Knife and Saw Mark Analysis on Bone

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Research funded by the National Institute of Justice and the National Forensic Academy

Syracuse University Dialogues in Forensic Science: Trauma I

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I Introduction to Trauma
1 Sources of trauma → Blunt; Ballistic; Sharp; Burn; Healing
- Description of each type

2 Toolmarks overlooked
- Discussion of the potential of dismemberment interpretation
- Current Status in Toolmark Analysis in Bone

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3 Class (not type) characteristics help narrow field of potential saws/tools
4 Saw Terminology and Characteristics
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1 Use of microscopes and scanning electron microscopes
2 Analysis of cut surfaces without a microscope
3 Straight cut surface indicates a power saw
4 Cut surfaces do not reveal diagnostic characteristics
5 Hesitation marks?
6 Anthropologists need to measure and quantify everything

VII Practical Demonstration
1 Using the ELMO and Saw Mark Data Collection Sheet Dr. Symes will go through the analysis of an exemplar case
2 The class will split into groups
- A cut deer metapodial will be analyzed and, using the Saw Mark Data Collection Sheet, results will be compared to a short list of potential saws in the back of manual

VIII Final discussion of relevance of analysis
1 Comparison of anthropological vs. toolmark analyst approach
2 Class vs. individual characteristics
3 Comparison of equipment—is it possible to do toolmark analysis for class comparisons on a comparison microscope?

Introduction to Saw Mark Analysis on Bone

It is important to understand a few basic concepts about saws and saw blade action before attempting to interpret saw marks in bone. All saws have teeth. As saw teeth cut into bone a groove, or kerf, is formed. Saw mark analysis essentially examines saw cut kerfs. A kerf can be defined as the walls and floor of a cut. Floors are expressed in false-starts and occasionally in break-away spurs. Kerf floors, when present, offer the most information about the points of each tooth and the relationship of the points to each other or the set (lateral bending) and number of teeth per inch. Kerf walls offer information about the sides of the teeth. Wall striae commonly represent only those teeth set to that particular side; while shape, depth, and frequency of these striae may represent the shape of the blade, the amount of energy transferred to the material, and the motion in which the blade travels to cut bone (Symes 1992). The object of saw mark analysis is to recognize characteristics on kerf walls and floors that may accurately reveal:

1. The dimensions and shape of the blade and teeth of a saw
2. How the tool was powered, mechanically or manually
3. How a tool was used to accomplish the dismemberment or mutilation.

Individual characteristics are subject to interpretations of positive identification, consistency, elimination, insufficient results, and unsuitable comparisons (AFTE Criteria for Identification Committee Report 1990:276-277). However, the narrowing of potential saws is facilitated by class (not individualizing) characteristics. This narrowed field of tools can aid in the search for an appropriate tool utilized in a crime and the documentation of criminal behavior. With a standardized analysis of saw marks, the following class characteristics can be identified:

1. Saw Size
2. Saw Set
3. Saw Shape
4. Saw Power
5. Direction of Saw Motion

This manual is organized using these five class characteristics. Each characteristic is followed by definitions of the features used in determining that characteristic. Each definition is marked with the most appropriate location of the saw cut by which to observe that feature, whether it be kerf floor (KF), kerf wall (KW), break-away spur (BA), or false start (FS)

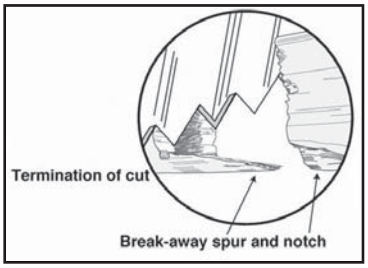
Introductory Terminology

Kerf

The walls and floor of a cut. Floors are expressed in false-starts and occasionally in break-away spurs. Kerf floors, when present, offer the most information about the points of each tooth and the relationship of the points to each other or the set (lateral bending) and number of teeth per inch (TPI). Kerf walls can also offer information about teeth per inch, saw power, and direction of cut.

Break-Away Spur

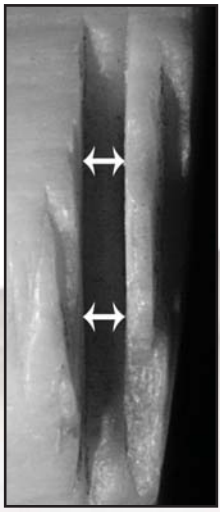
The break-away spur is a projection of uncut bone at the terminal end of the cut after the force breaks the remaining tissue which commonly occurs on the stable end of the bone. The break-away spur is often as diagnostic as the kerf floor. The size of the spur often depends on the amount force applied across the bone resulting in a fracture of the bone. For instance, the weight of a handheld circular power saw or chain saw often produces a large break-away spur.



