Eliot Springer,[1] *M.S.*

Toolmark Examinations—A Review of Its Development in the Literature

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ABSTRACT: The development of toolmark examinations in the literature is reviewed.

KEYWORDS: forensic science, toolmark examinations, criminalistics, physical evidence, review

Physical evidence is a term which relates to evidence that originates from various inanimate objects as opposed to originating from eye-witness testimony. Physical evidence is of especially great importance in those cases where no one has witnessed the crime, such as property crimes and sexual assaults.

One of the important means developed by various crime laboratories throughout the world for confronting this problem of the absence of an eyewitness to the crime is that of toolmark evidence. Here, the tool used in the commission of a crime is identified and used to link the suspect to the scene of the crime. The identification of the tool is based, as we shall later see, on a series of scratches, depressions, and other marks which the tool leaves on the object it comes into contact with. The combination of these various marks have been termed toolmarks and the claim is that every instrument can impart a mark individual to itself. Or as put by the Supreme Court in the State of Washington:

> "Courts are no longer skeptical that by the aid of scientific appliances, the identity of a person may be established by fingerprints. There is no difference in principle in the utilization of photomicrography to determine that the same tool that made one impression is the same instrument that made another impression . . ." [*1*].

When a suspect is apprehended and a tool is found in his possession, it is possible to compare the marks of this tool to those previously collected from crime scenes. This enables one to link the suspect (or at least his tool) to past committed crimes. Collections of crime scene toolmarks exist and are in use by many countries [*2*].

In the past, various courts have cast doubt as to the stature of toolmark evidence as a judicial proof. The nature of these doubts relates to the lack of objective or quantifiable criteria used by the toolmark expert in making his decision [*3*].

Lack of objective criteria has also prevented the automation of toolmark comparisons. This work intends to review the development of toolmark examinations in the literature. Special emphasis will be made in regard to the attempt to make these examinations of an objective nature.

Toolmark Examinations—A Review of Its Development in the Literature

The Turn of the Century

The literature regarding the development of toolmark examinations, published in the U.S. at the turn of the century, is very sparse. A literature search reveals that most of the early works in this field were written either in Europe or in South America and dealt with the firearms aspect of toolmark identification. This is apparent from a bibliography of firearms identification that was published in 1934 [*4*].

F. Thomas claimed that a Prof. Krockel of Leipzig, Germany initiated the method of striation matching at the turn of the century [*5*]. He cites that in two papers authored by Prof. Krockel, all the information regarding striation matching is given except for mathematical proof. He further states that these types of examinations were used by other Europeans throughout the first two decades of the twentieth century. Mention is also made of a dissertation on the subject of toolmarks made on wood by an ax. This was in fact a final examination paper, written by a student at the University of Lausanne, Switzerland, where the first forensic laboratory was established.

In reply to Thomas's claims that striation matching was mainly used first in Europe, Dougherty mentions two cases that took place in the U.S. around the turn of the century [*6*]. In the first, a Dr. Hall claimed at a meeting of the Medical Association of Central New York in October, 1899, that he could identify a particular bullet as being shot from a specific gun. However, no detail is given as to how Dr. Hall went about making these examinations.

The second case was that of the "Affray at Brownsville." The Brownsville incident involved cartridge case comparisons of impression marks and not striation comparisons using a microscope.

1910–1940

In April, 1925, there appeared the first published description in the U.S. of the use of a comparison microscope for the matching of striae on bullets [*7*]. However, the first noteworthy mention of toolmark comparisons in the U.S. is in a 1930 article by Luke May

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[1]Head, Fingerprint Development Laboratory, Israel National Police H.Q. Division of Identification and Forensic Science (D.I.F.S.), Jerusalem, Israel.

