Issue 4 - 2016

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Received: July 06, 2016 | **Published:** July 15, 2016

Introduction

Many times throughout the process of an autopsy, a medical examiner or a forensic pathologist may need the ability to evaluate saw marks left on/in bones for a forensic determination. However, such a determination is often difficult due to the following three technical challenges. First, there is often inability to determine whether a saw or some other tool made a particular cut in the bone. Second, even if a saw is determined, there is often inability to distinguish the type of saw used with reasonable certainty. Third, there is often inability to differentiate a mixture of multiple cuts involving multiple saws and other instruments.

The above challenges often result from the following practical limitations of current methods. First, the bone is usually too big for an observation in an autopsy room using a regular stereo microscope due to the limitation of viewing distance. Second, a microscopic observation is often not feasible in the field (due to a lack of a power supply). Third, it is very difficult to observe saw marks on a piece of a bone using a regular stereo microscope if the mark was on a location in the body or bone which is not movable. Lastly, no device was readily available to measure saw marks in real time with quantitative measurements. This last statement is of particular interest if forensic medicine and pathology desire to further follow the suggestions outlined in the National Research Council's Report: Strengthening Forensic Science in the U.S:A Path Forward.[1] This landmark report criticized many of the current evidentiary examinations in the field, in the lab, and in the courtroom as being less scientific because traditional examinations of evidence rely heavily on patterns, details of minutia, and feature characteristics evaluated from the subjective perspective of the trained examiner, while lacking rigorous scientific, objective, and quantitative procedure.

A brief literature review indicates class characteristics of saw marks have been published in various dissertations, theses, articles, and book chapters.[2–6] However, actual examinations of saw mark analyses have not been overly successful largely due to the difficulties mentioned above. Further, although techniques of tool-mark examination have had a long-standing history in the literature, the examination and interpretation of saw marks on bones as individual features has received little more attention than a cursory consideration in the forensic literature.[7]

While it comes as no surprise a murder investigation always involves reconstructing complicated acts involving many characteristics, one category of murder weapon lacking in research is the saw and its various types and associated saw marks on/in bones. Therefore, bones can ultimately play an important role in determining at least what type of a saw a murderer used on a victim. To be more specific, saw marks on/in bones can indicate unique markings or incisions, which provide details about the type of saw used. However, a lack of equipment to perform such a task hinders further improvement in autopsy and investigations. Therefore, a portable device is justifiably needed to perform such a task in the autopsy room, in the field, and in the courtroom via quantitative measurements. This need is further exemplified in the following real world cases.

Case I

In June 1997, the brutal murder of an 11-year-old boy occurred in Kobe, Japan.[8] His murderer placed his beheaded head just in front of the gate of a junior high school. Surprisingly, the murderer even challenged the authorities by putting a note in the victim's mouth threatening to kill again. The manner of death was easily determined to be a homicide and the means of death (by what instrument) from the fatal wound was determined to be a handsaw. The police in Japan eventually found their primary suspect, a 14-year-old boy, by looking for a young adult, a rather typical search for a murder case involving such a young victim. Once the police arrested the suspect, he confessed to the crime he committed. The police eventually found the murder weapon, which was indeed a handsaw.

However, the police did not reveal the evidential leads they used to be able to both locate the suspect and determine the means of death as being the handsaw. From a forensic and/or pathological perspective, the way the suspect killed is very important if challenged in a later trial. In other words, it is vital to analyze the bone cut and saw marks to determine whether the saw-marks in the bones correspond to the weapon found for purposes of later evidentiary and testimonial admissibility. Here, several tests for comparison of different types of saws are needed.[9] Most important, a specialized device such as a handheld device is particularly needed to analyze the saw-marks in the bone via quantitative measurements for a pathological determination.

Case 2

In December of 2006, another horrific killing happened in Central Trinidad as the result of the kidnapping of a prominent female executive.[10] The killers cut off her lower body at the point of her navel, both of her arms from the shoulders, and her head. They then placed her body parts into black garbage bags and buried them in a hole in La Puerta, Diego Martin. Later, prosecutors alleged the ten defendants who exhumed and dumped her body parts into the sea. Police have not found her main body.