False Starts

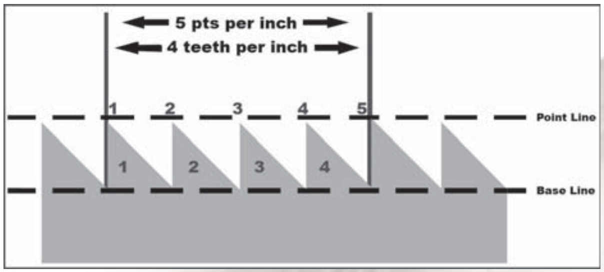
False start kerfs are cuts that do not completely section bone and are composed of two initial corners, two walls, two floor corners, and a floor. These are not considered 'hesititation' marks.

Saw Size



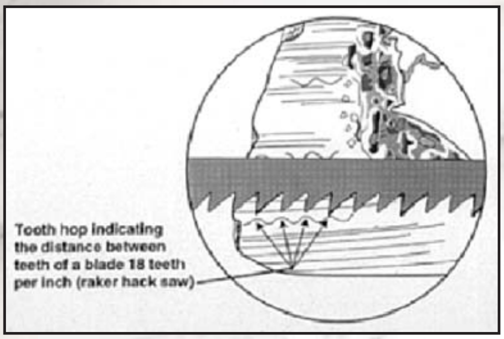
Blade Width

Minimum Kerf Width. This is simply a measurement of the width of a kerf. The minimum kerf width is directly related to the width of the set of the blade.



Teeth Per Inch (TPI)

This is literally the number of teeth per inch. It is a measure of the number of completely occurring (not just points) teeth per inch. There is one more point per inch (ppi) than there are teeth per inch.



Tooth Hop. Striae across the face of the bone generally progress in a straight pattern. With close observation, the residual kerfs (striations) occasionally show patterned hopping or predictable waves. Blade hopping is created as teeth begin to enter the kerf and each successive tooth strikes bone, which produces movement of the whole blade. Measuring from peak to peak or dip to dip of each wave indicates the distance between teeth of the saw. It has been demonstrated that tooth hop can occur with a variety of saws and accurately indicates spacing of saw teeth. (KW)

Pull Out Striae (Tooth Scratch). Pull out striae are simply the presence of perpendicular striae on the cut surface of the bone. These are created when the saw is withdrawn from the kerf in mid-stroke. This has been recognized by Bonte (1975:319) as appearing “vertical to the sawing level which extend[s] over several saw marks . . . [and] corresponds, with normally set saws, to twice the distance between the teeth.” Pull out striae are characteristics that do not easily stand alone and are most useful when used to corroborate other more reliable estimations of tooth distance. Unfortunately the phrase “normally set saws” is a misleading one. Alternating set saws can leave this type of pattern but a saw with a raker set may leave striae that represent the distance of three rather than two teeth. (KW)

Harmonics. Saw mark harmonics are described as peaks and valleys exhibited three-dimensionally in bone cross sections. Harmonic oscillations are found to exist in nearly all blades with alternating set teeth, and are the direct result of normal cutting action in hand and mechanically powered saws. Harmonics are simply the expression of blade drift progress and are good indicative characteristics of blade set and TPI. (KW)

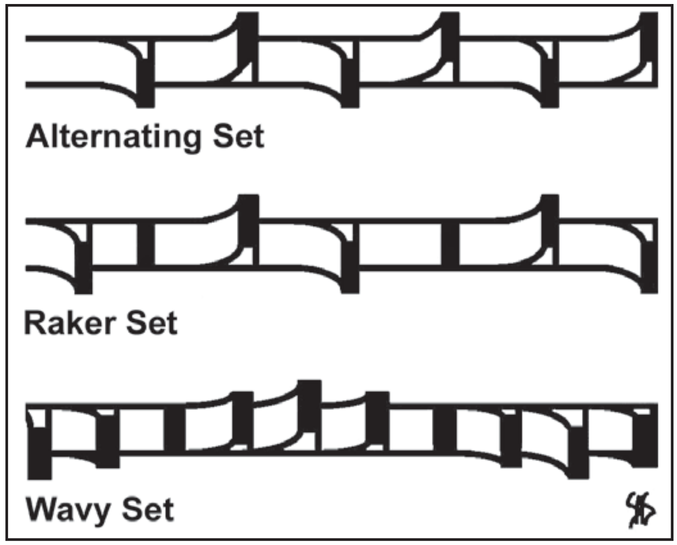
Tooth Imprint and Floor Dip. These are resultant of saw teeth combining actions to cut a kerf floor in bone. When the floor of the kerf is examined on end, the seemingly flat-bottomed kerf may actually be notched or wavy. Tooth imprints and floor dip are residual imprints from tooth points in the kerf floor created after a saw is interrupted in the cutting stroke. Consecutive tooth imprint features can be measured in false starts and break-away spurs to represent the distance between teeth, indicate the set (shape) of the blade and indicate the shape of the individual tooth. (Andahl 1978:36-37; Symes 1992). (KF)

