Chapter

Forensic Analysis and Interpretation of Tool Marks

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Abstract

The forensic analysis and interpretation of tool marks raise for consideration key methods and advances in the field of tool marks in forensic science. This chapter shows how tool mark analysis can be utilized in the course of criminal investigations. The focus of the chapter is on bringing together as much scientific knowledge in the area as possible in an accessible manner. It covers all aspects of tool mark evidence from the crime scene to the courtroom. This chapter provides information about tool marks in an effort to assist tool mark examiners as well as people practicing forensic science, crime scene examiners, crime investigating officers and members of the legal profession. It includes information about the analysis of tool marks at the crime scene and in the laboratory, the interpretation and assessment of challenges for examination and interpretation and also the way in which tool mark evidence can be presented in a courtroom.

Keywords: forensic analysis, tool marks, investigation, court, crime scene, interpretation

1. Introduction

Tool mark identification is a fascinating forensic science discipline. By comparing the pattern of the tool marks in question and the pattern of the tool marks generated by the tool in a laboratory environment, a skilled analyst can give an opinion based on the accuracy of the questioned tool mark produced by a specific item [1]. This assists the forensic investigator in matching the marks on tools to crime scenes. Forensic tool mark identification includes firearms identification, an area of tool mark investigation that specializes in identifying different firearms and parts of a firearm being used at crime scenes. It also includes fracture matching or a physical fit [2], whereby two specific objects are analyzed to determine whether they have been at one time a single unit. If that is the case, the investigator will further analyze how the two objects come into contact and how they affect each other.

Tool marks can be generally understood as impressions or marks that are produced by a tool [3]. When a tool contacts a surface with sufficient force, a mark or an indentation is permanently left on the receptive surface.

A striation, as defined by AFTE, is a range of marks on the surface of an object [4]. These marks are produced by a combination of impact and motion. A pry mark made by the tip of screwdriver is a type of striated tool mark [2]. Similarly, an impression can be defined as a range of marks on the surface of an object [4]. As with a striation, an impression is produced by a mixture of impact and motion.

Notably, impressions are not caused by strong impact but appear on a surface as soft or shallow indentations. A hammer impact is a type of impressed tool mark.

Tools may be connected to tool marks and vice versa due to certain patterns or anomalies during the manufacturing process embedded in their surface. It is argued that patterns and anomalies of the tool mark are specific to each tool; the distinguishing features of a particular tool may be one aspect, just as the markings on a bullet can lead to a particular one and can be identified and compared visually. In consideration of this, a forensic investigator can become familiar with the manufacturing processes used to manufacture the working surface [5] of a tool and can compare the class features with the same surface of the tool such that it is possible to measure the uniqueness of a tool and its tool mark. Knowledge and understanding of tool manufacturing methods, along with close examination of tools and markings of tools, will make it easier to carry out this particular recognition.

There was no direct way in the past to associate a tool mark with the tool itself, and little progress has been achieved with the advent of modern forensic technology. In using tools to gain entry, a burglar will invariably leave tool marks behind that are of forensic significance and potentially incriminating, which can provide vital evidence to investigators and prosecutors. Given this, the essential factors that influence both tool mark production and the subsequent inspection of such marks in the forensic examination can be determined. These factors include the following:

1. The surface material that the tool is functioning on

2. The material used in order to construct the tool

3. The relative hardness of each material

4. The manufacturing procedure followed in order to construct the tool

5. The tool operational surface [6].

2. History of tool marks

Since many previous centuries, a historical understanding of the tool mark has been recognized that marks can be connected directly to tools, but few written references are typically found on this specific subject. A cited example often comes from China in the Twelfth century, where various wound shapes created by cutting tools such as sickles were considered, but even in China, there is little evidence of their importance.