According to the prosecution, based on the statements of the persons involved, three of the accused men put on whitish rubber gloves and took turns in cutting up the victim's body with a red-and-white colored power saw. The prosecution was unable to determine whether the victim was actually dead or alive during this dismembering. Again, from a forensic and/or pathological perspective, the potential challenge in the trial for such a mutilation case would definitely lie in the determination by the medical examiner(s) of the means of death: whether the wounds from the body parts correspond to the power-saw located. This case ended up in an acquittal of the eight persons accused by May 2016 due to several serious issues, and one more trial for the two accused remaining awaits. However, one main issue in the case is again the evidentiary evidence of saw marks in the bones of the victim.

To address the practical challenges, the author has employed a handheld digital device with potential field implications. First, the palm-sized device (the size of a flashlight) can take a digital image in JPEG format (See the five figures provided), which allows medical examiners and forensic pathologists to observe any area of a body and in any position due to its small size and its extended cable. The device's lens has a five-foot long cable so the lens is capable for the examiner to hold it at any position. Next, the device is capable of connection via USB to a laptop computer, using the laptop's battery as the power source. Moreover, the lens has a range from 5X to up to 50X magnification, permitting a close examination of any cut as small as 0.5 mm in width in sharp detail. With such a minutely detailed image, examiners can also see any attached materials such as blood, metal residues, or sand. Finally, the device allows the examiner to measure any cuts on a piece of bone in a real time manner with three digits after the decimal point (mm). For example, the device can quantify the width and the length of the cut, the triangle of the saw teeth mark, the curve of the kerf, and/or the depth of the saw cut in this study.

The determination of saw cuts in bones with a quantitative measurement is a potential direction in crime scene investigations, in coroners' offices, and in courtroom testimonies. With the device, a quick comparison or differentiation among three major types of saw marks (circular, regular, and hand) becomes feasible. Finally, the rapid identification technique even enables crime scene investigators to analyze saw marks during their actual on-site crime scene investigations. In order to provide more successful expert testimony during cross-examinations at trial, medical examiners and/or pathologists should rely more on experimental tests with validated data for their evidentiary evaluations, which the two case studies mentioned certainly demonstrate a strong need for.

Materials and methods

To maximize a real saw-cut situation, the author selected three main types of saws by blade and used them to cut a piece of dry cow bone. These three saws were

A. A circular power saw with crosscut teeth (labeled A).

B. A regular power saw with rip teeth (labeled B).

C. A handsaw (labeled C) with smaller rip teeth.

The purpose of using three different saws was to see if the handheld device could differentiate via quantitative measurements the three types of saw-marks left in the bone. The importance of the study lies in the fact that the study can provide a supplementary method for medical examiners or forensic pathologists who at present heavily rely on a regular microscope with a naked eye.[11]

As required for a scientific study, the author should first provide feasible methodology and operational definitions. In this study, the author chose a purposive sampling of the three main types of saws based on the nature of the case studies, time and resource limits, as well as the well-known research conducted by Symes.[7] Methodologically speaking, the author referenced and modified eight key criteria to be feasible from the study. The following are the eight operational definitions of the comparison criteria for the three main types of saw marks used in this quasi-experimental design:

A. Types of saws are the types of movements used to do the cutting: namely circular and reciprocating (linear) motion by electrical power as well as hand motion, which is also a reciprocating motion but by human force.

B. Types of blades correspond to the types of saws. A circular saw usually has crosscut blades with consecutive teeth filed at opposing angles (usually at 70 degrees) which cuts directly rather than chiseling away at the bone. On the other hand, a regular saw usually has rip blades without angled or filed teeth and thus the saw chisels away at the bone via its teeth rather than cutting it. Finally, a handsaw also chisels away at the bone in the same manner as the regular chainsaw, but with much less power provided from a human hand.