Tooth Width

Saw tooth width can be calculated in two ways, measurement of floor patterns and measurement of residual tooth trough. Floor patterns give an average estimation of saw tooth width while the residual tooth image, if properly interpreted, produces an accurate image of an actual tooth. (KF)

Saw Set

There are three major types of saw tooth set describing the lateral bend of teeth; alternating, raker, and wavy. A cheaper blade may exhibit no set if there is no lateral bend to the teeth.

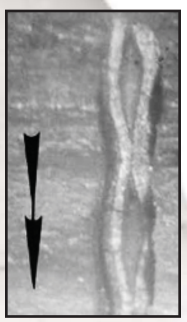


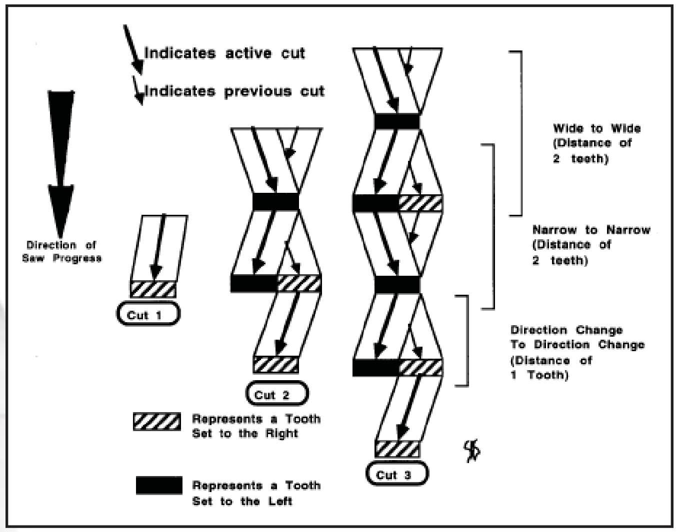
Alternating Set

Each subsequent tooth is laterally bent to the opposite side in an alternating pattern.

Blade Drift. There are certain drift actions that all blades with alternating set teeth follow since saw teeth are set to produce a cut wider than the saw blade. This pattern of teeth drifting across the kerf floor is defined here as saw blade drift, where every tooth entering the material creates a direction change in the tooth carving the bone. (KF)

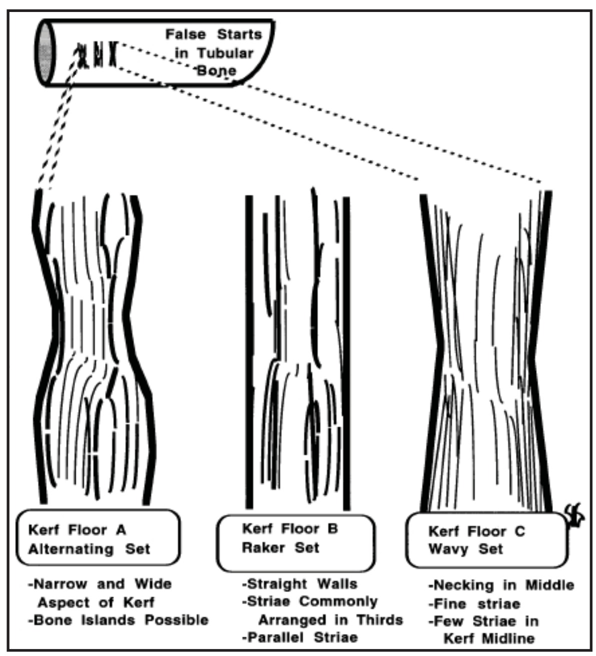
Bone Islands. Bone islands are a characteristic associated with alternating set blades and blade drift. A wider set increases blade drift and leaves material in the midline of the kerf. (KF)





Raker Set

Teeth are laterally set to opposites similar to the pattern in alternating set saws. The raker set, however, introduces a tooth with no lateral bend subsequent to the two teeth set to either side.