Henry Goddard (1800–1883) of Scotland Yard is remembered as the first investigating officer to collect forensic evidence by analyzing a bullet and its related pattern to investigate a murder [7]. In 1835, using a bullet recovered from the autopsy victim's body, a defect was discovered that could be traced back to the original mold from which the bullet was made. In 1891, Hans Gross published a book entitled "Handbuch für Untersuchungsrichter als System der Kriminalistik" detailing all the basic precautions for the analysis of tool marks [8].

In 1953, a popular book entitled "Crime Investigation" textbook written by the renowned criminalist, Paul Leland Kirk (May 9th, 1902 – June 5th, 1970), explains the need for cast marks found in crime scenes if the item with the mark cannot be transported to the laboratories and makes a strong distinction between "compression marks" and "sliding marks." In his book, he examined immersed marks by using macrography while comparison microscope was used to analyze striated marks, along with the examination of physical fit. In the 1974 edition, there is a reference to the work by Biasotti [9], *The Principles of Evidence Evaluation" as applied to Firearms and Tool Mark Identification*, which contains some of the first references for objective methods for evaluating striated marks.

In 1958, a book entitled 'An Introduction to Tool Labels, Weapons and the Striagraph' was written by John E. Davis, a prominent criminalist and the chief of the Oakland Police Department (CA) Criminalistics Division (Crime Lab). This textbook also introduced a new advanced piece of research equipment called "Striagraph," which was able to calculate, trace and record microsurface contours and was the precursor to advanced laser and digital imaging techniques for future bullet surface scanning technology [10].

The Association of Firearms and Tool Mark Examiners (AFTE), an international nonprofit organization devoted to facilitating the identification of firearms and tool marks, was founded in the United States in 1969 [11].

3. Definition of tool marks

Tools are mostly directly related to object markings, because at the time of tool production, such designs or irregularities are imprinted on their surface, so it is implied that these patterns and variations might be part of the identification features of a particular object; for example, marking bullets can lead to a particular firearm. Furthermore, these substantially different types and irregularities of the instrument can be visually identified and compared using forensic techniques [12].

The term "tool mark" is defined in a number of ways. A widely accepted AFTE definition defines tool mark as "If any object or instrument reaches the surface with enough force to allow its signature design to be indented, this form of marking is referred to as a tool mark.". In another definition [6], it is stated that "An instrument that is considered to be sufficiently stronger from two objects acquires comprehensive force when it comes into contact with each other, which leads to the softer one being marked.".

Biasotti and Murdock [13] state that "When two objects begin to interact, the extremely hard object will stamp the surface of the softer object. The relative hardness of the two artifacts, the pressures and motions, and the appearance of the microscopic discrepancies on the object are all factors influencing the character of the generated toolmarks." It is necessary to establish the correlation between a tool mark and the tool that produced it in criminal investigations such as burglaries. For instance, if a burglar chooses wooden or metal bars to force entrance into a home, the marks left by the tool on the doorway are strong evidence of the involvement of that tool for that legitimate purpose at the scene of the crime. If the tool is linked with, or close to, a suspect, it enables for the identification of a link between the accused person and the incidence of the crime.

4. Types of tool marks

Generally, there are three categories of tool marks left by tools on the surfaces they hit. These impressions are produced by the possibility of a compression action, sliding action or cutting action occurring.

A compression impression: Probably the most common and most negative representation of the surface of the tool, caused by pressure, blow or gouge of the tool on the surface of a wood, metal or other surface. Compression is imprinted on softer material when tool surface presses against its surface [14]. For instance, a screwdriver is most often used to tighten or loosen screws. However, if it is used to pry open a widow, it will leave impressions in the windowsill.

Friction marks (sliding action): The second type is a mark of abrasive wear or resistance left by the tool's sliding or chopping action that creates striations on a marked surface. Friction marks are fine parallel striations and are a characteristic feature left by a tool scraped across a smooth surface, such as dressed wood or metal. It is common to focus on such striations when making bullet and tool mark comparisons. Parallel lines have the potential to be matched using microscopic comparison. There are an infinite number of ways to apply a tool to a surface, and the resultant striations are the effects of every variation. For example, when a crowbar is forced into the area between a door and the front part of the door to force the door wide open, pressure is applied to the tool handle. An abrasion or friction mark is created by forced application of the crowbar. The majority of bull cutter marks on rods or wires, screwdriver scratch marks and knife or axe cut marks are examples of friction mark markings.

