Chapter 16.2: Forensic Identification of Firearms

Introduction

Firearm identification often plays a particularly valuable role in forensic laboratory investigations. Important questions as to how and by whom gun-related crimes were committed may be answered through a detailed examination of the bullets and firearms recovered either from a crime scene or taken from suspects. The Association of Firearm and Toolmark Examiners (AFTE) has defined the field of forensic firearms identification as determining “if a bullet, cartridge case, or other ammunition component was fired by a particular firearm.” In this section, we will focus upon several of the most important types of firearms investigations that are routinely employed in forensic investigations.

Bullet Comparisons

Firearm evidence, especially bullets and ammunition casings, are often recovered from crime scenes. Investigators usually want to know key information such as the type of gun that fired the recovered bullets and the likelihood that they were fired from one specific weapon. If they can link a suspect to the specific weapon that fired the shots, much of an investigation can quickly fall into place. Fortunately, there are several well-established ways that this type of information can be provided.

Bullets recovered from a crime scene can sometimes be measured to provide information about the caliber and the type of ammunition. Additionally, the chemical composition of a bullet, along with the composition of any gunpowder residue and material from the gunbarrel, can be analyzed to provide comparative information. This information significantly limits the possible range of weapons that the bullet could have been fired from, along with the possible manufacturers of the ammunition, narrowing the search for the weapon down significantly. One of the best ways, however, of connecting a bullet with a type of weapon or even with one particular weapon comes from a close examination of the rifling marks that were inscribed upon the bullet as it passes down the gun’s barrel.

Figure 16.2.2. A mandrel, showing the raised pattern, forms striations on the bullet by a gun barrel’s rifling (firearmshistory.blogspot.com/2010/05/rifling-manufacturing-hammer-)

Figure 16.2.3. Marks from a gun barrel’s rifling on bullets (gunsandammoexpert.com/page2/page2.html).

Figure 16.2.1. (Top) A broach cutter, and (bottom) a button template that forms all the grooves at once when forced down the barrel of the gun (www.pyramydair.com/blog/2006/10/how-are-barrels-rifled-part-2-button.html).

The rifling, the lands and grooves inside the barrel of a gun that cause the bullet to spin upon firing, are made in a variety of ways – all of which are employed in the manufacture of weapons today. Several methods are employed to form the grooves in the metal on the inside of the barrel, either all at once or one groove at a time. A broach cutter (Figure 16.2.1) is used to cut all of the grooves simultaneously by forcing a cutter head down the smooth, drilled-out barrel of the gun while rotating the cutter with a characteristic twist rate. A second method, probably the most commonly employed technique today, employs a hot “button” (Figure 16.2.1) that is forced down the smooth barrel at very high pressures, compressing the metal into the grooved shapes *rather than cutting* the grooves into the metal. Alternatively, a mandrel (a sort of rod-shaped, grooved template) that has raised ribs corresponding to the desired rifling grooves (Figure 16.2.2) is first inserted into a slightly oversized, smooth barrel and then the barrel is compressed or hammered into shape around the mandrel, leaving the grooves and lands formed inside the barrel when the mandrel is removed.

When a bullet passes along the barrel of a gun, the softer metal of the bullet is distorted and shaped to match the lands and groves of the barrel. Examination of the fired bullet can then provide information about the gun it was fired from, such as the number of grooves, the direction of twist (left-handed or right-handed), and the twist rate (Figure 16.2.3). Investigative agencies, such as the FBI, maintain databases of this type of information for an enormous number of manufactured weapons. This information, coupled with the caliber and overall shape and chemical composition of the bullet, can identify unambiguously the make and model of the gun that shot the bullet - very useful class characteristics. Similarly, if the number, size, handedness and twist of a bullet do not all match a suspect gun, then that gun can be eliminated as a possible weapon employed in

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*Figure 16.2.4. Stria, or imperfections, occurring on the barrel of a handgun* (http://accessscience.com/content/Forensic%20firearms%20identification/YB110188).

*Figure 16.2.5. Test-firing a suspect gun in order to compare the stria on the test-fired bullet with the stria on an unknown bullet* (http://library.thinkquest.org/04oct/00206/tte_forensic_lab.htm).

*Figure 16.2.6. Comparison of a test-fired and an unknown bullet (note the vertical dividing line between the two bullet images in the center of the picture)* (www.mcohio.org/government/invct/firearms.html).
firing the bullet. But recovered bullets can also provide individual information as well as class characteristic information about the gun that fired it.