Wavy Set

In wavy set blades, teeth are laterally bent in groups. The number of teeth in a group varies and this is most typically seen in fine-toothed hacksaw blades.

Saw Shape

Shape applies to the contour of the blade, the tooth as it is cut out of the saw blade, and if the teeth are filed at an angle. The most common classifications are rip and crosscut saws. These styles are important in that each function in a different manner to effectively cut different types of material.

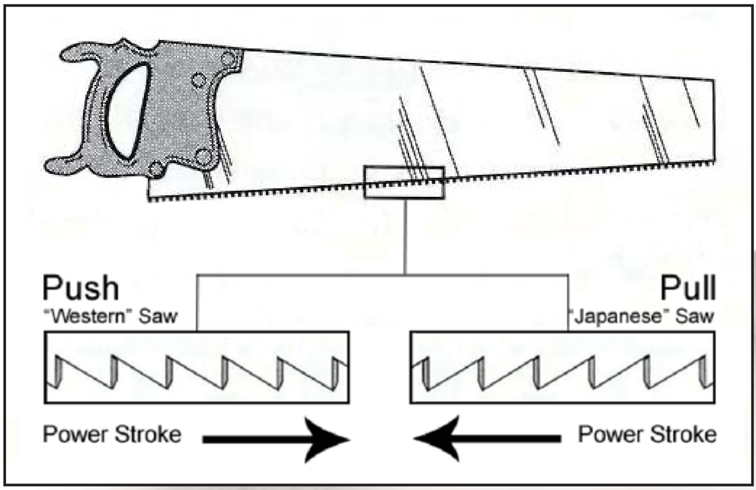
Contour

Flat. Typical straight blades, inclusive of both hand- and mechanically-powered saws produce a flat-bottomed kerf. (KF)

Curved. Curved blades (such as circular saws) and flexible blades (such as gigli saws) will leave a curved kerf floor. (KF)

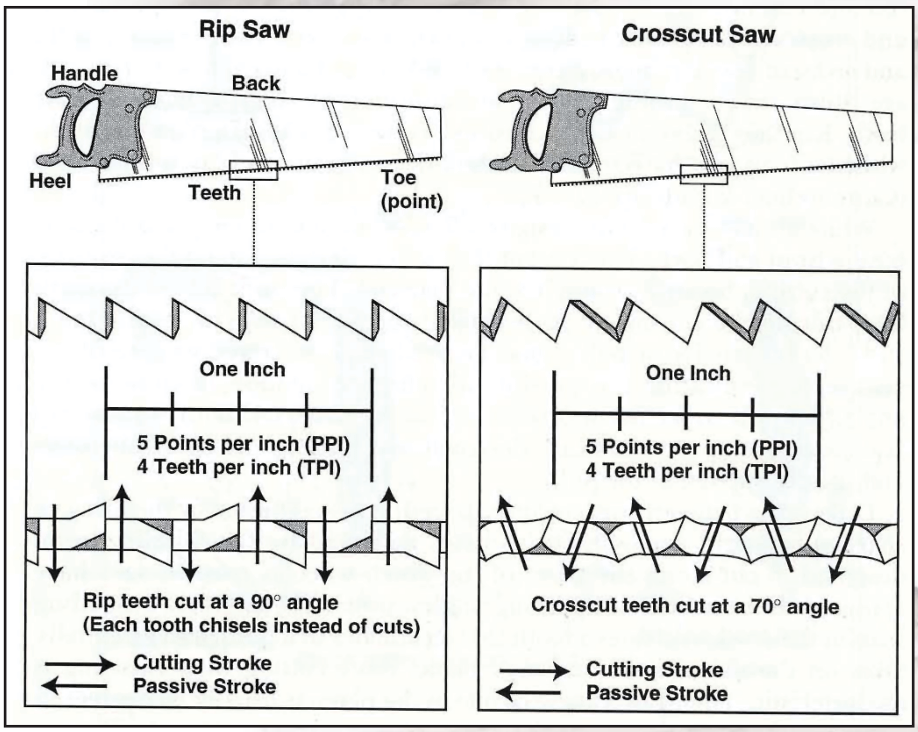
Tooth Orientation

Tooth orientation is diagnosed in concert with the direction of sawing motion. The confluence of features visible in analyzing saw direction will allow for a determination of whether or not a blade's power stroke is occurring on the push or the pull.



