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# Tool Marks in Bones and Cartilage

Tool mark examinations hold an eminent place in criminal routine work. Since the fundamental treatises of Kockel [*1-3*], the examination technique has continually been improved and extended to numerous methods of criminal investigation. Thomas [*4*] has given a fascinating survey of this development and has listed a series of notable authors. Further important publications are those by Mezger et al [5], Burd and Kirk [*6*], Burd and Greene [*7-9*], Flynn [*10*], Biasotti [*11*], Burd and Gilmore [*12*], Rees and Cundy [*13*], and, in German publications, by Mezger et al [*14,15*], Nippe [*16*], Specht [*17,18*], Bessemans [*19*], Angermayer et al [*20*], Winkler [*21*], Katona [*22*], and Hantsche and Schwarz [*23*].

In the investigation of deaths caused by violent means, the identification of the injuring implement plays an important roll. Skin wounds are, according to the experience of Janssen [*24*], less suitable for this purpose. Indentations or punctures of the skull, on the other hand, often reveal quite reliable evidence, as shown in the reports by Ziemke [*25*], Holzer [*26*], Smolaga et al [*27*], Thomas and Cuelenaere [*28*], and Kobiela and Socha [*29*]. Motovilin [*30*], succeeded in identifying the tool marks in a pierced cervical vertebra. The knowledge concerning tool mark analysis gathered during the examination of wooden or metal objects has long been used for the examination of injuries to the human body as well. Thomas [*31*], reporting on two of De Rechter's cases [*32*], thinks Reiss [*33*] to have been the first to dare this step. Among the German literature, however, there was a publication by Schulz [*34*] as early as 1906 following directly upon Kockel's observations. Kockel himself makes a comment upon this treatise [*35*]. Notch marks on skull bones have repeatedly been described, as by Esser [*36*], Korpássy and Tacács [*37*], and Bonte [*38*]. In most cases the tools identified were axes, more seldom a hammer, and, in one case, a gun barrel.

Recently Bosch [*39*] and Bonte [*40*] drew attention to knife wounds in rib cartilage which are frequently encountered in cases of thoracic stabbing and which offer excellent opportunities for tool classification. Important progress has also been achieved lately in the analysis of saw marks incurred during the criminal dismemberment of corpses [*41,42*]. Since, as far as we know, neither of these kinds of marks has yet been mentioned in Anglo-American literature, a short description seems appropriate.

## Stab Injuries in Cartilage

The direction of the knife piercing the cartilage depends entirely upon the shape of the blade. Knives with blades which decrease in width from the back to the cutting edge are displaced, upon entry, parallel to the blunt edge of the point. Only after overcoming the curve of the back does the knife start moving parallel to its total axis. Thus, the mark

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sketch (Fig. 1) is distinguished by two differently directed sets of parallel rills whose intervals, after an exact reconstruction of the dynamic progress, yield more or less exact

