Clarity of Microstamped Identifiers as a Function of Primer Hardness and Type of Firearm Action

By: L.S. Chumbley [1], J. Kreiser [2], T. Lizotte [3], O. Ohar [3], T. Grieve [1], B. King [1], D. Eisenmann [1]
[1] Iowa State University, Ames Laboratory, Ames, Iowa
[2] Illinois State Police, Retired, Springfield, Illinois
[3] Pivotal Development, LLC, Manchester, NH

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ABSTRACT

The transfer of microstamped identifiers to the primers of fired cartridges was examined using a stereomicroscope and scanning electron microscope (SEM). The identifiers were placed on the firing pins of three different 9mm handguns, namely, a Sig Sauer, a Taurus, and a Hi-Point. Ten different brands of ammunition were fired from each handgun, 100 rounds being fired using each brand for a total of 1000 rounds fired per handgun. The quality of the markings was evaluated using a simple observation rubric. These results were compared to Vickers hardness values obtained from the ammunition primers and are discussed in light of the types of actions of firearms used.

Introduction

In recent years the area of comparative forensic examinations have come under increasing attack, with various claims and charges being made in popular literature that they are unscientific and highly subjective in nature [1, 2]. These allegations have arisen due to a combination of controversial court cases [3], mistakes in fingerprint identification [4], selective use of remarks made in a National Research Council (NRC) study on the subject of ballistic imaging [5], and a later, highly critical NRC study on forensic science in general [6]. While the completeness of the latter study especially has been called into question [7] the fact remains that forensic examiners often find themselves on the defense when it comes to presenting their expert opinions.

The success of DNA evidence in providing a numerical assessment of duplication made possible by known population statistics has created a call for comparative examinations to reach a similar level of confidence. Such a mandate is somewhat unreasonable given the nature of the evidence and the factors associated with the various types of analyses involved. However, there is no question that some degree of objectivity can be (and in some instances has been) introduced into, comparative examinations [8]. However, a problem lies in determining by which method to apply comparative standards. This is a difficult proposition given the wide range of examinations possible, e.g. questioned documents, fingerprints, tool marks, tire impressions, shoeprints, etc. and of course, firearms. For the purposes of this paper, past efforts and current suggested solutions aimed at introducing additional objective analysis into the area of firearm and tool mark examinations will be the only area discussed.

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Forensic identification of firearms and tool marks makes use of the fine series of markings that are impressed or scratched on bullets, cartridges, and surfaces when they come in contact with the tool under consideration, be it a common hand tool or components of a firearm. The markings often exist in the form of a fine series of parallel scratches and one of the earliest efforts to introduce statistical analysis was suggested in 1959 by Biasotti [9]. This approach is based on observation and tabulation of groups of "consecutive matching striae" in firearm and tool mark examinations [10] and is known as the CMS method. Considerable work has been done investigating this possible technique. More recently, quantitative measurements of tool marked surfaces using surface and optical profilometers have been evaluated using a statistical algorithm to identify possible match pairs in a completely objective manner [8]. However, this study showed that trained examiners making subjective judgments are still able to distinguish between true matches and nonmatches at a higher level of success than these objective methods [8].

It is well known that using the fine markings present as a means of identification has certain problems and limitations, especially in the case of firearms, and these have been documented quite extensively [11, 12]. In recent years a method has been developed that may augment traditional firearms identification by purposefully placing unique identifiers on certain critical pieces of a firearm, such as the firing pin, breech face, etc. that are stamped into a cartridge when fired [13]. Termed Microstamping, this technique has received a large amount of political and media attention. In some cases local and state officials have introduced bills aimed at implementing microstamping of either firearms or ammunition, perhaps without a proper understanding of the process or a consideration of best practices concerning the use of the technique [14].

Certainly, one of the difficulties in any shooting investigation is to locate possible "suspect" firearms that can be test fired to generate marks that can be compared to recovered items of evidence. In theory, recovered items of evidence with microstamping could yield information that could assist investigators in locating the responsible firearm much more quickly. However, while microstamping does have the potential to greatly aid in firearm identification it clearly is not a panacea for the difficulties associated with traditional examinations. For example, the criminal can always remove firing pins, alter scratch patterns by the use of abrasive polishing media, etc. Steps can be taken to minimize the effect of such alterations by use of microstamping in several places but such possibilities cannot be prevented entirely and will always exist. These considerations are not the topic of this discussion.

What is of importance and should be understood by those who suggest or are contemplating implementing laws utilizing microstamping is the effort that must be undertaken in order to optimize the microstamped mark and ensure maximum transfer of the pattern. In other words, microstamping involves more than just "blasting a number onto a firing pin using a laser", which to the layman may seem how the technique works. For each model of firearm an optimization process must be run. The optimization process considers many physical characteristics of the area of the firing pin that strikes the primer and how the laser used for engraving interacts with this area. These characteristics would include material hardness, as well as shape, size and curvature of the firing pin. The optimum number of characters and their arrangement for maximum clarity must also be considered, along with laser parameters such as power input necessary to achieve this clarity. Thus, optimization is a complex process involving a series of experimental determinations that must be conducted for each model firearm of each manufacturer. [13]. Once completed the determined set of parameters can be applied to other firearms of the same type and material specifications in a production process. The cost of optimization becomes small once an appreciable number of parts have been produced. However, when one considers the large number of different firearm brands and models produced by any one manufacturer, the effort to optimize all possible firearms becomes a significant research project of considerable cost that must initially be undertaken. Such a project is separate and apart from the economic costs that might be incurred by a company required to adopt microstamping. The latter includes industry fears related to the purchase and maintenance of equipment, training of operators, the speed of the process and its effect on production, etc. For example, if laws requiring that unique identifiers be placed on numerous separate parts are passed, industry will have to ensure that guns are assembled as a unique set of parts, rather than in a batch process of interchangeable parts, as is currently typical.