Based upon a thesis in partial fulfillment for the requirements for the masters degree at the Graduate College of the University of Illinois at Chicago.

entitled: "The Identification of Knives, Tools, and Instruments" [*8*]. May claimed to have been using these methods since 1912 and apparently developed them unaware of the progress in this area in Europe and South America [*9*]. He mentions the works by Col. Calvin Goddard in the area of firearm examinations but lists no other references. The methods mentioned are almost the same used today and include special lighting and observation with a comparison "magnascope." Although photomicrographs are presented of various positive comparisons, May did not explain any of the theory behind reaching the conclusion of a positive comparison. He talks of perfect matches and the presence of more than one hundred identification marks.

In the 1930s, toolmark comparisons became wider spread and were more extensively treated in the literature. Numerous articles reported on varied uses of these comparisons [*10,13*]. Mention was also made of the fact that by 1934, twelve jurisdictions of superior courts in the States had accepted the concepts behind firearm identification [*14*]. The celebrated case of the Lindbergh kidnapping gave prominence to toolmark comparisons in much the same way that firearms identification received from the St. Valentine's Day Massacre. In the Lindbergh case, toolmark comparison techniques were used to trace the ladder used in the kidnapping [*15*].

A need to make toolmark comparisons more objective is apparent from articles reporting on various instruments, such as an electron tube rifling depth profilometer, for use in firearms identification [*16,17*]. These instruments were of use for only class characteristics. Hatcher, a renown firearms expert of the time, made an attempt at explaining the theory behind toolmark comparisons and the conclusion of linking a specific mark to a specific tool [*18*]. His explanation was that of simple probabilities. He did not, however, explain exactly how many congruent lines one must have in order to arrive at a conclusion of a match. He, along with other firearms experts of the time, speaks of "near perfect" or "good, congruent" matches [*19*].

1940–1960

In 1942, an important article appeared by Burd and Kirk in which several aspects of toolmark examinations were addressed [*20*]. The authors felt that until that time, no adequate studies had been made regarding factors which affect toolmark comparisons. They carried out a few experiments in order to give an indication as to what criteria should be used in reaching a conclusion of a positive match. The general conclusion reached was that for one hundred lines (striations) compared, one must have at least sixty percent matching in order to reach a conclusion of a common source. When only forty percent of the lines match, this is an indication of a "no match." Between forty and sixty percent is questionable. Two new and seemingly similar screwdrivers gave only a twenty to twenty five percent match. They also reiterated the fact that what is actually being done is contour comparison and that striation counting was a technically advantageous method of illustrating contour similarity.

Toolmark comparisons continued to be widely used throughout the 1940s and 1950s and striation matching was taken for granted [*21–25*]. This is evident from the lack of articles addressing the theories behind these comparisons. Despite this general acceptance, Flynn in 1957 wrote that toolmark identification still hadn't come into its own like its parent, firearm identification [*26*]. The truth being that although firearm identification had come into its own, scientifically based studies were also lacking in this area for if they had existed, they would have sufficed for toolmark examinations too. Flynn also reported of a study in which one hundred sequentially manufactured chisels were used to carry out toolmark comparisons.

Five thousand and fifty comparisons were conducted and the conclusion reached was that each toolmark produced by a chisel was very different than any toolmarks produced by the other chisels.

The late 1950s produced two outstanding works by Biasotti [*27*] and Davis [*28*] which brought toolmark comparisons into a new era.

Davis, on one hand, did not attempt to address the problem of toolmark comparisons in a statistical fashion. He stated that there are no rules or formulas or required number of points needed to reach the conclusion of a match. Even more so, he felt that statistical studies were not amenable to striation comparisons. The conclusion reached was based largely on experience and the methods of the examiner. On the other hand, he emphasized the fact that striation comparisons are actually surface and contour comparisons. The method used for comparisons using the comparison microscope was just a way of visualizing and comparing the contour of two surfaces. Adapting methods for profile, surface, and contour analysis that had been used in industry since the thirties, Davis constructed instruments that could be used in toolmark comparisons. Davis's methods were novel or even revolutionary. They presented a way of performing objective toolmark comparisons since contours could be quantified. Using his equipment, one could perform more accurate studies of toolmarks than had been done until that time. Unfortunately, however, his methods and equipment did not become wide spread in the forensic science community. Instead of being used to advance the understanding of toolmark comparisons, his work was noted and set aside for all practical purposes.