The mechanical process of first drilling out the smooth bore of the gun barrel and then forming the rifling grooves in the barrel (using one of the methods described above) leaves tiny random imperfections, called stria, in the metal walls of the barrel (Figure 16.2.4). These imperfections from the manufacturing process are thought to be unique to each particular weapon, a sort of “signature” for the individual weapon. Additionally, each time that the weapon is fired, the barrel wears and is scratched slightly in unique ways that form individual characteristics in the pattern of each gun barrel’s imperfections. These tiny imperfections are imprinted in the soft metal of the bullet as it rapidly travels down the barrel when the gun is fired. Matching the stria from a fired bullet with the stria inside a particular weapon can provide very convincing evidence that the bullet was actually fired from that individual weapon.

It is, however, exceedingly difficult to directly compare the internal stria on the inside of the gun barrel directly with those on a fired bullet so, instead, the matching process usually involves test firing a bullet from the suspect gun using ammunition comparable to the crime scene bullet (Figure 16.2.5). The stria on the test-fired bullet are then compared with those on the unknown bullet using a comparison microscope (Chapter Four). Matching these stria can indicate a high probability that the two bullets were fired from the same weapon, as illustrated in Figure 16.2.6.

It is not uncommon, however, for the stria not to match exactly at every point between the test-fired and the bullet in question. These differences can arise from several causes. Bullets are often distorted or even largely destroyed upon impact, providing only a small amount of surface area suitable for comparison. Also, the striations in a weapon are not permanent features but change slightly with each and every bullet fired. Thus, even two successively fired bullets are expected to have slightly different patterns. Nonetheless, the stria patterns between two bullets fired from the same weapon usually are overwhelmingly the same.

Since shotgun barrels are not rifled and use small shot instead of bullets (Figure

Figure 16.2.7. Matching patterns from two cartridge cases, one test fired and the other unknown (http://accessscience.com/content/Forensic%20firearm%20identification/YB10188).

Figure 16.2.8. Microscopic image of a firing pin impression (www.forensictechology.com/d1/).
16.1.18), stria are not typically useful in shotgun identification. If the wad, the paper or plastic piece that pushes the cluster of shot down the barrel upon firing, is recovered, however, it can often be related back to the gauge of the shotgun and possibly even to the manufacturer of the ammunition.

**Other Stria Comparisons**

There are a number of other places on a gun where the tiny stria imperfections can be imprinted upon various components of fired ammunition. For example, when a bullet is fired, a firing pin forcefully strikes the detonator to set off the primer charge. Any pattern on the firing pin can be transferred to the end of the cartridge case. Comparing the firing pin pattern on a test-fired and a crime scene cartridge casing can link the weapon and the recovered bullet (Figures 16.2.7 and 16.2.8).

Relatively recently, some gun manufacturers have begun to microscopically stamp identification information onto the end of the firing pin. When the cartridge is struck by the pin, the identifying information is transferred from the pin to the casing, such as shown in Figure 16.2.9. This allows for the rapid identification of the make, manufacturer, and sometimes even the manufacturing lot of the weapon that fired the ammunition.

When a bullet is fired, the explosive reaction propels the bullet forward and at the same time it pushes the metal ammunition casing backward with equal force. When this cartridge casing strikes the back of the firing chamber (called the breech block or breech face), any imperfections in the metal surface of the breech are also transferred to the end of the casing. Once again, comparing a test-fired and crime scene casing can link a casing with a particular gun (Figure 16.2.7 and 16.2.10).

In automatic and semi-automatic weapons, a mechanical extractor ejects spent casings after each bullet is fired to allow a new cartridge to be loaded. When this happens, the extractor can scratch the sides of the casing in

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**Figure 16.2.9.** A firing pin that has been stamped with microscopic identifying information (top) and the impression left on a cartridge case by a microstamped firing pin (www.forensictechnology.com/d4).

**Figure 16.2.10.** Comparison photo of stria on a test-fired and crime scene cartridge casing (www.michigan.gov/msp/0,4643,7-123-1593_3800-15966--00.html).

**Figure 16.2.11.** Marks left by an extractor when a semi-automatic weapon expels spent ammunition casing (dofs.gbi.georgia.gov/00/article/0,2086,75166109_75730713_31669962,00.html).
unique ways that are useful in identifying the type and possibly even the individual weapon, such as shown in Figure 16.2.11.