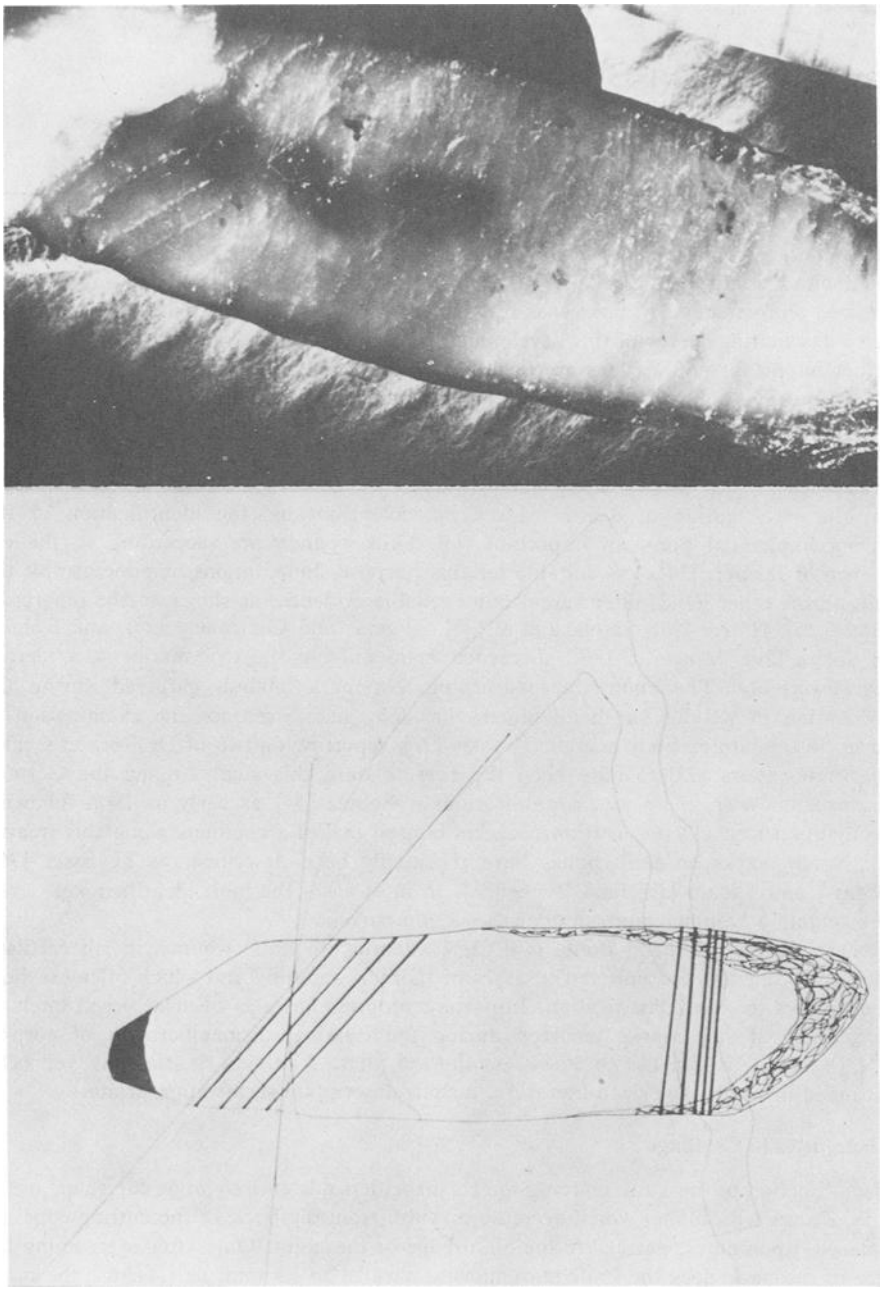

FIG. 1—*Pierced cartilage with two differently directed sets of parallel rills and graphic explanation of the mode of formation.*

data about the shape of the point of the knife and about the type of grinding. On the other hand, knife blades with their edges curved upwards towards the back of the knife move from the very start straight forward and on axis through the rib cartilage. If one projects vertically the points on a curve produced by the rills made from the individual knife teeth, the distance between the rills is seen to grow progressively greater (Fig. 2). Stiletto-shaped knives which are ground on both edges likewise leave particularly characteristic tool marks.