Pull Saw. A typical "Japanese" saw cuts on the pull stroke. It has a thinner blade and produces less material waste which, in turn, creates a narrower kerf. In general, pull saws have smaller teeth and more teeth per inch producing a cleaner cut but at a slower rate than a push saw.

Push Saw. A typical "Western" saw cuts on the push stroke. It has a wider blade and produces more material waste which, in turn, creates a wider kerf. In general, push saws have larger teeth and the push stroke is more powerful giving the cuts a more accurate and efficient action than a push saw.



Tooth Angle

Rip. The teeth of a rip saw are not angled or filed. The teeth are simply notched out of the blade. As such, these saws essentially chisel out material rather than cut it. Rip saws are designed to cut with the grain of wood.

Crosscut. A crosscut saw has teeth that have been filed to an angle. The filing allows each tooth to act as a tiny blade which will cut through material. Crosscut saws are designed to cut across the grain of wood.

Saw Power, Hand vs. Mechanical

Separating hand powered from mechanically powered saws is approached in by the examination of three characteristics; consistency of cut, energy transfer, and material waste. All characteristics increase with mechanically powered saws.

Consistency of Cut

Consistency of cut is anticipated in continuous cut power saws, where the blade continuously cuts material at high speeds. However, this consistency is evident in all power saws, even those with reciprocating actions. Hand powered saws typically exhibit an inconsistency in cut evident on the kerf wall. (KW)

Energy Transfer

Mechanically powered saws increase energy transfer to cut bone. Increased tooth speed, saw weight, and torque lead to a tendency to inadvertently discontinue a cut. Because of the ease of the cut, it is not important to reinsert the blade in the kerf that was initially started. The opposite tendency is true in hand powered saws as it is more efficient to reinsert the blade in the false start. (FS)

Material Waste

Power saws are generally characterized as wasteful of material. This may be accredited to the stout blade design or the "ease" of producing a cut. If power saw cuts are produced with little energy expended, it is likely that more cuts are produced and more material is wasted. (FS)

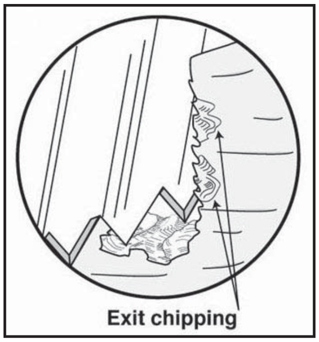
Direction of Saw Motion

Cutting Stroke

Cutting stroke is defined as a continuous action or a single direction of a reciprocating action that produces a majority of the cut. If an equal force is applied to a reciprocating blade, the direction of stroke cutting or chiseling the most bone is the direction of the cutting stroke.

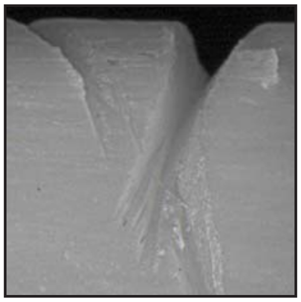
Blade Progress

Indicators of direction of saw progress center on the false start and break away spur. Initial cuts are commonly accompanied by false starts, where individual teeth strike and incise material or where actual kerfs are abandoned for another cut. The plane formed between the false start and the break-away spur or notch gives the precise direction of saw progress. Direction of blade progress is perpendicular to stroke and tooth striae.



Entrance Shaving. As the saw enters the side of the bone, the blade can shave the bone entrance giving it a polished and scalloped appearance. This shaving can be due to twisting of the saw such that the blade is not allowed a direct path into the kerf, but more often it is simply due to the tooth set being wider than the blade, forcing each tooth to cut a kerf. Seldom is there chipping as the tooth enters the bone, and if present, it is difficult to observe. (KW)

Exit Chipping. Exit chipping is present with few exceptions and even exists in cuts created by saws designed with no front or back to the teeth. Exit chipping will occur at the end of the cutting stroke or on the side of the stroke emphasized by the individual sawing. As a rule, the largest chips of bone are removed on the cutting stroke as the blade exits the bone. (KW)



Kerf Flare. Kerf flaring occurs on only one side of the kerf floor. It indicates the 'handle-end' of the blade as it expresses the increased movement of the flexible blade as it continually enters the kerf. The opposite end of the kerf floor does not exhibit flaring by virtue of the blade becoming stabilized as it progresses along the kerf. (KF)