Another consideration is the nature of the unique identifier selected for placement on each firearm. Possibly the most common perception is that microstamping would involve placing the serial number of the firearm on the firing pin. While large numbers of characters can be placed on a firing pin [15] the most viable suggestion involves placing a more limited number of identifiers on the pin, analogous to present license plates. This would provide for larger characters that are more easily produced on a firing pin, transferred during the firing process, and recognized by an examiner. By using a combination of alphanumeric characters, a six-digit code would provide a database of 36^6 unique designations (i.e. almost 2.2 billion possibilities), ten times the approximate number of firearms in the U.S. today. A rapid field identification then becomes a simple matter of tracing the number, in the same manner that license plates are traced today. In cases where the characters are not readily readable a subsequent examination by a trained examiner would be necessary.

However, the question then arises as to who would oversee the assignment of identifiers and maintain database integrity. Ideally, an oversight board could perform this function in much the same way as the American Society for Testing of Materials (ASTM) oversees material specifications or the Accreditation Board for Engineering and Technology (ABET) accredits the quality of university engineering programs in this country. These organizations are voluntary societies whose stated goals are to preserve the quality of the members, industries, and institutions that they represent. A similar arrangement, possibly consisting of sportsman associations, industry representatives, and advocacy groups, might be formed to maintain a database and assign codes to participating companies that choose to implement microstamping. The goal of the group would be to ensure that database integrity is safeguarded while at the same time offering material assistance to law enforcement agencies.

Given the above considerations it is apparent that legitimate questions exist related to both the technical aspects, production costs, and database management associated with microstamping that should be addressed before wide scale implementation is legislatively mandated. However, it should be noted that none of the above objections are inherently insurmountable. While it is likely that microstamping will never approach the discriminating power associated with DNA evidence, it is a viable method for providing rapid identification of a firearm in many cases, possibly decreasing the current high workload of forensic examiners.

The purpose of this exploratory study is to examine one aspect of microstamping, namely, the performance of a microstamped identifier on a small test set as a function of ammunition brand, hardness, and firearm action type. Three different firearms representing the two most common operating principles for semiautomatic pistols were chosen as well as 10 different brands of ammunition. The results of the study and discussions concerning the various effects of primer hardness and firearm brand are presented below. It is hoped that studies of this type can guide future decisions as to the nature of the microstamped identifier that should be used, the probability of unambiguous transfer, and the parameters that most affect clear transfer of the identifier.

Experimental

The test set for this study involves use of three different 9mm semiautomatic handguns, namely, a Sig Sauer model P226 semiautomatic pistol (short recoil action), a Taurus model PT609 semiautomatic pistol (short recoil action), and a Hi-Point model C9 semiautomatic pistol (simple blowback action) where the firing pin also acts as an ejector. These guns were selected to represent a range of performance and ejection properties and the actions are typical of the types of that leave fired cartridges at crime scenes. Additionally, the firearms represent three different market price points, the Sig Sauer being a higher priced firearm, the Taurus a medium priced item, and the Hi-Point being a lower priced firearm.

Microstamping of the firing pins was optimized for a 6 character alphanumeric code and a circumferential gear code for each firearm, which is intended to confirm the alphanumeric code. The gear code is deciphered by dividing the circular code into eight equal sectors, excluding the wedge at the top of the gear code in **Figure 1**. Beginning at the wedge, the code is read clockwise. Within each sector, the notches are read as a six-bit binary code. For example, the first sector is read as 011001, which corresponds to the letter "S" and the first identifier in the alphanumeric code. Subsequent sectors correspond to the alphanumeric identifiers being read left to right. Further details concerning use and interpretation of the gear code are available in the literature [13].

The optimization process involved a cycle of fire analysis to ensure optimal mark transfer by identifying the surfaces, locations and vectors that provide the highest capability of transfer and repeatability [13]. Both codes are designed to act in different ways to the multivariate kinetic motion and the various instability vectors acting upon the cartridge during the cycle of fire. Both codes are designed to be spatially out of phase with each other, ensuring that degradations (such as pin drag and smear) which might wipe out certain characters in one code provide a high probability of survivability for that character on the other code surface. Reading both codes provides a means of extracting the final code. One example of a stamped impression is shown in Figure 1, imaged using a scanning electron microscope (SEM).

Figure 1: SEM image of a microstamped mark on a cartridge fired by the Sig Sauer. Note the gear code surrounding the alpha-numeric identifier.

The ammunition chosen for the study represents a considerable range of possibilities. Ammunition brands were selected with a consideration of primer hardness [15] and a desire to include sealant coated and manufacturer imprinted primers. Ten different brands were selected and are listed in **Table I** in the order in which they were fired from the handguns. Before firing all of the cartridges were marked using an electric scribe with a letter to denote the firearm used and then sequentially marked from 1 to 1000 to make the firing sequence identifiable, **Figure 2a**. Thus, the T 306 cartridge was the 306th cartridge fired by the Taurus pistol. The order of ammunition used was randomly selected by drawing brand names out of a hat.