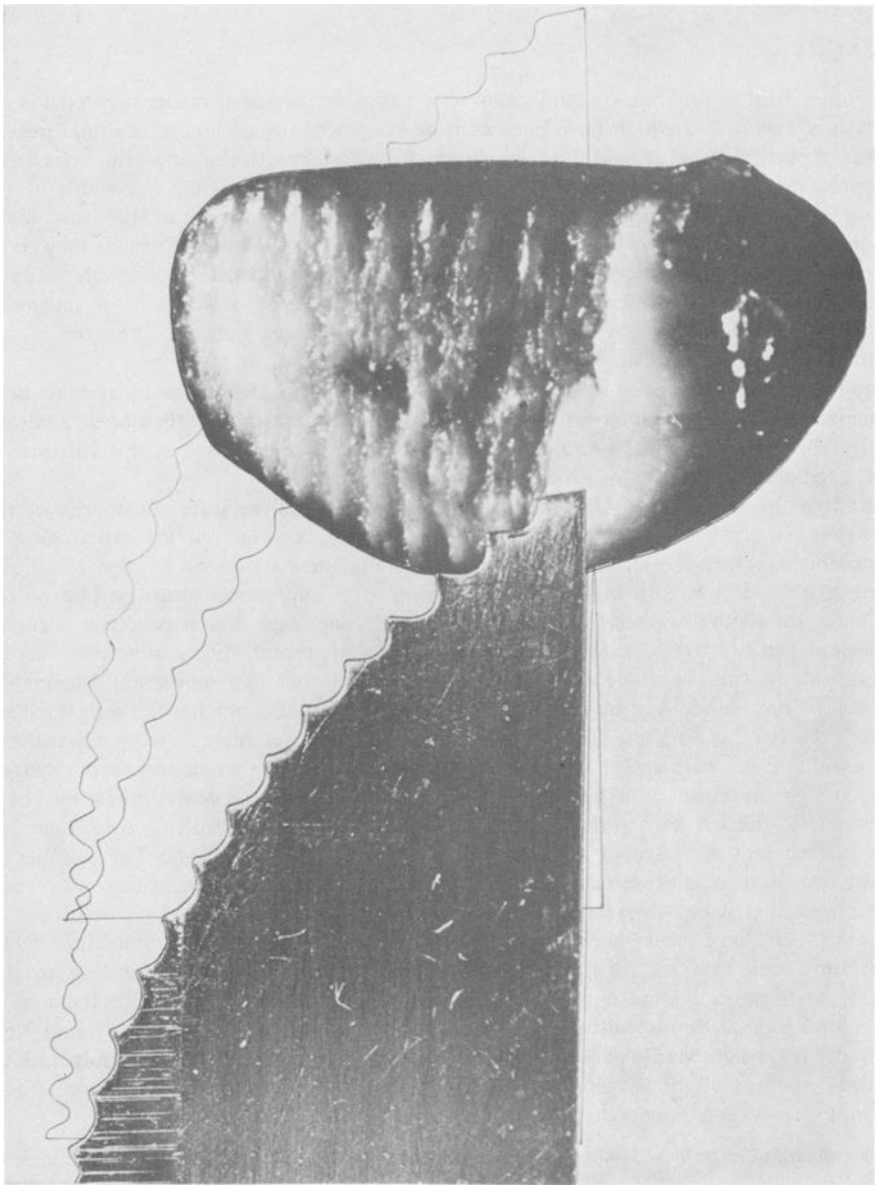

FIG. 2—*Pierced cartilage with progressively growing distance between the rills.*

Besides such class characteristics of serrated knives there also occur distinct marks produced by accidental nicks in the knife blade, which may then allow an individual identification going beyond class identification. Since even brand-new knives may show micronotches due to the grinding process, one can almost always count on finding individual marking patterns. However, the distinction of the marking details at both sides of the stab canal, produced by different knives of the same fabrication series, requires a special examination technique where the so-called light-section microscope has proved helpful [*43*].[2]

**Saw Marks**

Another field of tool mark examination which thus far has been rather neglected is the analysis of saw marks which have been considered practically useless in criminal investigation. Apart from occasional damage caused by collision with the saw grip, which can be appraised as impression marks [*44,45*], it was known only that the width of the groove left in an incompleted sawing is evidence of the setting of the saw blade [*15,46,47*]. Bellavić [*48*] observed certain striations to recur in similar form. If they could be more or less reproduced the author spoke of the marks as "relatively equal." Recently, however, Pichler and Röhm [*49*] have been using sawdust as a means of identification since there is supposed to be a correlation between the size of the chippings and the saw teeth.

Saw marks which occur in human bones during criminal dismemberment have been recognized as such by numerous authors [*41*], but in no case have they been analyzed further. Only recently could more extensive experiments be performed at this Institute of Legal Medicine, the results of which are now available.