Cutting edges are not as commonly used in the commission of crimes as prying tools with blunt edges, so finding marks of cutting tools is not frequent. There is a high significance in cut marks being positively identified with the tool producing them. A cutting impression is a combination of these two impression types, as is found in scissors.

From these three tool mark impression types, both the class and individual characteristics of the tool can be identified; for instance, marks left on a doorway from a pry bar can be matched back to that specific pry bar.

During tool mark analysis, the analyst may discern what type of tool made a particular mark, and whether a tool in evidence is the tool that made it. The tool mark can also be compared to another tool mark to ascertain if the marks were made by similar, or the same, tools.

5. Types of tool marks comparison

A well-known and extensively used forensic methodology is the comparison of tool marks, which is typically regarded to provide convincing trial evidence and facilitate the investigation of a crime. However, there is a great deal of ambiguity as to the uniqueness of such marks and, in particular, the probability of more than one tool replicating a mark. According to Houck and Siegel [15, 16], tool mark examiners need to have a conceptual understanding of how to produce and machine a variety of tools. Limitations on comparative forensics have initiated the need for an objective, as each tool has specific surface characteristics for the identification of tool marks to facilitate scientific research. In 2009 National Academies report, researchers recommend reinforcing the scientific justification for the standards and specifications for the tool mark identification in forensic science.

The forensic principle of comparison explains that only the like can be compared with the notion of comparison. It reinforces the need for samples and specimens to be included for comparison with the objects in question. Therefore, the prime purpose of forensic comparison is to establish which characteristics and specifications of the samples in question obtained from the crime scene (including a tool or a population of reference items, screw bag or plastic bag roll) varied or directly correlate with those obtained from the source on the control item. Comparing features, however, is a deceptively simple process, but understanding what the outcome implies is much more difficult if one does not understand exactly what the characteristics and specifications are or how they were acquired.

Another challenging part of a comparison is to examine the manufacturing patterns associated with the "control" object. The manufacturing process leaves distinctive microscopic striations on the tool's operating surfaces as the marks produced depend not only on the type of tool being used but also on how it is used (as a hammer, or lever or force exerted), the contact position (leading angle or trailing angle) and other factors that may help to identify the metal tools [16].

There are three categories of features that an examiner will need to identify:

- Class features: A combination of features that facilitate the positioning of the sample in a class of related material properties. Champod et al. [17] state that the class characteristics of a tool are usually unique and macroscopic; for example, class characteristics of firearms are correlated with the tensile strength of the weapon and projectile or cartridge steel and the rifling in the firearms barrel that is transferred to the bullet.

- Subclass features: Attributes that are not specific to a particular object but provide some discriminatory practices among groups of tools with features of the very same class. They appear during processing but are not necessarily introduced. Over time, the reference of subclass functionality can evolve. Nichols [4] explains what qualifies a characteristic as subclass: "If one were to examine a cast of the bore of a firearm, such characteristics would have to exist for the entire length of the cut surface. If a certain characteristic appeared after the cut surface had already started, then it would be an imperfection caused by the current process. If it disappeared before the end of the cut surface, then it is gone and by definition of its absence cannot be passed onto the next cut surface. Therefore, the only characteristics capable of being defined a subclass would be those that persist for the entire length of the cut surface."

- Individual/unique characteristic: Individual characteristics relate to the specific characteristics of both the questioned samples and the reference samples, which share a similar origin with a high degree of reliability. Examples of evidence possessing individual characteristics are fingerprints, tool marks and markings on bullets.