C. Kerf Width is the horizontal linear dimension between the two edges of the cut made by a particular type of a saw blade.

D. Kerf Length is the vertical linear dimension between two ends of the cut made by a particular type of a saw blade.

E. Kerf Wedge Mark refers to the cut shape or angle (in degrees) on the lower area of the right side unique to a particular type of saw blade. The right lower area is usually the initial point of contact when the saw blade touches the bone surface from a perpendicular position.

F. Kerf Wall Curve is the cut shape or arc of the upper area of the left side unique to a particular type of saw blade. The left upper area is usually the initial point of contact when the saw blade touches the bone from a perpendicular position.

G. Ker Floor Mark is the shape of the penetration or angle (in degrees) at the bottom unique to a particular type of a saw blade upon impact at the bottom of the cut.

H. Ker Floor Angle refers to the angle (in degrees) at the floor corner of the cut from a frontal (perpendicular) view unique to a particular type of a saw blade.

The three types of new saws (without any worn-out or used-defects) were purchased at a tool-shop. In the lab, the author used them separately to cut a piece of dry cow bone at a perpendicular position (90 degree) to the tip of the bone. To maximize levels of reliability and internal validity for scientific accuracy, the six images taken by the handheld device utilized the same viewing distance position at 25 X (times) magnification and with the standard calibration process provided by the software. The author employed three geometric formats for quantitative measurements (linear, triangle, and arc modes) following the best-fit rule of measurements in each image.

Results

While the comparisons of the Types of Saws (No. 1) and Types of Blades (No. 2) are straightforward as already mentioned above in the definitions, the observational results start from the kerf width (No. 3). The author presents all the measurements of the remaining six criteria in Table 1 and as demonstrated by Figure A-F. First, for the three kerf widths, the crosscut blades of the circular saw (A) cut the bone with two sides, thus making the widest gap (DLO L=3.310 mm) among the three. The rip teeth from the regular chainsaw (B) chiseled away at the bone from only one side and made a narrower width (DL0 L=1.361 mm) than the circular saw. The handsaw (C) has the smallest blades and thus produced the narrowest space (DLO L=0.990 mm). Further, the different widths are also consistent with the varying amounts of power (mechanical versus human). Second, in terms of kerf length (No. 4), the corresponding measurements are DL1 L=12.868 mm, DL1 L=12.033 mm, and DL1 L=13.081 mm. In reality, the impulse (amount of force applied over time) determines kerf length: the greater the impulse, the longer the kerf length.

Table 1 Comparison of three main types of saws and their related saw marks in bones

Types of Saws	Circular Saw (A)	Regular Chainsaw (B)	Handsaw (C)
Type of Blades	**Crosscut Blades**	**Rip Blades**	**Smaller Rip Blades**
Kerf Width in Figures 1-3	DLO L = 3.310 mm	DL0 L = 1.361 mm	DLO L = 0.990 mm
Kerf Length in Figures 1-3	DL1 L = 12.868 mm	DL1 L = 12.033 mm	DL1 L = 13.081 mm
Kerf Edge Mark in Figures 1-3	TAO = 38.386 degree	TAO = 34.641 degree	TAO = 20.099 degree
Kerf Wall Curve in Figures 1-3	ARO =108 degree	ARO = 50 degree	ARO = 73.928 degree
Kerf Floor Mark in Figures 1-3	TA1 = 45 degree	DL2:W=1.083 mm L=1.3 mm	N/A
Kerf Floor Angle in Figures 4-6	TAO = 77 degree Depth = 4.532 mm	ARO=197.523 degree Depth = 1.949 mm	ARO=103.37 degree Depth = 2.660 mm

Third, for the kerf edge mark (No. 5), the circular saw (A) has made a deep triangle- shaped wedge pointed toward right (TAO=38.386 degrees) on the lower area of the right side of the cut. The wedge cuts when a blade initially strikes the surface of the bone from an angle. With the regular chainsaw (B), a triangle-shaped wedge (TAO=34.641 degrees) also appeared on the lower area of the right side of the cut. However, the triangle-shaped wedge pointed downward. The handsaw made a light triangle-shaped wedge (TAO=20.099 degrees), which is also pointed downward. The lighter damage in the bone was certainly due to its smaller teeth resulting in the weakest force applied. While the cut by the handsaw was clean without any damage to both sides of the cut, it would take considerably more effort to cleanly cut through the bone manually as opposed to with an electrical power saw, meaning cutting through bones with a handsaw requires a lot of physical power and strength.