Of course, fingerprints and other similar markings can also be found on bullet casings and gun handles. It is sometimes quite amazing that criminals may be very careful about fingerprints elsewhere at a crime scene and completely forget about transferring their fingerprints to the cartridges when they handle ammunition in loading the gun (Figure 16.2.12).

**Gunshot Residues (GSR)**

When a weapon is discharged, not all of the ammunition is dissipated as a gas. Some of the unreacted explosive charge, along with solid combustion byproducts, are discharged from every opening in the gun, especially from the muzzle, into the nearby environment. These telltale residues often coat the hands, clothing and body of the shooter and victim if they are close enough (Figure 16.2.13). Swabs taken from potentially contaminated surfaces can be chemically analyzed using a variety of techniques (Chapter 13), especially atomic absorption, X-ray and scanning electron microscopy, to show that a discharge has taken place nearby (Figures 16.2.15). Especially useful are analyses for lead, barium, copper, chromium, and antimony. Scanning electron microscopy can also be used to compare the shapes of the residue particles and help determine the type of powder used in the ammunition (Figure 16.2.16).

When a firearm is discharged, gunshot residue is propelled out of the barrel of the gun. This residue can travel up to about 10 ft and still be detected upon a surface in its path, such as on clothing, a victim’s body or a wall. As the residue moves away from the muzzle (end of the barrel), it tends to spread out. Determining how much spread occurs is done usually by firing a series of test shots at various distances and experimentally measuring the spread and density of the GSR on the surface. Knowing how the residue spreads out, a muzzle-to-target distance can be estimated by measuring the size pattern of any residue present on clothing or any other surface of the target. Often, sufficient information can be gained

![Figure 16.2.12. A latent developed fingerprint on a bullet casing](www.flickr.com/photos/27119371@N04/).
through simple visual or microscopic inspection of the target material, but chemical analysis is also commonly employed.

GSR can also be chemically identified through the application of a number of different chemical tests. The most common of these are color “spot” tests that detect nitrates, nitrites or lead.

Gunshot residue may persist on clothing and hands for a surprisingly long period of time. Many components of GSR are not very water-soluble and the irregular shapes of particles can firmly lodge them within the mesh of clothing and fabrics. Hand washing, however, may be effective in reducing the GSR levels to below useful quantities. Similarly, vigorous treatment or any inadvertent contact may spread the GSR, causing undesired contamination effects that reduce the values of any analysis. For this reason, the hands of victims and suspects are often protected at the crime scene by placing bags around them to prevent GSR loss or contamination. This is particularly important in potential suicide cases. Suspects are also tested as soon as possible for GSR contamination, including at different places on their hands and arms that might help to show if and how the weapon was held (Figure 16.2.14)

Figure 16.2.15. A scanning electron micrograph of a gun shot residue (www.tescan.com/gallery-
audio/en/sb=52&menu=2).

Figure 16.2.16. Elemental analysis of gunshot residue (GSR) by SEX-EDXA (http://library.med.utah.edu/WebPath/TUTORIAL/GUNS/GUNGSR.html).

Figure 16.2.17. Restoration of a scratched out serial number using chemical methods (dps.mn.gov/divisions/bca/bca-divisions/forensic-science/Pages/serial-number-restoration.aspx).
Serial Number Restoration

Manufactured guns are stamped in one or more places with uniquely indentifying serial numbers. These numbers are registered and may be used to trace the point of manufacture, sale, and ownership of a weapon. These numbers allow police investigators to easily trace weapons back to their owners. Weapons used in criminal activity, however, often have been tampered with in attempts to obliterate the identifying serial number by scratching or grinding it out. It is important to try to restore these illegible numbers to effectively trace a recovered weapon. Fortunately, this may be possible.

When a serial number is stamped into the metal of a gun, a very hard die containing the serial number is pressed into the metal with a great deal of pressure. When this happens, the crystal structure of the metal underneath the stamped numbers is deeply stressed and distorted by the stamping process. Removing the outermost layer of metal through scratching or grinding fortunately cannot change the deep modification of the metal’s structure that happens during stamping. It is, therefore, possible to restore illegible serial numbers chemically by selectively developing the areas where the metal has been “stressed.”

In this process, the “stressed” metal below the die-stamped numbers is more easily etched away chemically than the surrounding block of metal. For example, a water solution containing hydrochloric acid (HCl) and copper(II) chloride etches away the stressed metal crystallites faster than the unstressed metal. In this process, the metal to be restored is first cleaned and polished. Then a hydrochloric acid/CuCl₂ solution is applied to the surface. After a period of time, the “stressed” region of the stamped numbers is dissolved away to reveal the ID number. An example of the results of this process is shown in Figure 16.2.17.