Therefore, in order to analyze the results, it is imperative to understand the sets of features and details generated during the production process and then use, how they will be portrayed in a mark and how to differentiate between the different types, as this will determine what you can say about the comparison. The quality of the situation mark in a mark comparison is always the main limitation. Information that may have been visible on a tool may not have been replicated in a mark for certain variables, such as the physical parameters of the material. If they are considerably weaker than the tool, the information of interest cannot be replicated completely.

However, occasionally, the difference will be significant and on occasions may even be to the extent that one expert will say the tool was responsible and the other that it was not the tool. Occasionally, while the difference is apparent, it may be to the degree that one analyst states that the tool was accountable and the other that it was not the tool. With all this perspective, the importance of the independent critical results test of a secondary tool mark expert should not be overlooked. However, this is not always necessary, and in order to settle the debate, a third expert may be required to conduct a verification.

AFTE Theory of Identification (1998) classified four categories of tool examination:

- Identification is the inference that the class traits of two samples appear to be the same and that the individual features are reasonably agreed to conclude that the same weapon was shot. If they agree, for instance, two copper jacketed bullets are found.

- Inconclusive agreement of class characteristics is defined as "the outcome of a comparison in which there is some agreement of individual characteristics and all discernible class characteristics, but insufficient for identification, agreement of all discernible class characteristics due to an absence, insufficient, or lack of reproducibility, agreement of all discernible class characteristics and disagreement of individual characteristics but insufficient for an elimination".

- A substantial disparity between distinguishable class characteristics and/or individual characteristics is triggered by elimination, or exclusion from the analysis. For fired bullet comparisons, an exclusion is usually based on observed differences in some of the general rifling properties.

- In the absence of microscopic marks, "Inappropriate for comparative analysis," appears.

6. Forensic examination of tool marks

The purpose of the analysis and comparison of the tool mark is to determine whether a mark or a series of marks in dispute have been made by a specific tool. Careful examination of the questioned tool mark(s) typically offers descriptions of the class characteristics and size of the tool responsible for making the marks in question, if the tool is damaged and how the tool was used to produce the alleged marks [10]. A tool mark analysis primarily initiates with a morphological examination of the tool and its features. For each tool mark, such as branding, cutting, compression, crimping, engraving, firing, etc., Klees [18] therefore suggests a categorization system to enhance the common classification systems found in the literature and to provide a more standard way. Tool mark analysts are objective and conceptual analysts who seek to assess if they are combating a tool mark and a similar tool. They use their results on the basis of their assessment of the evidence. Tool mark examiners collect information about a piece of evidence in order to establish a hypothesis about what occurred, so that it can be linked with certain other observations and results. Tool mark analysts are unbiased and conceptual analysts who aim to determine whether a tool mark and a particular tool are being countered. They employ their conclusions on the basis of their analysis of the proof. In order to create a hypothesis about what happened, tool mark examiners collect information about a piece of evidence so that it can be combined with other information and conclusions.

6.1 Physical matching

Physical fits, also pointed to as "mechanical fits," can be identified in a massive variety of criminal investigations, even as part of a more detailed instance of the tool mark. A physical fit exam is required when it is imperative to ensure that two or more parts of the product that have been partitioned, broken, cut and often forcibly removed were actually attached or fitted together [19]. Further, Jayaprakash [20] emphasizes on the unique characteristics that make a fundamental paradigm relevant for individualization. Restricted physical comparison literature reviewed that in the course of the trial, the objective scientific reliability and admissibility of such physical comparisons tend to be regarded with skepticism.

Features participating in physical matching and comparing rendered definitive judgments in patterned evidence that eliminate ambiguity during investigation and also an array of measurable units that comprise the entire pattern area, raising the probability of a pattern of verisimilitude known to trigger infinity that provides evidential justification for individuality [19].