The cartridges were loaded ten at a time into a magazine and fired. The highest shot order number being loaded first and the lowest shot order number loaded last. The lowest number would then be fired before the higher numbers. In the event a cartridge did not fire on the first try, the cartridge was not

Firing Order	Ammunition Brand	Primer Type	Cartridge Material	Description
1	Brown Bear	Berdan	Lacquered Steel	115 gr., full metal jacket, brass primer
2	DAG	Boxer	Brass	124 gr., full metal jacket, brass primer
3	Federal - American Eagle	Boxer	Brass	115 gr., full metal jacket, nickel primer
4	Remington - UMC	Boxer	Brass	115 gr., Flat Nose Enclosed Base, nickel primer, letters "H F" stamped into the primer
5	PMC	Boxer	Brass	115 gr., full metal jacket, brass primer
6	Silver Bear	Berdan	Zinc-plated steel	115 gr., full metal jacket, brass primer
7	CCI Blazer	Boxer	Aluminum	115 gr., full metal jacket, nickel primer
8	Cor-Bon	Boxer	Brass	147 gr., full metal jacket, nickel primer
9	Independence	Boxer	Brass	115 gr., full metal jacket, nickel primer
10	Sellier & Bellot	Boxer	Brass	115 gr., full metal jacket, brass primer, covered with red lacquer sealant

Table I: Ammunition brands studied

removed from the chamber and a second pull of the trigger was tried (in the Sig Sauer and Taurus pistols that were both single action and double action). If the cartridge failed to fire on the second try, no further attempts to fire it were made and the misfired cartridge was placed in order with the fired cartridge cases. A second attempt at firing was not carried out using the Hi-Point pistol, which is only single-action. The spent rounds were collected during firing using a lightweight cage / net that could be affixed to the gun hand of the person conducting the firings, **Figure 2b**.

The pistols were cleaned after each 100 rounds. Cleaning consisted of brushing out the bore with a nylon brush soaked in "PRO-SHOT 1 Step Gun Cleaner & Lubricant". The bore was then wiped out with a clean cotton flannel cleaning patch. The breech was thoroughly brushed using a tooth-brush like commercial nylon brush. The top of the magazine and magazine follower were wiped with an oily cleaning patch.

The fired cartridge cases were placed back into the original box/tray from which they came and the box was labeled with the pistol letter designation and the corresponding shot order numbers. Thus a box labeled S601—S650 would contain shots 601 through and including shot 650 fired by the Sig Sauer pistol. Cartridges missing from a tray would reflect casings that could not be found at the firing range.

After firing, the primers of the cartridges were examined and graded as to the quality of the microstamped impression. In conducting an assessment of this nature it becomes a matter of concern whether a character is truly visible or whether the examiner, knowing what the character is supposed to be, unconsciously ascribes greater clarity than actually exists. For example, after seeing 95 clear impressions of a code it would be difficult to not immediately interpret the 96th cartridge as being clear, even though some smearing may be present. Ideally one would want a different person to view each separate cartridge without knowing what the identifier was supposed to be. This was obviously not possible in this study. In order to somewhat account for this possibility two examinations were undertaken. Firstly, Mr. Kreiser examined the cartridges and was instructed to be conscientiously conservative in assigning his assessment. The examination involved use of a stereomicroscope equipped with a polarized light for illumination and a simple rubric where the number of characters clearly visible using a stereoscopic examination was tabulated. Thus, a "C6" assessment means all six characters were clearly visible while a "C3" would mean only three characters could be read easily immediately. For this examination only the alphanumeric identifier was evaluated and observations concerning multiple stamped identifiers, misfires, etc. were also noted. Secondly, the cartridges were viewed and evaluated by T. Grieve, who has no training in forensic examinations at all. The examination again involved a stereomicroscope with a polarized light source. In addition to the alphanumeric identifier she examined whether there was any observable transfer of the gear code. This evaluation was qualitative and did not determine what percentage of the code was visible, only whether any useable portion survived. Thus, a "Y" evaluation meant that at least part of the code transferred while "N" meant none was visible.

Note that the evaluation rubric employed by Mr. Kreiser might represent a "worst case scenario" for the alphanumeric identifier while that used by Ms. Grieve is a "best case scenario" for the gear code. Neither evaluation rules out the possibil-

Figure 2a: Unfired cartridge with inscribed identifier

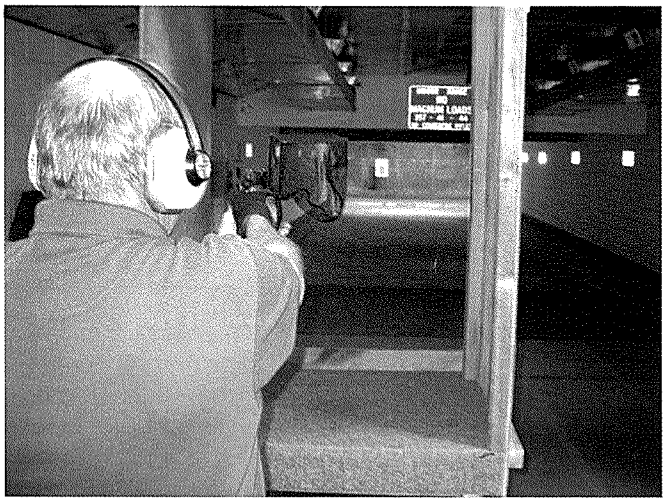

Figure 2b: Firing in progress with catch-basket

ity of identifying either more characters or more of the gear code using a more advanced imaging technique, nor does it necessarily preclude reconstructing the entire code [13]. As an example of what might be visible using a more advanced technique, certain cartridges having low C and gear code ratings were examined using a JEOL SEM capable of both secondary (SEI) and backscattered (BES) electron imaging. Both imaging techniques were used and the best images were chosen for presentation.