Next, digital images of the kerf wall curve (No. 6) displayed three distinguished curve- shaped slopes. The circular chainsaw (A) produced the largest curve-shaped slope (ARO=108 degrees) on the upper area of the left side of the cut due to its crosscut blades. The regular saw (B) cut the smallest slope (ARO=50 degrees) on the upper area of the left side. Interestingly, the handsaw made a larger slope (ARO=73.928 degrees) than the regular saw, which may be accounted for by a more stable force from a human hand.

Fifth, the kerf floor mark (No. 7) revealed three unique marks by the three types of saws. The circular saw (A) penetrated the kerf floor into the inner cavity of the bone with an upside-down triangle-shaped hole (TA1=45 degrees) due to the triangle-shaped crosscut blades having the strongest power output. The regular saw (B) also penetrated the inner cavity but by a square hole (DL2: W=1.083 mm by L=1.3 mm) because of its blade shape. The handsaw (C), however, did make any hole at all at the bottom largely due to the weakest force applied by the human hand.

The final comparative criterion is the kerf floor angle (No.8) and the author took the three images from a front perspective. While the circular saw (A) produced a clear V–shaped cut (TAO=77 degrees) with a depth of 4.532 mm, on the other hand, both the regular saw and the handsaw did not produce any triangle-shaped cut. Rather, they produced two curve-shaped contours with ARO=197.523 degrees for the regular saw and ARO=103.37 degree for the handsaw due to their reciprocating as opposed to circular motion. Interestingly, the handsaw made a deeper cut than the regular chainsaw, which the author speculates is due to the difference in vertical force applied. However, the left wall by the handsaw indicated a more serrated surface.

With the quasi-experimental design, the author intended to examine and measure quantitatively saw mark striate of the three different types of saws in a piece of dry cow bone. The author contended the three types of saws produced unique saw marks in terms of morphological and microscopic appearances in eight quantifiable criteria selected due to their different types of blades and motions. As a first step, a correct differentiation of the three main types of saws and their associated saw mark features have been achieved and would certainly assist medical examiners, forensic pathologists, and criminal investigators to narrow down the actual type of saw involved even without having located the actual saw used itself (Figures 1–6).

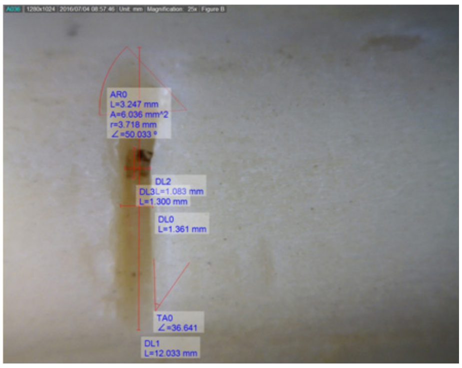

Figure 1 Mark by a Circular Saw.

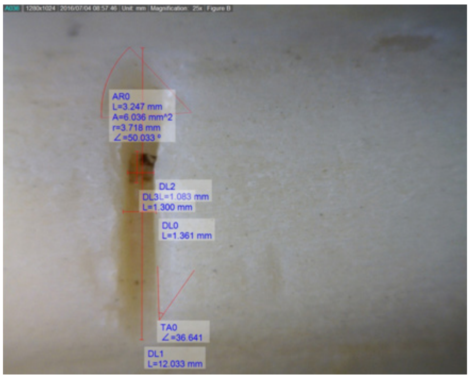

Figure 2 Mark by a Regular Saw.