The hypothesis had been that saw marks destroy themselves since the marks of the preceding saw teeth would be covered by those of the following, but the explanation of the manner in which the characteristic stepped arrangement is formed has led to quite a different idea. Indeed, during—and only during—the unpowered return stroke of the saw blade do all the saw teeth lie on approximately one level, which produces a rather crude and deep furrow. During the forward stroke, however, during which the actual sawing is done, the saw blade at the same time shifts deeper in a movement diagonal to the axis of the blade. At this each tooth leaves a fine mark which is slightly inclined towards the rougher furrow. Thus, between two rough grooves there develop several very thin parallel rills, the number of which depends upon the number of saw teeth engaged (Fig. 3). The number of engaged teeth in normally set saws, whose teeth are bent alternately to the left and to the right, can be determined by multiplying by 2, since on each surface only those teeth bent in that direction can be engaged. The number is usually two thirds of all the teeth. The number of levels or return stroke furrows reveals the number of strokes necessary to complete the sawing through.

Saws which have been used for a longer time sometimes show individual teeth protruding somewhat out of the phalanx of the remaining teeth. According to the position of these individual abrasion or damage features, bones sawed with them have been found to show levels with more prominent rills (as in Fig. 3). Since a frontal view under streaking light rarely allows one to decide whether one is dealing with indentations or ridges, such as might be caused by the loss of individual teeth, an additional cross-sectional view is recommended.

[2] The apparatus casts a band-shaped light beam on the mark groove which follows the form of the fine profile and, regarded microscopically at a right angle, is comparable to a quantitatively fully interpretable width-depth diagram.