Vickers hardness measurements of the primers from the 10 selected ammunition types were made using a LECO LM 247 AT microhardness tester. Loading was set at 50g and dwell time was 13 seconds. The measurements were made on the already fired primers as far as possible from the firing pin impression in order to minimize any work hardening effects.

Results

Microstamp Evaluation:

The results of the stereo-observations are summarized below in **Tables II-IV**. The data is summarized both by firearm used and by brand of ammunition. The totals displayed in Table II confirm that the ratings by J. Kreiser are more conservative as anticipated and discussed above. It is also apparent from examination of **Table II** that the results show a strong correlation between the transfer of the identifier and the price point of the firearm, i.e. the most advantageous transfer occurs for the Sig Sauer, the worst by the Hi-Point.

The lacquer present on the Sellier & Bellot ammunition initially prevented clear observation of the numbers and gear codes for the Taurus and Hi-Point fires, so cartridges 901-1000 for these firearms were not graded by J. Kreiser and therefore are not shown in **Table II**. This results in somewhat lower totals for the Taurus and Hi-Point samples. The optical analysis carried out by T. Grieve is delineated in **Table II** by the use of italics. Note that the lacquer was subsequently removed from 95 of the cartridges after J. Kreiser had examined them and before T. Grieve conducted her examination. *(Note: Five cartridges with lacquer were reserved to conduct further imaging experiments on at a later time) and the totals obtained are included in the comments section. In either case, it is clear that the use of lacquer has significantly degraded the ability to achieve total identifier transfer.*

It is interesting that it was often found that poorly marked cartridges would be grouped together. This tendency was seen for all firearms but clearly occurred more often for the lower cost Hi-Point. For example, for the Hi-Point 125 of the 237 non-C6 ratings found by Kreiser came in runs of two to five consecutive cartridges. The tendency for multiple groups of poorly marked cartridges seemed to be exacerbated by the presence of lacquer. For example, of the 52 non-C6 ratings found by Kreiser for the Sig Sauer firings, eight groups of two and one run of nine non-C6 ratings occurred, i.e. 25 out of 52, all in the Sellier & Bellot cartridges. For the Taurus both Kreiser and Grieve found four runs of two or more for the non- Sellier & Bellot ammunition; in the Taurus Sellier & Bellot cartridges Grieve noted an additional six runs of two or more, the largest run being six consecutive non-C6 ratings.

SEM Evaluation:

After the optical examination a few of the lower-scoring cartridges were selected for SEM examination. One example from each of the firearms used is shown below. **Figure 3** shows cartridge #S198, rated as C3-Y by T. Grieve and C4 by J. Kreiser. For comparison see **Figure 1**, obtained from a cartridge rated as a C6-Y.

It is left to the reader as an unbiased observer to decide how many of the alphanumeric characters are visible. To the authors (who, admittedly, know the code) it appears the code is S23SX7, i.e. complete identification can be made using a

Strike Grade Summary							
Sig Sauer							**Comments**
C6	**C5**	**C4**	**C3**	**C2**	**C1**	**C0**	Cartridge #808 was lost and not graded or included in the totals. There were 36 C6 double impressions. There were 3 C5 double impressions. *Cartridges S901-S1000 were graded after the lacquer was removed by T. Grieve.*
948	30	14	5	1	0	2	
968	*19*	*7*	*2*	*1*	*1*	*2*	
Taurus							
C6	**C5**	**C4**	**C3**	**C2**	**C1**	**C0**	There were 26 C6 double impressions, 1 C5 double impression, 1 C4 double impression and 1 C1 double impression. 3 C6 misfires appeared. Cartridges 901-1000 ungraded by J. Kreiser. *Cartridges T901-T1000 graded after the lacquer was removed by T. Grieve produced C6:56, C5:26, C4:10, C3:1, C2:1, C1:0, C0:0*
848	43	3	1	3	2	0	
854	*35*	*5*	*3*	*2*	*1*	*0*	
Hi-Point							
C6	**C5**	**C4**	**C3**	**C2**	**C1**	**C0**	There were 52 C6 double impressions, 14 C5s, one C4, one C3 and one C2. There was one C6 triple impression. Of the 12 misfires, 6 were C6, 4 were C5, 1 was C4 and 1 was C0. Cartridges H901-H1000 ungraded by J. Kreiser. *Cartridges H901-H1000 graded after the lacquer was removed by T. Grieve produced C6:49, C5:15, C4:12, C3:8, C2:4, C1:5, C0:2*
663	139	47	26	15	5	4	
684	*113*	*65*	*25*	*7*	*4*	*1*	

Table II: Quality of microstamp as a function of firearm. Note that the numbers are out of 1000 fires for the Sig Sauer, out of 900 for the Taurus and Hi-Point. T. Grieve numbers in italics.

higher quality image. The gear code, though visible, is difficult to discern in small regions of this particular cartridge. **Figure 4** shows an example cartridge from the Taurus, #T944. Rated a C2-N optically by T. Grieve (not rated by J. Kreiser due to the lacquer), this example shows the problems involved when using a lacquered cartridge. The four alphanumerics at the corners, difficult to discern using optics, are clearly visible using SEM, being T13A5L. The gear code is totally lacking, and in general the gear code did not transfer for the Taurus handgun.