In 1959, Biasotti published a statistical study relating to firearms identification [*29*]. This study was presented at a conference in 1957 and was part of his Master's thesis. Here, he stated that there was almost no factual or statistical data available regarding the problem of establishing identity in firearms identification. He therefore hoped that his statistical study could help answer the question of what constitutes an identity or a non-identity in firearms comparisons.

It should be noted that after close to fifty years of firearms/toolmarks identification and their use and acceptance in courts, this question had still not been properly addressed.

Biasotti's study involved two groups of guns (16 used and 8 new) and entailed about twelve hundred different comparisons. Previously it had been accepted that in striation comparison, the important finding is the percent of total matching lines between the two samples [*30*]. Biasotti presented a new approach. In studying the frequency of occurrence of each series of consecutive matching lines, probability estimates were calculated. He concluded that percent of matching lines is unimportant once the idea of consecutive lines is taken into account. When only a relatively few matching lines are associated by consecutiveness, one can conclude a match with a high degree of certainty [*31*]. He also stated that it was apparent that there is no such thing as a perfect match. For the types of bullets he compared, this meant that the presence of only three or four consecutive matching lines could suffice to conclude a match.

1960–Present

In the 1960s, a paper appeared in which a claim was made that there was a great deficiency of published research and data in the various criminalistics fields [*32*]. Availability of research data would enable more objective criteria to be used in the evaluation

of physical evidence. In response to this claim, F. Thomas suggested that this research had been performed and published many years before and had simply been forgotten or had not been available to the newer generation of forensic scientists [*33*]. To support this claim, he listed various references of published works that dated as far back as 1900 with most of the works appearing between 1900–1930.

In a review written by Biasotti in 1964, he concluded that in order to formulate objective criteria of identity in toolmark comparisons, much more statistical data must be produced and researched [*34*].

In 1967, the U.S. engaged in the First National Symposium on Law Enforcement, Science, and Technology. One of the suggested studies was for the design of a computer-based weapons identification system [*35*]. Although a prototype was presented, this system apparently never reached completion.

At the end of the sixties, a short but interesting work by Rees and Cundy appeared [*36*]. While the objective of this paper was to describe a useful method for casting and comparing toolmarks, reference was made to a "Talysurf" instrument.

This instrument was used in the Engineering Department of a regional college along with the casting material that was described. It was used for micro-surface contour measurement. Using it, the authors were able to measure the surface of the material casted and the cast itself, thus showing that the cast accurately reproduced the surface in question. This instrument was the same type as the industrial surface analyzers mentioned by Davis ten years earlier. The fact that the authors claimed to have come across this by chance, demonstrates the fact that Davis's striagraph did not receive proper attention.

In 1970, a Californian toxicologist published a study in which he attempted to develop a theoretical basis for striation analysis. He did this through use of idealized striated marks and their comparisons using various models [*37*]. In order to address the problem, the author simplified striations from a three dimensional comparison to a two dimensional one, similar to what one does using the comparison microscope. Brackett laid the foundation for future studies and suggested that use of the computer in applying his processes and principles could develop practical procedures for use by the criminalist in toolmark comparisons.

The seventies continued to produce studies by various authors who attempted to apply modern instruments and methods to various forensic science problems. Methods such as digital image enhancement, scanning electron microscope examinations, and use of the laser, among others, were suggested [*38–40*]. Peterson described the use of the laser to examine the contour of striated toolmarks [*41*]. His suggestion was indeed similar, as he stated, to the method of Davis, using however a different type of instrument for contour analysis. Advantages of this instrument over that described by Davis include the fact that it is a non-contact measuring instrument, less cumbersome, and possibly more accurate. The results reported were from the early stages of development of this laser system. The article demonstrated the potential of this method but did not present much data.