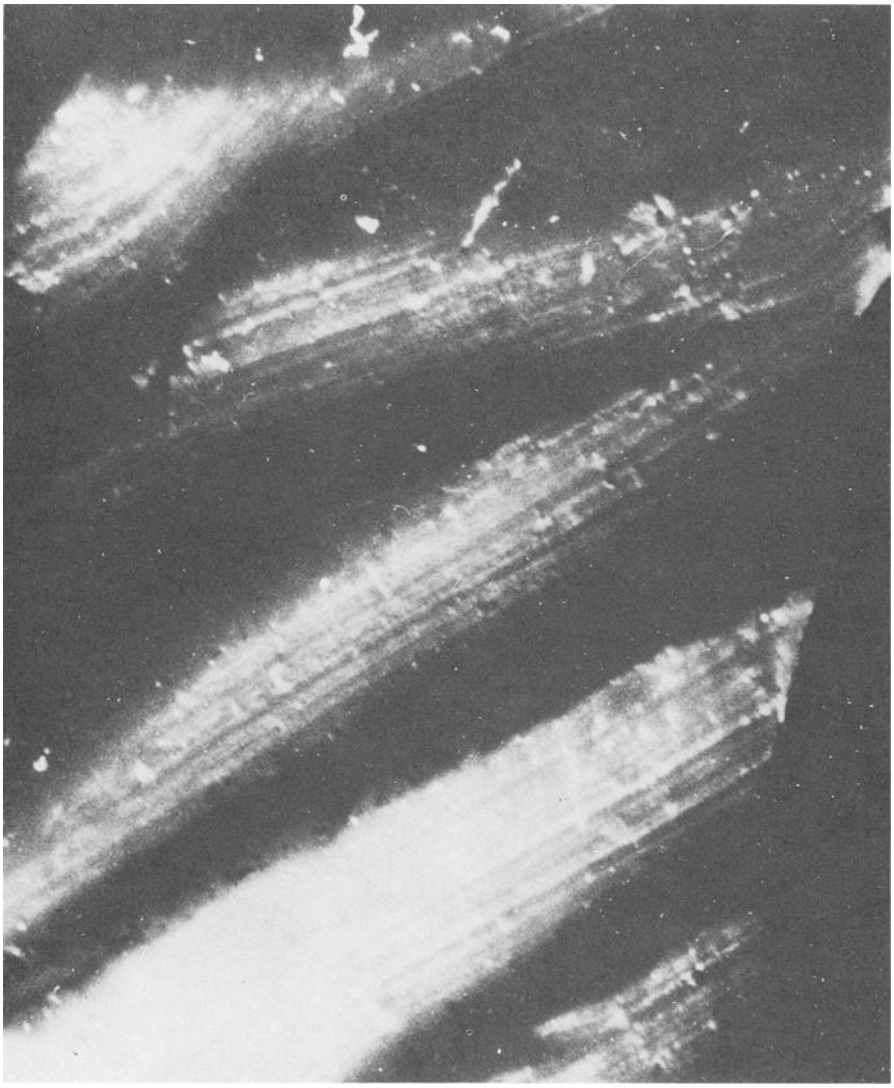

FIG. 3—*Saw marks showing two regularly recurring, prominent rills.*

Moreover, there may sometimes appear scratches vertical to the sawing level which extend over several saw marks (Fig. 4). According to our experiences they are produced by grazing saw teeth during the withdrawal of a jammed blade. Thus, the distance measured between the parallel scratches corresponds, with normally set saws, to twice the distance between the teeth. If it is possible in this way to determine the distance between the teeth as well as the number of the engaged teeth, one may even estimate the length of the saw blade.

Further conclusions can be drawn from the marks on the surface of the bone made during the initial setting of the saw into the bone and by a slipping saw blade. The theory that the setting of the saw blade can be concluded from the width of the sawed

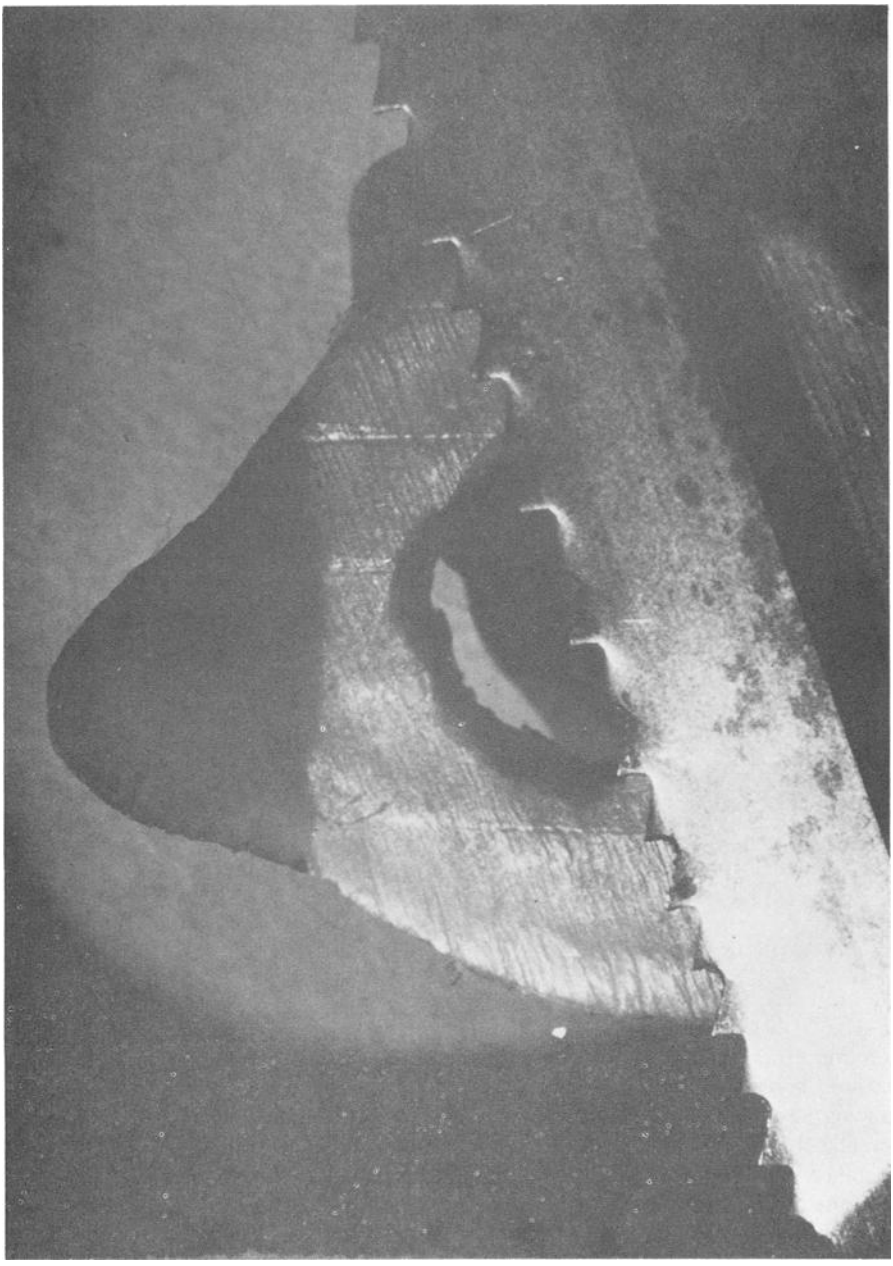

FIG. 4—*Four scratches vertical to the sawing level; their distance corresponds to twice the distance between the teeth.*