An example from the Hi-Point series is shown in **Figure 5**. The Hi-Point had the poorest transfer of the alphanumeric, although a high percentage of the cartridges had some gear code available, causing a much higher rating in this area than the Taurus. **Figure 5** makes it clear, however, that the gear code was present over a relatively small area, in this case the upper right quadrant. Rated as a C2-Y optically by T. Grieve and C3 by J. Kreiser, SEM imaging in this case sheds little light on the identifier, possibly allowing one additional character of the identifier H60PZE to be visible.

Hardness Evaluation:

The primer hardness values obtained from the 10 types of ammunition used are shown in **Table V**. The presence of lacquer on the Sellier and Bellot cartridges presents a special problem when measuring hardness. Just as it is clear that the lacquer prevents an immediately recognizable mark transfer while it remains on the cartridge, evaluating the hardness with the lacquer present is meaningless since the soft nature of the lacquer disrupts the method used to measure hardness, producing meaningless results. Thus, the lacquer was removed and the values reported in Table V reflect the actual hardness of the uncoated primer.

Discussion

It seems clear from the above results that both brand of ammunition and type of firearm play a role in identifier transfer. When considering ammunition no primary parameter could be identified as ensuring complete identifier transfer, i.e., no consistent trends were observed as a function of either primer material, type or hardness, and/or cartridge case material. For

Summary of Cartridge Types								Comments
Brown Bear (#1-100)								
Gun	**C6**	**C5**	**C4**	**C3**	**C2**	**C1**	**C0**	
Sig	99	1	0	0	0	0	0	
Taurus	93	7	0	0	0	0	0	2 misfires, C6
Hi-Point	92	7	1	0	0	0	0	1 triple impression
DAG (#101-200)								
Gun	**C6**	**C5**	**C4**	**C3**	**C2**	**C1**	**C0**	
Sig	99	0	1	0	0	0	0	
Taurus	89	9	1	0	1	0	0	
Hi-Point	86	8	2	3	0	0	1	Ctg. 159 pierced
Federal American Eagle (#201-300)								
Gun	**C6**	**C5**	**C4**	**C3**	**C2**	**C1**	**C0**	
Sig	97	3	0	0	0	0	0	
Taurus	92	2	1	1	2	2	0	
Hi-Point	62	23	8	3	2	1	0	Ctg. 251 lost
Remington UMC (#301-400)								
Gun	**C6**	**C5**	**C4**	**C3**	**C2**	**C1**	**C0**	Existing letters create interference with strike pattern
Sig	99	1	0	0	0	0	0	
Taurus	91	9	0	0	0	0	0	
Hi-Point	92	6	2	0	0	0	0	
PMC Bronze (#401-500)								
Gun	**C6**	**C5**	**C4**	**C3**	**C2**	**C1**	**C0**	
Sig	100	0	0	0	0	0	0	
Taurus	99	1	0	0	0	0	0	
Hi-Point	64	25	9	1	1	0	0	
Silver Bear (#501-600)								
Gun	**C6**	**C5**	**C4**	**C3**	**C2**	**C1**	**C0**	
Sig	99	0	1	0	0	0	0	
Taurus	89	10	1	0	0	0	0	
Hi-Point	58	20	8	7	4	1	2	4 misfires, C6
CCI Blazer (#601-700)								
Gun	**C6**	**C5**	**C4**	**C3**	**C2**	**C1**	**C0**	
Sig	99	1	0	0	0	0	0	
Taurus	98	2	0	0	0	0	0	
Hi-Point	73	15	5	5	0	2	0	1 misfire, C6
Cor-Bon (#701-800)								
Gun	C6	C5	C4	C3	C2	C1	C0	
Sig	96	2	1	0	0	0	1	
Taurus	97	3	0	0	0	0	0	
Hi-Point	67	22	6	1	3	0	1	4 C5 misfires, 1 C4 misfire and 1 C0 misfire
Independence (#801-900)								
Gun	**C6**	**C5**	**C4**	**C3**	**C2**	**C1**	**C0**	
Sig	99	0	1	0	0	0	0	
Taurus	100	0	0	0	0	0	0	
Hi-Point	69	13	6	6	5	1	0	1misfire, C6
Sellier & Bellot (#901-1000)								
Gun	**C6**	**C5**	**C4**	**C3**	**C2**	**C1**	**C0**	
Sig	61	22	10	5	1	0	1	
Taurus	-	-	-	-	-	-	-	Lacquer prevented observation in Taurus and Hi-Point
Hi-Point	-	-	-	-	-	-	-	Lacquer prevented observation in Taurus and Hi-Point

Table III: Quality of microstamp as a function of ammunition, J. Kreiser results.