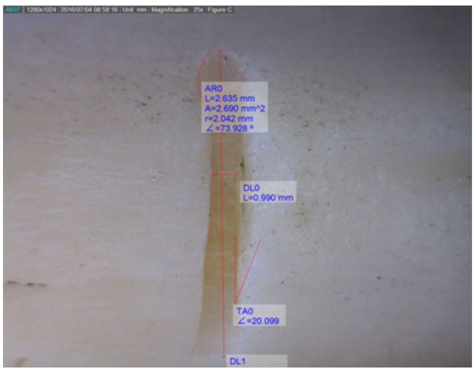

Figure 3 Mark by a Hand Saw.

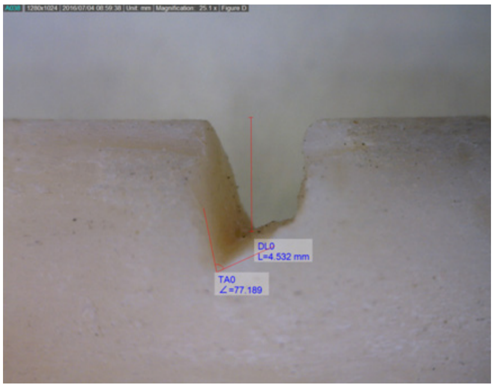

Figure 4 Kerf Floor angle of the Circular Saw.

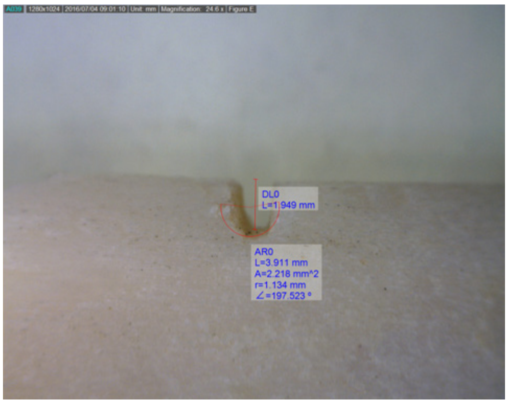

Figure 5 Kerf Floor angle of the Regular Saw.

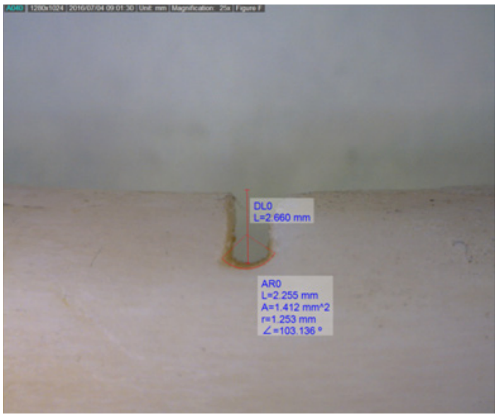

Figure 6 Kerf Floor angle of the Hand Saw.

Discussions and limitations

It is important to recognize by examining "unique" features for a positive match between the bone and the tool in question (as in the saw mark analysis done by this study), the author intended to differentiate types of saw (the three types of saws in this study) via individual characteristics, rather than to identify a specific saw. Therefore, the author provides several limitations as follows. First, this study only selects the three main common types of saws for this study. More studies are necessary of the additional subtypes of saws available for the commission of crimes. Second, the author only separately analyzed the saw marks made by the three types of blades selected. More studies are necessary for mixed saw marks by more than one type of saws used on/in bones in a crime. Third, the author only compared eight common criteria in this study. Future studies should utilize additional specific and quantifiable criteria (such as teeth per inch, points/peaks per inch, distances between teeth, and/or kerf depth using a 3D microscope) to increase the discrimination power of examination, comparison, identification, and interpretation. Finally, while the study intended to draw attention to this area of research by differentiating the saw marks on dry cow bones by the three main types of saws and did not seek to identify particular saw marks associated with any one particular saw, more studies are definitely much needed for such an identification purpose in the future.[12]

Acknowledgments

None.

Conflicts of interest

The author declares there are no conflicts of interest.

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