Unfortunately, the records of serial numbers of older weapons may not be available or a crime weapon may have been stolen or passed among many people such that serial numbers, even when present, might not provide much valuable information.

Ballistics

Understanding the trajectory of a bullet can help to reconstruct in detail the events that occurred during a shooting. The paths of the bullets may be determined by carefully measuring and positioning any known end points, impact angles, trajectory data in autopsy reports, and other known points (Figure 16.2.18). Ballistics information can provide important information about the location and sequence of events involved in a shooting (www.crime-scene-reconstruction.com/Shooting%20Incident%20Reconstruction.htm).
16.2.18). This information can then be integrated into a representation of the crime scene; increasingly computer-assisted design (CAD) programs are being used for this purpose, such as shown in Figure 16.2.19. This type of crime scene reconstruction can provide very relevant and detailed information about the relative positions of the shooter and victim, the timing of the shots, and the movements of the participants during the incident.

Part of theballistics testing in the laboratory is also to determine if a particular weapon is both capable of firing and potentially has recently been fired (GSR analysis). Obviously, an inoperative weapon could not have been used in a shooting incident.

**Integrated Ballistic Identification System (IBIS) and National Integrated Ballistics Information Network (NIBIN)**

In 1999, the formerly separate databases maintained by the FBI and ATF were merged together to form the National Integrated Ballistics Information Network, called NIBIN. In this system, law enforcement partners use the Integrated Ballistic Identification System (IBIS) to input and recover digital images of the markings found on fired bullets and cartridge cases either recovered from crime scenes or from test-fired weapons (Figure 16.2.20). These digital images are then compared with those previously stored in the NIBIN system. The computer matching system then searches for comparable images that investigators can then examine microscopically. Using the NIBIN systems, law enforcement investigators are able to “discover links between crimes more quickly, including links that would never have been identified absent the technology.” For example, the New York City Police Department has identified nearly 3,000 “hits” using the NIBIN system.

**Figure 16.2.20.** NIBIN image of a recovered cartridge case (www.maine.gov/dps/msp/criminal_investigation/crimelab/nibin.htm).

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**Sacco and Vanzetti**

On April 15, 1920, an afternoon robbery in Braintree Massachusetts left a paymaster and a security guard dead and nearly $16,000 in payroll gone. It was a case that helped change the landscape of criminal justice and immigrant rights in the US.

Police investigations of the homicides quickly centered upon a group of local Italian anarchists and militants. On May 5th, 1920, Nicola Sacco and Bartolomeo Vanzetti were arrested when they showed up to claim a car that the police suspected had been used in the assault and robbery: both men were armed, carried anarchist literature, and Vanzetti had unusual shotgun ammunition in his pockets similar to that used during the robbery.

After a highly publicized trial with a near-frenzy of public interest, Sacco and Vanzetti were convicted of the murders. In the following six years, all appeals failed and the two were executed on August 23, 1927. The public outrage from the proceedings and results of the trial led to some important reforms in legal process, especially regarding the handling of evidence and what constitutes “expert”
A major part of the trial centered upon forensic firearm analysis. Many witnesses were presented by both sides, including a large number of “non-experts” that presented “expert” analysis (59 for the prosecution and 99 for the defense in total), some of whom testified regarding the match (or non-match) between a bullet test-fired from Sacco’s gun and that found in the body of the victim. Additionally, the prosecution argued that the type of ammunition used in the assault was of an obsolete and rare type but that it matched the unusual collection of ammunition found in Vanzetti’s pockets when he was arrested. It has been reported that even some of the defense experts changed their minds on examining the test-firing evidence and agreed that the fatal bullet was fired from Sacco’s gun.

Through the years, attention has remained centered upon the central question in the case: was the fatal shot fired from Sacco’s gun? In later investigations in 1961 and 1983, using significantly improved ballistic testing methods, the analysis concluded that the fatal shot had indeed been fired from Sacco’s gun. Various authors have continued to argue about both guilt and innocence, however, and the debate continues. In 1977, Gov. Michael Dukakis of Massachusetts issued a proclamation that Sacco and Vanzetti had been unfairly tried and convicted. The proclamation did not, however, imply guilt (as a pardon would do) nor their innocence. Nonetheless, significant questions still remain and the Sacco and Vanzetti case continues to be actively debated.