Summary of Cartridge Types								
Brown Bear (#1-100)								Comments
Gun	**C6**	**C5**	**C4**	**C3**	**C2**	**C1**	**C0**	
Sig	95	2	0	1	1	1	0	Y=100 N=0
Taurus	89	11	0	0	0	0	0	Y=0 N=100
Hi-Point	86	13	1	0	0	0	0	Y=95 N=5
DAG (#101-200)								
Gun	**C6**	**C5**	**C4**	**C3**	**C2**	**C1**	**C0**	
Sig	94	3	2	1	0	0	0	Y=81 N=19
Taurus	97	1	1	1	0	0	0	Y=0 N=100
Hi-Point	89	3	4	2	0	2	0	Y=95 N=5
Federal American Eagle (#201-300)								
Gun	**C6**	**C5**	**C4**	**C3**	**C2**	**C1**	**C0**	
Sig	99	1	0	0	0	0	0	Y=100 N=0
Taurus	95	1	0	1	2	1	0	Y=55 N=45
Hi-Point	64	23	8	3	1	0	0	Y=95 N=4
Remington UMC (#301-400)								
Gun	**C6**	**C5**	**C4**	**C3**	**C2**	**C1**	**C0**	
Sig	99	1	0	0	0	0	0	Y=100 N=0
Taurus	98	2	0	0	0	0	0	Y=0 N=100
Hi-Point	89	7	4	0	0	0	0	Y=98 N=2
PMC Bronze (#401-500)								
Gun	**C6**	**C5**	**C4**	**C3**	**C2**	**C1**	**C0**	
Sig	100	0	0	0	0	0	0	Y=100 N=0
Taurus	100	0	0	0	0	0	0	Y=0 N=100
Hi-Point	63	16	13	7	1	0	0	Y=98 N=2
Silver Bear (#501-600)								
Gun	**C6**	**C5**	**C4**	**C3**	**C2**	**C1**	**C0**	
Sig	99	1	0	0	0	0	0	Y=93 N=7
Taurus	82	13	4	1	0	0	0	Y=0 N=99
Hi-Point	63	14	12	5	3	2	1	Y=86 N=14
Blazer (#601-700)								
Gun	**C6**	**C5**	**C4**	**C3**	**C2**	**C1**	**C0**	
Sig	100	0	0	0	0	0	0	Y=100 N=0
Taurus	99	1	0	0	0	0	0	Y=0 N=100
Hi-Point	83	12	3	2	0	0	0	Y=94 N=6
Cor-Bon (#701-800)								
Gun	**C6**	**C5**	**C4**	**C3**	**C2**	**C1**	**C0**	
Sig	98	0	1	0	0	0	1	Y=97 N=3
Taurus	95	5	0	0	0	0	0	Y=0 N=100
Hi-Point	74	13	9	3	1	0	0	Y=91 N=9
Independence (#801-900)								
Gun	**C6**	**C5**	**C4**	**C3**	**C2**	**C1**	**C0**	
Sig	99	1	0	0	0	0	0	Y=100 N=0
Taurus	99	1	0	0	0	0	0	Y=0 N=100
Hi-Point	73	12	11	3	1	0	0	Y=97 N=3
Sellier & Bellot (#901-1000)								
Gun	**C6**	**C5**	**C4**	**C3**	**C2**	**C1**	**C0**	Lacquer removed from cartridges
Sig	85	10	4	0	0	0	1	Y=77 N=23
Taurus	56	26	10	1	1	0	0	Y=0 N=95
Hi-Point	49	15	12	8	4	5	2	Y=78 N=17

Table IV: Quality of microstamp as a function of ammunition, T. Grieve.

example, if one simply uses the total number of C6 ratings per ammunition type as a rough comparison system, the three highest rated ammunitions are the Brown Bear (115 gr., brass primer, 157.88 Hv), the UMC (115 gr., nickel primer, 236.31 Hv), and the DAG (124 gr., brass primer, 177.71 Hv). Given that the transfer quality does vary substantially, further study is necessary before any definitive statements can be made concerning the effect of ammunition type. However, it is clear that the presence of lacquer is of paramount importance in identifier transfer. For example, for the Sig Sauer results examiner J. Kreiser scored 52 non-C6 marks, 39 of which were seen in the Sellier & Bellot before the lacquer was removed, i.e. 75% of the poor markings came in the lacquered ammunition. The effect of the lacquer was so great on the Taurus and Hi-Point marks that Mr. Kreiser did not even attempt to rate these cartridges. Even after removal of the lacquer the effect was still apparent; Ms. T. Grieve found that 15 of the 32 non-C6 marks she recorded for the Sig Sauer (47%) came from the Sellier & Bellot cartridges and 38 of 90 for the Taurus (42%). For the Hi-Point 46 of the 95 Sellier & Bellot cartridges examined (48%) were non-C6.; this compares to an average of 24% non-C6 ratings for the rest of the ammunition types examined.