groove was confirmed by experiments on bones. Since bone apparently shows traces better than wood, the creation of rills can sometimes be observed at the bottom of the partially sawed portion of a bone which was afterwards broken. These rills can yield information concerning the gauge of the saw blade and the set of the saw (there can also be saw blades with a waved set) (Fig. 5).

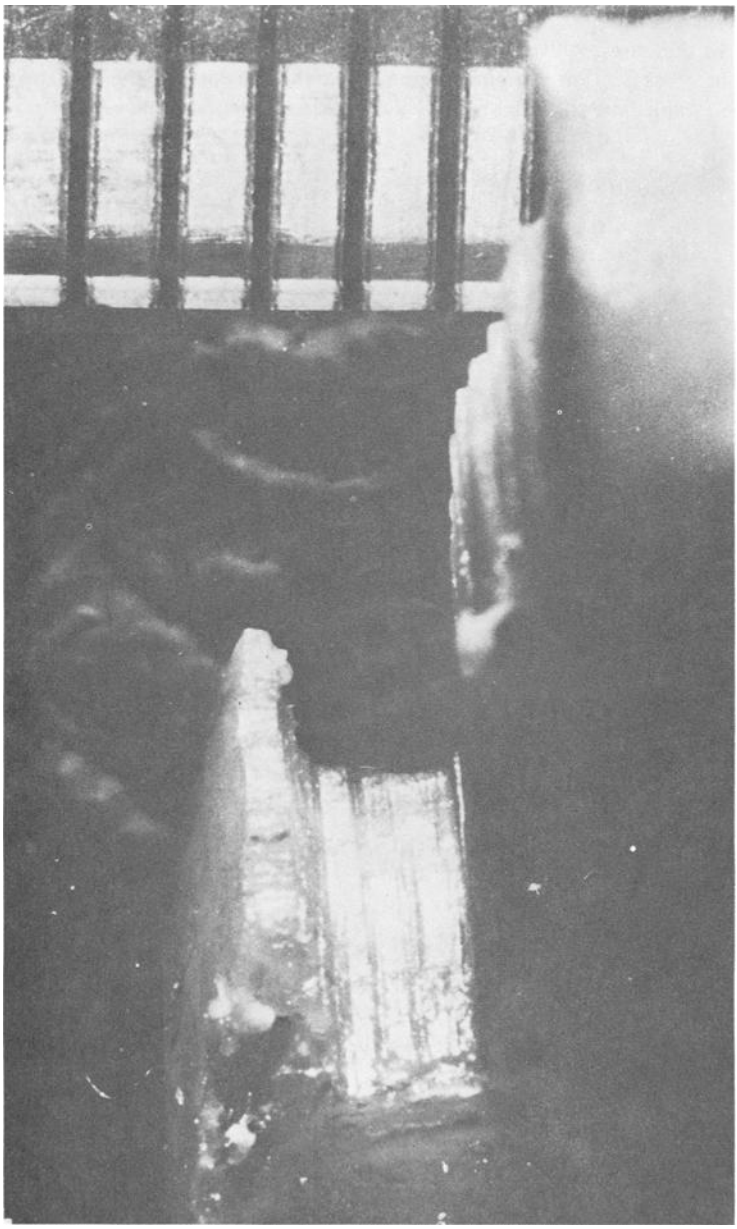

FIG. 5—*Breakage of a partially sawed bone: the rills yield information concerning the gauge of the saw blade and the set of the saw.*

**Discussion**

As can be seen, in favorable cases it is possible to identify practically all essential metric features of the saw used in a crime by examining the tool marks found on the bones of dismembered bodies. Most of these traces reveal class characteristics. Usually the possibilities of identifying individual characteristics are less satisfactory. Apart from damages to the saw in the form of warps of the blade or of loss of single teeth, there are variations in the shape of the saw teeth, too, which can be drawn for individual evidence. In the cases of "trial" beginnings, those variations may leave traces which are identical in cross section. In uncommon anomalies of shape, the variations at least permit the establishment of highly individual evidence (Fig. 6).