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Exemplar Saws

Bone	Blade #	Blade Type	Blade Set Width	Tooth Height	Distance Between Teeth	TPI	PPI	Set	Tooth Type	Direction of Cut
	1	Rip Saw	0.060	0.165	0.205	4.5	5.5	ALT	CHISEL	PUSH
	2	Arched Pruning Saw	0.080	0.130	0.140	7	8	ALT	CUT	PULL
	3	Backed Saw	0.055	0.045	0.090	11	12	ALT	CHISEL	PUSH
	4	Coping Saw	0.030	0.040	0.045	15	16	WAVY	CHISEL	PUSH
	5	Carpenter Saw	0.050	0.160	0.083	14	15	ALT	CUT	PULL
	6	Hacksaw	0.040	0.020	0.060	18	19	RAKER	CHISEL	PUSH
	7	Stryker Saw	0.045	0.030	0.040	23	24	ALT	CHISEL	P/P
	8	Junior Hacksaw	0.040	0.035	0.015	24	25	WAVY	CHISEL	PUSH

TPI Reference

Distance Between Teeth	TPI	Distance Between Teeth	TPI	Distance Between Teeth	TPI	Distance Between Teeth	TPI
0.02	50.0	0.08	12.5	0.14	7.1	0.2	5.0
0.03	33.3	0.09	11.1	0.15	6.7	0.21	4.8
0.04	25.0	0.1	10.0	0.16	6.3	0.22	4.5
0.05	20.0	0.11	9.1	0.17	5.9	0.23	4.3
0.06	16.7	0.12	8.3	0.18	5.6	0.24	4.2
0.07	14.3	0.13	7.7	0.19	5.3	0.25	4.0

SAW MARK DATA SHEET (NOT FOR CITATION OR QUOTATION) Steven A. Symes

CASE NO:___________ OTHER:_________ DESCRIPTION:___________ BONE:_____________

CUT LOCATION: ________ From Prox/Dist end Total cut surfaces:______

ORIENTATION of cut to bone: [Prox________to__________Dist]
A P L M A P L M

DIRECTION
DIRECTION of Saw Progress [False -starts________to_________B-A spur/notch]
A P L M A P L M

DIRECTION of Cutting Stroke [Entrance Shaving_________to_________Exit Chipping]
A P L M A P L M

SAW BLADE AND TOOTH:

SIZE	tooth width_____			Based on ______
	tooth dist_____	thus TPI		Based on ______
	kerf min width_____	kerf max width_____		Based on ______
SHAPE	chisel (rip)_____	cut (cross-cut)_____		Based on ______
	flat______	curved______		Based on ______
	push______	pull______		Based on ______
SET	alt_____	raker_____	wavy_____	Based on ______
POWER	hand_____	power_____		Based on ______

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CASE NO:___________ OTHER:_________ DESCRIPTION:___________ BONE:_____________

CUT LOCATION: ________ From Prox/Dist end Total cut surfaces:_____

ORIENTATION of cut to bone: [Prox________to__________Dist]
A P L M A P L M

DIRECTION
DIRECTION of Saw Progress [False -starts________to_________B-A spur/notch]
A P L M A P L M

DIRECTION of Cutting Stroke [Entrance Shaving_________to_________Exit Chipping]
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	flat______	curved______		Based on ______
	push______	pull______		Based on ______
SET	alt_____	raker_____	wavy_____	Based on ______
POWER	hand_____	power_____		Based on ______

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CASE NO:___________ OTHER:_________ DESCRIPTION:___________ BONE:_____________

CUT LOCATION: ________ From Prox/Dist end Total cut surfaces:_____

ORIENTATION of cut to bone: [Prox________to__________Dist]
A P L M A P L M

DIRECTION
DIRECTION of Saw Progress [False -starts________to_________B-A spur/notch]
A P L M A P L M

DIRECTION of Cutting Stroke [Entrance Shaving_________to_________Exit Chipping]
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SIZE	tooth width_____			Based on _____
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	kerf min width_____	kerf max width_____		Based on _____
SHAPE	chisel (rip)_____	cut (cross-cut)_____		Based on _____
	flat_____	curved_____		Based on _____
	push_____	pull_____		Based on _____
SET	alt_____	raker_____	wavy_____	Based on _____
POWER	hand_____	power_____		Based on _____

NOTES:

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