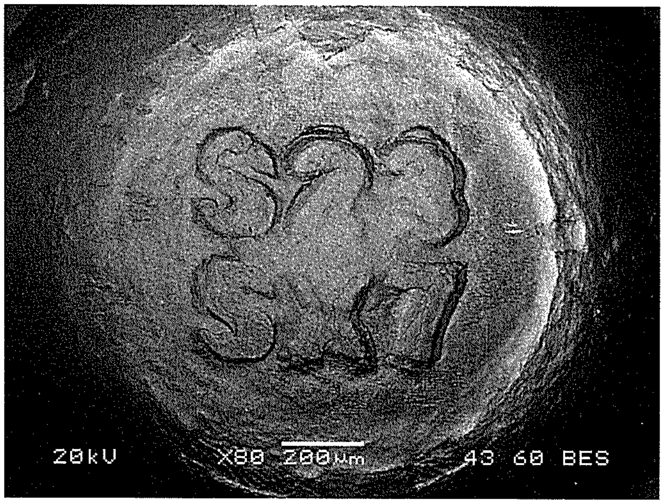

Figure 3: SEM imaging of cartridge #S198, DAG ammunition, Sig Sauer handgun

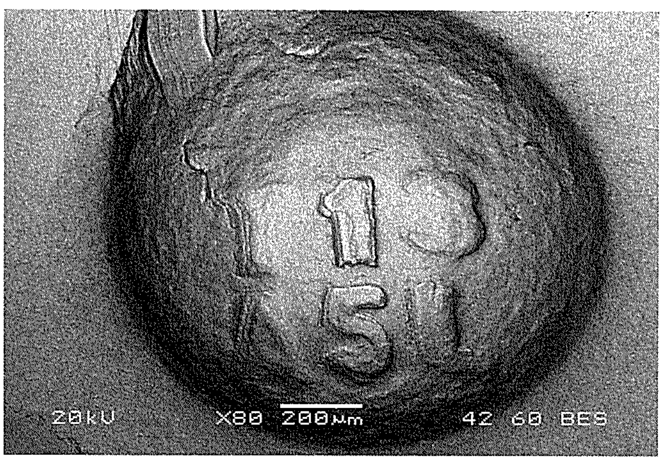

Figure 4: Cartridge #T944, Sellier & Bellot ammunition, Taurus handgun

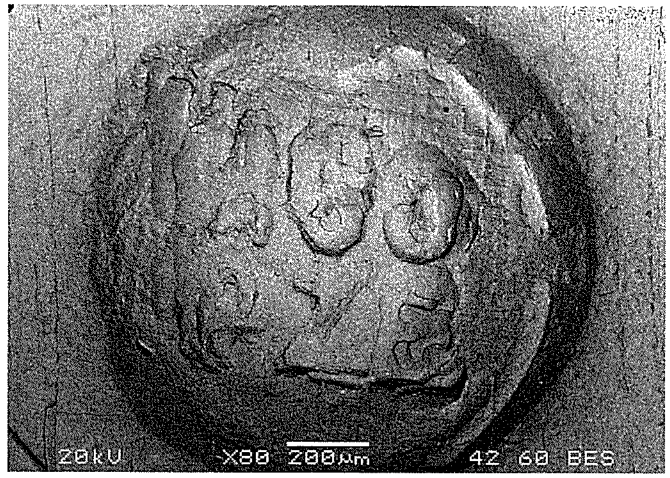

Figure 5: Cartridge #H519, PMC ammunition, Hi-Point handgun.

Ammunition Type	Average Hardness (HV)	Primer type	Comments
Brown Bear	157.88	Brass	284 total C6
DAG	177.71	Brass	274 total C6
Federal American Eagle	165.3	Nickel	251 total C6
Remington UMC	236.31	Nickel	282 total C6; Primer contained manufacturer-stamped letters
PMC Bronze	150.29	Brass	263 total C6
Silver Bear	162.8	Brass	246 total C6
CCI Blazer	176.62	Nickel	270 total C6
CorBon	164.38	Nickel	260 total C6
Independence	167.17	Nickel	267 total C6
Sellier &Bellot	160.68	Brass	Lacquer coated Primer, removed for hardness tests.

Table V: Vicker's Hardness of the ammunition studied

The type of firearm action seems to play the largest role in the overall quality of identifier transfer. Depending on whose evaluation you chose to use, success rate for a C6 transfer for the Sig Sauer was in the range 95-97%, for the Taurus 91-94%, and for the Hi-Point 68-74%. The firearms used were specifically selected to cover a range of pistol operating systems and prices and it is clear that the higher priced firearms, possessing a short recoil action, result in the transfer of a more easily distinguishable identifier than the Hi-Point which has a simple blowback mechanism with a firing pin ejector.

It should be noted that the firing pin is involved in the ejection of spent cartridges from the Hi-Point, and is necessarily in contact with the primer during this time. This makes it difficult to say whether the multiple strike marks seen on spent cartridge primers from the Hi-Point came solely from a multiple strike scenario (as would be the case for the Sig Sauer and Taurus firearms) or whether the ejection mechanism also contributed to the multiple markings. It is certainly true that the Hi-Point suffered a much higher rate of multiple markings than did either the Sig Sauer or the Taurus.

The poor transfer of the gear code in the case of the Taurus was investigated by examining additional firing pins that had also been microstamped using the same identifier for the purposes of this study. SEM images of the pins, shown in **Figure 6**, reveal that while the alpha-numeric number is clear the gear-code is somewhat sparse in detail compared to the Sig Sauer cartridge of Figure 1, and is not as clearly defined in some areas, particularly in the arc quadrant encompassing the "A" of the identifier.

Measurement of the radii of curvature of the firing pins for the three handguns examined revealed that the curvature of the Taurus pins is much greater than either the Sig Sauer or Hi-Point, the radii being 664 microns, 883 microns, and 1180 microns, respectively. Presumably this makes it harder for the gear code on the Taurus to effectively mark a primer.