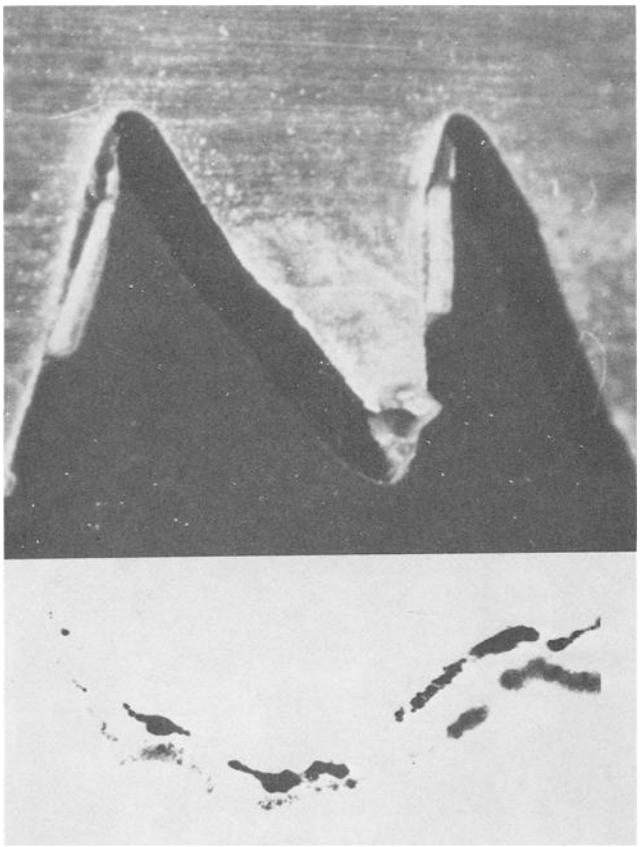

FIG. 6—*Uncommon anomality of a saw tooth whose cross section corresponds with that of a superficial "trial" saw mark.*

Furthermore, a detailed examination and analysis of cartilage stab injuries in thoracic knifings should be recommended as a matter of principle. In particular, the regular trace patterns on specially ground knives can be reproduced well. Besides the striking class characteristics, the relief of the stabbed cartilage frequently reflects finer individual marks. The technique of examination makes use of Kockel's well-known method or,

more favorably, realistically produces marks for comparison by experimenting on cartilage followed by the representation of the microrelief.

Modern criminology would now be unthinkable without tool mark examinations [*4*]. In the course of time the investigation technique has advanced continually from Kockel's original hypothesis, particularly in the wide field of ballistics. Tool mark identification still continues to be important. The more recent methods of establishing proof only supplement it; they cannot replace it. The purpose of this paper is to call to mind the fact that the method of tool mark examination which was founded by a forensic physician has not, despite the outstanding progress made in the field of criminal technique, lost meaning, but rather has won it, especially for the forensic physician. In his special task—the explanation of the causes of unnatural deaths, including the reconstruction of the criminal action—the forensic physician should take advantage of criminalistic experience. At the least, human bones and cartilage exhibit regularities similar to those found on inanimate materials. Our investigations prove that stab injuries in cartilage and saw marks in dismembered bones frequently permit the estimation of the type of implement and, moreover, sometimes enable the individual identification of the tool used.

**Summary**

The identification of the implement used is an important factor in the explanation of the causes of violent deaths. Hitherto existing knowledge has been almost exclusively confined to the damages to skull bones. This paper draws attention to tool marks in the area of pierced rib cartilage and considers the possibilities of their analysis. The evaluation of saw marks is further discussed on the basis of sawing experiments. Also, there are features and peculiarities which can help to solve the problems posed by criminal dismemberment.

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