Physical fit examinations fall into four main categories:

- Broken portions that will potentially be refitted, otherwise referred to as “jigsaw” suits.
- Broken items require a thorough tool mark examination such as microscopic comparison and casting in an effort to validate that the parts match together and therefore to form an inference.
- Broken, torn or split objects where knowledge of the manufacture and appearance of marks left on the surface of the material must be taken into account in order to facilitate a fit.
- Objects that were actually built to fit together were perhaps in touch for a period of time. Typically, these examinations require an analysis of what matter has been passed or is a function of the contact.

6.2 Casting

Collection, processing and examination of impression and tool mark evidence are one of the major components of forensics. The disadvantages associated with the selection and preservation factors are an unacceptable mix, creating a negative impression of resources and environmental factors. These restrictions relate to lack of detail, compromise of class perception and individualization of features used to position a particular piece of evidence at the scene of a crime. It is necessary to initially make the best cast possible with the inherent destructive potential of impression and tool mark casting. Occasionally, the circumstances of a crime scene impact the availability of casting techniques, contributing to the continuity of a cast [21].

A wide range of casting materials are often utilized to manufacture casts of tool marks: negative molding, low-melting metal alloys (e.g., wood metal) and silicone rubber. The material that most closely fits the specifications of an efficient casting material is silicone rubber. A tool mark’s microscopic detail is carefully repeated; it is impact resistant when kept at room temperature and is comparatively cheap.

The silicone rubber casting material is supplied as a partly polymerized base with which a catalyst must be mixed in order to allow polymerization. Forensic professionals focus on Microsil Silicone Casting Medium to recreate the subtlest tool markings and impressions. Laboratory studies have shown that they are superior to other established flexible silicone casting techniques by substantially improving the visibility of tool marks, firing pin impressions and latent fingerprint lifts. Microsil increases the likelihood of positive acknowledgment.

6.3 Automated system

An automated tool mark identification system uses an acquisition method for the processing of 3D data from tool marks left by tools on the sample surface, a signature generation module for the generation of tool mark signatures from the data collected and an analysis unit for the comparison of pairs of tool mark signatures in order to obtain a numerical similarity value representing their identical characteristics. The process is carried out with the aid of an integrated computer [22].

6.4 Databases of tool marks

A wide variety of different tool marks are found at the crime scene due to the different shapes and surface where the tool mark is rendered. Bolt cutters, wire cutters or crowbars have been used to break a door in many cases of burglary. These tools can produce marks that appear in various patterns: impressions and striation marks. Therefore, the Netherlands in collaboration with the Dutch Police developed a database for tool marks, known as Tool Mark Imaging System Database (TRAX). The device is designed for collection, restoration and comparing of tool images and their textual descriptors' width, kind of tool mark, etc.) [23].

6.5 Known tool marks test impressions

In practice, the investigator of the tool marks produces negative test tool marks using the suspect tool to compare microscopic surface characteristics between known test tool marks and evidence tool marks. It is recognized that the contrast between a suspected tool and a known test marks is always quicker and more effective than casting or even photography techniques [24]. It is also suggested to use known test tool marks developed in the very same way as the actual tool marks questioned. Traditionally, test tool marks are generated on sheets of soft metal or metal alloy, bars or tubes such as lead, wood alloy and, more recently, lead tape. Firstly, without losing the working surface of the tool, these surfaces are flexible enough to allow test casts with the finest tools. Second, their malleable nature enables the reproduction of the fine scrapes and ridges present on the instrument's working surface in the case of striation marks. Finally, the resulting known test tool marks are accurate, highly detailed, negative impressions of the working surface of the tool [10].

7. Interpretation

Impressions retrieved from crime scene are compared with reference tools to identify the impressions and to determine if they share a common origin. If there is a good fit between the two impressions, it is necessary to categorize the attributes and explain the probability of it being made randomly or on purpose. In the instance of a negative match between features, a careful investigation is required to determine whether the differences are significant or not and if there is a sensible and fair interpretation that can be made.