Although the complete identifier did not mark in every case, this is not to say that it could not have been reconstructed using more advanced imaging techniques. SEM imaging in many cases could reveal more of the identifier and gear code than was visible using simple optics. Previous studies [13] have shown that a combination of better imaging, examination of multiple cartridges from the same weapon and a careful analysis of the gear code can bring out additional information that is not immediately obvious by a simple examination. Such detailed studies again would have to be conducted by a forensic examiner trained in the use of both the necessary equipment and the methodologies used. Whether a simple optical examination using a low-powered magnifying glass by an untrained examiner is possible is a matter that needs to be investigated, and efforts are underway to secure funding to conduct a blind study of this type.

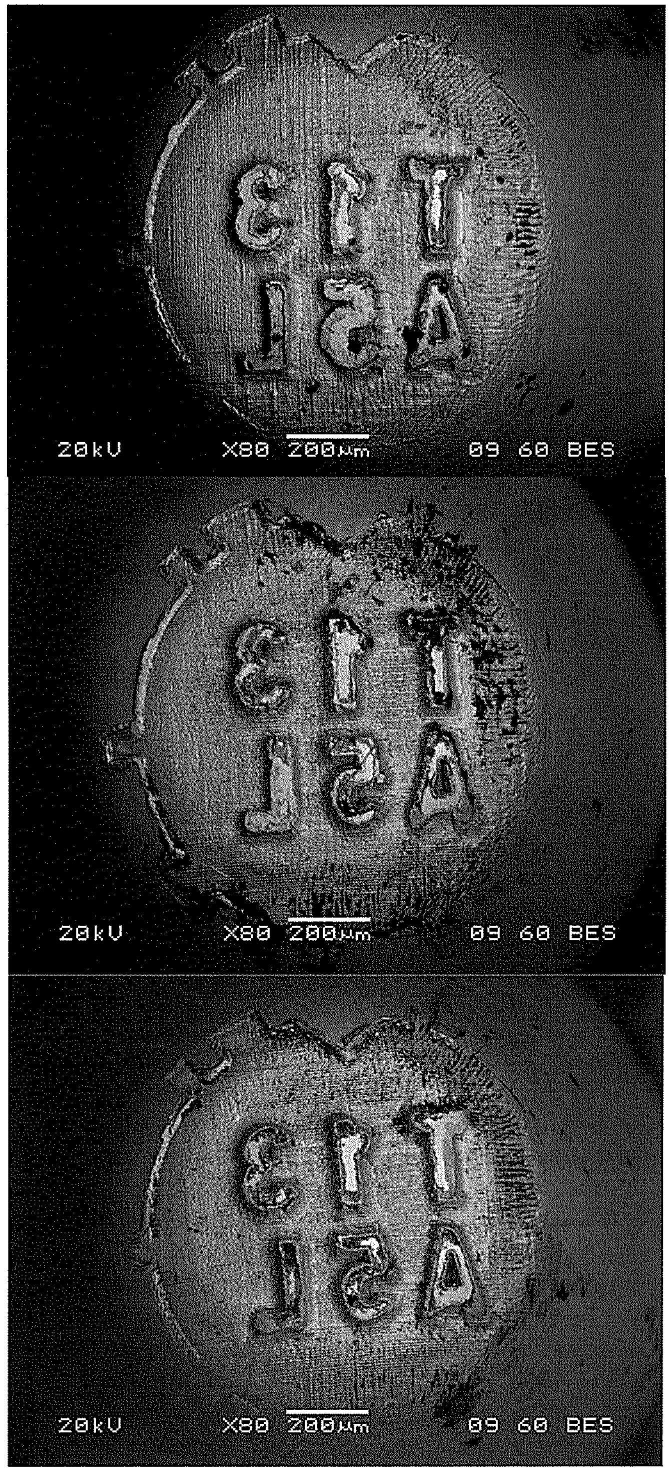

Figure 6: SEM backscattered images of three etched pins microstamped for the Taurus firearm.

Summary and Conclusions

In this study 10 different ammunition brands were fired from three different brands of firearms that were equipped with firing pins containing a unique microscopic identifier. Differences in the clarity of the microstamped identifier were evaluated using simple observation employing a stereomicroscope.

While some differences in clarity were seen as regards brand of ammunition, the observed results could not be related to most of the ammunition variables examined, which included primer material (brass vs nickel), hardness, type (Boxer vs. Berdan), or cartridge material (brass, aluminum, or steel). The only obvious difference in quality occurred when using lacquered ammunition, which degraded identifier transfer. Greater differences were seen when comparing the type of firearm, where the Hi-Point transferred less well than the Sig Sauer or Taurus. However, while the Taurus alphanumeric identifier transferred extremely well the gear code transferred either very poorly or not at all.

While readable microstamping was achieved on most of the cartridge cases, it was also clear that it is not a perfect technology, even on optimized weapons, as the poorer transfer of the Taurus gear code would indicate. As discussed in previous papers the interaction of any particular brand of ammunition with any given firearm is stochastic in nature [16]. Such a variable process prevents perfect transfer in all cases and makes interpretation of the results of this study difficult as regards primer hardness effects.

Despite shortcomings, microstamping does have the potential to place valuable information into the hands of the officer or detective at the scene of a crime in a timely fashion. If coupled with an independent, voluntary oversight board, established and maintained by firearm manufacturers and sportsman associations to control issuance of the identifier and maintain privacy, microstamping could enable tracking of fired cartridges in an efficient and timely manner.

Acknowledgments

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