Although the potential for more objective, instrumental methods had been recognized since the late fifties, two decades later, no one had developed any of the methods for proper laboratory use.

Studies and advances in technology in the 1980's provided hope for the advancement of objective toolmark comparisons. Several studies were published which incorporated attempts to mathematically model striations.

Cashman, in his doctoral thesis on similarity analysis, suggested its implementation in firearms examination [*42*]. He thought that similarity analysis could be utilized to determine the minimum number of consecutively matching striae required for an identification and the minimum number of mismatched striae needed to insure the exclusion of a source [*43*].

Deinet reported twice on applications of several probability theory models to toolmark examinations but felt that his conclusions were not sufficient to use for automation [*44,45*].

Arndt et. al. [*46*] reported results of a study to develop an improved automated system for high speed classification and comparison of bullets. New analysis techniques were applied to greatly enhance the correlation capabilities of the system.

According to their conclusions, it was now possible to set up a practical bullet comparison system for use by law enforcement agencies. For some unknown reason, this very promising study was overlooked by the forensic science community and was not developed or examined any further.

Biasotti and Murdock attempted to describe the individualization process [*47*]. They explained why it is important to develop objective criteria and the research needed to meet this goal.

Uchiyama's studies began to appear in English in the late 80's and continued to appear in the nineties. The studies were translated with editing by Biasotti, who had pioneered works in the field three decades earlier. The study that first appeared used models in order to aid in decision making regarding striae comparisons and identification [*48*].

In March, 1988, a new journal called "Surface Topography" was published. This was the first journal that was devoted exclusively to surface topography, a topic which is of course directly related to toolmark comparisons, but is used much more in industry.

In an editorial by K. J. Stout in the first issue, a brief history of the topic is given [*49*]. It is interesting to note that the author claims that this subject was in existence for approximately fifty years. According to the forensic literature, toolmark examinations were in existence for a little longer. In 1979, an inaugural meeting took place entitled: "Metrology and Properties of Engineering Surfaces." The community established by this conference helped direct the focus of research in the field away from pure theory and towards applications. Stout concludes that the major breakthroughs in the field will probably come from three dimensional topography visualization techniques along with more flexible software.

In the same issue of this journal, a review of the field of surface topography was written [*50*]. The scientific study of roughness is claimed to have been initiated in Germany with the first purpose-built instrument for its study being the light-section microscope. Forensic literature mentions toolmark comparisons as also being initiated in Germany. Due to limitations of the light-section microscope, the next instrument to be developed was the stylus instrument. This instrument was the basis used by Davis for the Striagraph. The wave of the future is predicted to be using techniques based on light scattering. These techniques are potentially very fast, non-contacting, easy to automate, and responsive to an area much larger than a line profile. Such instruments include the confocal scanning microscope, interferometers, and the scanning tunneling microscope. Cheap computing power along with the growing field of nanotechnology will of course also greatly contribute to the advance of the field of surface topography.

Conclusion

The early 1990s shows much promise for the advance of objective toolmark comparisons. According to the Association of Fire-

arms and Toolmarks Examiners' Criteria for Identification Committee, interpretation of toolmark individualization and identification is still considered to be subjective in nature, based on one's training and experience [*51*]. Commercial comparison systems have already been reported, although they have not yet gained wide-spread use [*52*]. Continued promising studies reported by Uchiyama [*53*], advances in the science of surface topography measurement, and the law enforcement community's needs seem to indicate [*54*] that by the end of this decade, the puzzling problem of objective toolmark striation comparisons will be solved. The challenge is not only to technologically develop a solution but to do it in a way that will enable most of the forensic laboratories to acquire and operate such systems.

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Eliot Springer
Israel National Police HQ
Division of Identification and Forensic Science
Jerusalem, Israel 91906