The forensic examiners can build a complete probative importance of the decision based on such similar and non-similar findings in order to present it as substantial court evidence. This also demonstrates the examiner's extensive knowledge in explaining and analyzing the fabrication process as well as the tool's wear and tear over time.

The following concerns will arise while an expert is doing a mark comparison.

1. Mark the Class and individual characteristic such as substrate and pressure used to create the impression and so forth.

2. Determine the number and characteristics of the impression present on the questioned tool as well as whether or not you would anticipate to see them reproduced in an impression and how well they relate (or do not) to tool attributes.

3. This would be a problem if characteristics like pressed lines, milling, and broaching were designed in such a way that they could appear on numerous tools made in a similar way and be indistinguishable from other tools. Similarly, if qualities like grending or damage breakdown were produced at random and regarded unique, no other instrument would have them.

4. Extraneous particles detected on the surface of impressions retrieved from crime scenes and at the surface of reference tools may be affected by external factors such as the nature of the substrate, the direction and the amount of pressure applied.

8. Evaluation

Evaluation is the framework of a conclusive judgment based on analysis and interpretation in significant detail by weighing what the findings mean in reference to the prosecution and the defense statements. There are (at least) three perspectives about how investigators can report their conclusions.

1. In one approach, the examiner must make claims that represent the balance of probabilities. The investigator either makes a conclusion about the forensic evidence's reliability based on the balance of likelihoods or makes a judgment about the relative probability of the observed findings under alternative theories.

2. The second method necessitates a two-step study.

   - The examiner starts by comparing the objects (tools) to see if there are any significant differences that rule out the possibility of a common source. When identifying characteristics are noted, the investigator decides that the items do not share a common source, a process known as "exclusion."

   - When the objects cannot be differentiated (i.e., the likelihood of a common source cannot be ruled out), the examiner then evaluates the rarity or uniqueness of the shared features as a second step. If the examiner believes that the shared features are so unique that they are peculiar (one-of-a-kind), the examiner may infer (and report) that the items are all from the same source—this conclusion is often called individualization or identification. If the examiner believes the shared characteristics are not identical, he or she could state the uniqueness of the related features or the probability that a random tool of the same kind will have them. Similarly, the examiner may claim unequivocally that the artifacts are indistinguishable or that they "play," without mentioning the match's rarity. Eventually, the analyst may conclude the comparison inconclusive.

3. In a third approach, the examiner will use numbers (e.g., "there is a 99% chance this tool mark was produced by the suspected tool") or words (e.g., "it is extremely likely that these marks were made by the same tool") to draw conclusions about the likelihood that the objects have a similar source. These conclusions are sometimes called source probabilities. This third approach is distinguished from both the first (balance of likelihoods) and the second (two-step analysis) approaches in that it allows the examiner to take a position or make judgments about the prior odds that the items being compared have a common source. To put it another way, the examiner's decision must be based on more than an assessment of the physical characteristics of the tools being comparison.

Additionally, after these two requirements are accomplished, evaluative reports that can be used in court should be generated [25, 26]:

- A mandating authority or party has asked the forensic practitioner to analyze and/or compare material (typically recovered trace material with reference material from known potential sources).

- The forensic practitioner attempts to evaluate findings in relation to specific conflicting propositions established by the unique case circumstances or as specified by the mandating authority.

In court, the results of forensic examinations should be evaluated using a probability ratio relying on the findings, associated data and expert knowledge, case-specific propositions and conditioning information. Since the value of the results is dependent on the case information and propositions, this should be emphasized in the report.

The forensic expert opinion should be carried out on the basis of four precepts first stated in an AFSP paper [27]:

- Balance: in order to reinforce the truth, the expert should accept at least one pair of the hypothesis proposed by the prosecution and defense, and if it is not possible to find a reasonable alternative for any reason, the expert will be able to examine only one proposition, but will make it clear that the strength of the proof cannot be measured.

- Logic: evaluative reports should address the likelihood of the findings given the propositions and relevant background information, rather than the likelihood of the propositions given the findings and background information. Statements that transpose the conditional should not be included in the report.

- Robustness: the opinion of an expert should be resilient and satisfy the reliability standards set by other experts for cross-examination.

- Transparency: by addressing and evaluating hypotheses, examination results, and theoretical facts, it would be necessary for the expert to demonstrate how he came to his inference.

To be these above things, experts need to make it express exactly what they have done and with what technique, what highlights have been thought of and why, what grants have been made and why and, last and most importantly, by unmistakably spreading out an indictment and a defense viewpoint upon which to consider the outcomes. These perspectives will without a doubt be restricting and, in instrument mark assessments, as a rule address the expected wellspring of the mark(s). The indictment view that "the submitted tool made the scene mark" is not hard to define [28].

9. Conclusions

A significant aspect of many forensic investigations is the interpretation of tool marks that may have an impact on a number of disciplines, including anthropology, archaeology and pathology. The reason for the determination of the tool mark is not specific but usually refers to the recognition, adjustment and comparison of the marks/indentations left on the surface after contact with the tool. Mark evidence involves the analysis of any object where a mark or impression has been rendered during criminal conduct to link the mark with the object or tool that made it.

The AFTE argues that the idea of identification appears contextual, an evaluation that helps researchers to establish protocols that are more precise and detailed. However, new technologies and tools provide the forensic community with a new basis and support to understand, refine and spread the methodology to the experts, which helps to interpret the marks of the tool. Technologies used in surface characterization is constantly changing, and computers are becoming more and more efficient, making it less burdensome for extensive computations, so new methodologies can be more sophisticated. These modern methodologies generally involve first converting a tool mark scan to a digitized striae depth representation in given distances along the mark, collected using a profilometer or similar tool, rather than manually aligning two photographs or imprints of the tool marks. Forensic databases can provide a measure of the accuracy of the identification of certain recognition characteristics, helping to become beneficial in the analysis of evidence. The results of the use of databases will apply not only to court documents but also to organizational activities.

When evidence marks are forwarded for analysis, the investigator shall be given four plausible explanations when assessing the marks: recognition, inconclusive, elimination or unacceptable. Examiners often come down on the side of uncertainty and only accept identification when this conclusion is unanimously accepted. The anticipated qualities of a forensic evaluation are defined by four principles: rational, unambiguous, balanced and rigorous, facilitating the field to transition from a collection of concealed secrets within professionals to a formal body of information from which one can be qualified to be an examiner. Therefore, it is evident that tool mark evaluation and interpretation are complex operations requiring consideration of several intrinsic and extrinsic variables, and so it is not surprising that this is a field of research that has attracted significant interest and discussion over a fairly long history.

Conflict of interest

"The authors declare no conflict of interest."

Acronyms and abbreviations

AFTE	Association of Weapon and Tool Mark Examiners
TRAX	Tool Mark Imaging System Database

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References

[1] Zheng AX, Soons J, Thompson R, Villanova J, Kakal T. 2D and 3D topography comparisons of toolmarks produced from consecutively manufactured chisels and punches. AFTE Journal. 2014;46(2):143-147.

[2] Levin N. The Forensic Examination of Marks A Review: 2010 to 2013. 2013:1-52

[3] Nichols RG. Defending the scientific foundations of the firearms and tool mark identification discipline: Responding to recent challenges. Journal of Forensic Sciences. 2007;52(3): 586-594.

[4] Nichols R. The scientific foundations of firearms and tool mark identification—A response to recent challenges. California Association of Criminalists News. 2006:8-27.

[5] Mozayani A, Noziglia C, editors. The Forensic Laboratory Handbook Procedures and Practice. Springer Science & Business Media; 2010.

[6] Miller J. An introduction to the forensic examination of toolmarks. AFTE Journal. 2001;33(3):233-247.

[7] Forensics H. History of Forensics | Alibi Channel [Internet]. Alibi.uktv.co.uk. 2020 [cited 29 December 2020]. Available from: https://alibi.uktv.co.uk/article/history-forensics/

[8] Burney I, Pemberton N. Making space for criminalistics: Hans gross and fin-de-siècle CSI. Studies in History and Philosophy of Science Part C: Studies in History and Philosophy of Biological and Biomedical Sciences. 2013;44(1): 16-25.

[9] Biasotti AA. The principles of evidence evaluation as applied to firearms and tool mark identification. Journal of Forensic Sciences. 1964;9(4):428-433.

[10] Petraco ND, Chan H, De Forest P, Crim D, Diaczuk P, Gambino C. Application of Machine Learning to Toolmarks: Statistically Based Methods for Impression Pattern Comparisons. National Institute of Justice; 2012

[11] Grieve TN. Objective analysis of toolmarks in forensics [Graduate Theses and Dissertations. 13014]. 2013. Available from: https://lib.dr.iastate.edu/etd/13014

[12] Hueske EE. Firearms and toolmarks. In: Mozayani A, Noziglia C. editors. The Forensic Laboratory Handbook Procedures and Practice. Humana Press; 2011.https://doi.org/10.1007/978-1-60761-872-0_9

[13] Biasotti A, Murdock JE. Firearms and toolmark identification: Legal issues and scientific status. Modern Scientific Evidence: The Law and Science of Expert Testimony. 1997:124-151.

[14] Lee HC, Harris HA. Physical Evidence in Forensic Science, Lawyers and Judges Publishing Co. Inc., Tucson, AZ. 2000.

[15] Burd DQ, Kirk PL. Tool marks. Factors involved in their comparison and use as evidence. Journal of Criminal Law and Criminology (1931-1951). 1942;32(6):679-686.

[16] Houck MM, Siegel JA. Chapter 16-paint analysis. Fundamentals of Forensic Science (2nd ed), Academic Press, San Diego. 2010:391-408.

[17] Champod C, Lennard CJ, Margot P, Stoilovic M. Fingerprints and Other Ridge Skin Impressions. 1st ed. CRC Press; 2004. https://doi.org/10.1201/9780203485040

[18] G.S. Klees,The categorization of toolmarks and tool types, AFTE Journal, 49 (2017), p. 14

[19] Baldwin D, Birkett J, Facey O, Rabey G. The Forensic Examination and Interpretation of Tool Marks. John Wiley & Sons Incorporated; 2013. https://doi.org/10.1002/9781118374078

[20] Jayaprakash PT. Practical relevance of pattern uniqueness in forensic science. Forensic Science International. 2013;231(1-3):403-4e1.

[21] Athanasopoulos D, Plaza OP, Dale A, Sorrentino E. Research and Development of Impression Evidence. 2013

[22] Bachrach B. A statistical validation of the individuality of guns using 3D images of bullets. Contract. 2006

[23] Geradts ZJ, Keijzer J, Keereweer I. A new approach to automatic comparison of striation marks. Journal of Forensic Science. 1994;39(4):974-980.

[24] De Forest PR, DeForest PR. Forensic Science: An Introduction to Criminalistics. United States of America: McGraw-Hill Humanities/ Social Sciences/Languages; 1983.

[25] ENFSI Guideline for Evaluative Reporting in Forensic. n.d. Available from: http://enfsi.eu/docfile/enfsi-guideline-for-evaluative-reporting-in-forensic-science/

[26] Stoney DA. What made us ever think we could individualize using statistics?. Journal-Forensic Science Society. 1991;31(2):197-199.

[27] Association of Forensic Science Providers (2009) Standards for the formulation of evaluative forensic science expert opinion. Science and Justice, 49 (3), 161 – 164.

[28] Willis S. Standards for the formulation of evaluative forensic science expert opinion Association of Forensic Science Providers. Science & Justice. 2010;1(50):49.