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AN ANALYSIS OF FIREARM IDENTIFICATION AND FORENSIC SCIENCE

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ABSTRACT

In criminal investigations, forensic science is essential, and one of its most important subfields is firearm identification. The scientific analysis of bullets, cartridge cases, and firearms to ascertain whether a certain firearm was used in a crime is known as firearm identification, or forensic ballistics. This procedure depends on the examination of both individual and class features, such as distinct microscopic striations and firing pin impressions that are transferred to ammunition components during discharge from a weapon and caliber and rifling patterns, respectively. Forensic examiners can connect firearms to crime scenes and suspects by carefully comparing bullets and cartridge cases using specialized instruments like comparison microscopes and cutting-edge imaging technologies. Forensic firearm identification is still a strong and trustworthy scientific field that is crucial to justice and public safety, even in the face of persistent obstacles like the wide variety of firearm types and the possibility of identical marks on many guns.

KEYWORDS : Criminal Investigations , Forensic Science , Firearm Identification , Forensic Ballistics , Ammunition , Bullets , Cartridge .

AN ANALYSIS OF FIREARM IDENTIFICATION AND FORENSIC SCIENCE

1.0. INTRODUCTION

The study of projectile and weapon motion, behavior, and effects is known as ballistics. The scientific study of guns, ammunition, and their effects is known as forensic ballistics, and it is mostly used to support criminal investigations and court cases. In order to ascertain the origin and use of firearms and ammunition-related evidence in criminal cases, forensic scientists specialize in the field of firearm identification. In particular, firearm identification entails matching bullets, cartridge cases, and other ammunition components to the precise firearm from which they were discharged. This process is frequently referred to in general terms as ballistics.This paper's goal is to investigate weapon identification methods and the ways in which ballistic evidence might connect firearms to criminal activity. At a crime scene, firearms and the spaces around them might yield a variety of evidence. In addition to being important for the main crime, this weapons-related evidence can support the development of compelling parallel criminal cases, such as those involving international firearms trafficking.

2.0. FIREARMS

A firearm is a tool used to shoot one or more projectiles. These projectiles are propelled by expanding gasses produced when a propellant powder charge burns quickly. In essence, a firearm is a weapon that uses the expansion force of gases created by an explosive material to fire a projectile[313].

A firearm is defined by the Indian Arms Act as any arm that is made or modified to fire a

[313] Hogg, I. V., & Weeks, J. (2016). *Military small arms of the 20th century* (8th ed.). Krause Publications

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projectile of any type using an explosive or other energy source. Included in this definition are:

1. Weapons made or modified to release any toxic liquid, gas, or comparable material, such as artillery, hand grenades, riot pistols, and others.

2. Add-ons for any of these guns that are made or modified to lessen the brightness or noise they make when they discharge.

3. Appliances and platforms for mounting, moving, and maintaining artillery, as well as parts and equipment for producing guns and ammunition[314].

Small firearms are designated by the UN as weapons meant for personal use. In general, revolvers, self-loading handguns, assault rifles, light machine guns, submachine guns, rifles, and carbines fall under this group[315].

2.1. VARIANTS OF FIREARMS

1. Shotguns
2. Revolvers
3. Pistols Rifles
4. Sub- machine guns
5. Machine guns
6. Muzzle Loaders
7. Improvised firearms

There are numerous variants of firearms in each category . The most commonly used weapons are 12 bore shotguns and improvised firearms, in india .

2.1.1. HANDGUNS: Weapons that can be fired with just one hand are known as handguns. Handguns include, for example, revolvers, derringers, and pistols[316]. One kind of pistol made to be fired from the hand is a revolver. It has a barrel with a rifled edge and a cylinder that turns and usually has 5 to 7 chambers. Each chamber holds one bullet. [317]. Revolvers may be classified into several types: Solid Frame (like the Samuel Colt model from 1835), Swing-Out, and Break-Open. A pistol, also designed to be fired from the hand, has a rifled barrel as well. Single-shot, semiautomatic, and fully automatic pistols are all possible. Cartridges of an automatic pistol are kept in a detachable magazine [318].

2.1.2 . RIFLES: weapons that require shoulder support in order to fire and have a rifled barrel. A single shot, a lever action, a bolt action, a pump action, or auto-loading (often mislabeled "automatic rifles") are among possible types[319].

2.1.3. SHOTGUNS: There are several kinds of smooth-bored firearms that need shoulder support in order to fire, including: a. Single shot b. Above and underneath c. Triple barrel d. Action of bolts e. Action of levers f. Action of pumps g. Auto-loading[320] . With one or two unrifled barrels that can be positioned over, under, or side by side, a shotgun is a long, shoulder-fired weapon.Usually, it is made to fire numerous tiny projectiles, or "shots," as opposed to a single bullet. The gauge of a shotgun, which is often greater in diameter than other small arms, is known as its caliber. Shotguns are typically single-shot, although they can also be made to be semi-automatic or repeating.

2.1.4. SUBMACHINE GUNS: Weapons that shoot pistol ammo and have a rifled barrel and are fully automatic. To shoot, they require hip or shoulder support[321].

2.1.5. MACHINE GUNS: weapons with a rifled barrel that are fully automatic and shoot rifle ammo. To shoot, they require hip or shoulder support [322].

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2.1.6. REVOLVER

A revolver is a short, handheld pistol that is distinguished by its rotating cylinder, which normally has five to nine chambers. Cartridges are manually fed into these chambers. Pulling the trigger causes the hammer to be released, firing the cartridge as the cylinder rotates into place. The spent cartridge cases remain inside the cylinder until they are manually unloaded. Revolvers are generally classified as repeating firearms. They can operate in one of two ways, depending on the trigger mechanism: single action, where the hammer is manually cocked before firing, or double action, where pushing the trigger also cocks the hammer[323].

2.1.7. PISTOL

A handgun is a compact, portable firearm with a semi-automatic mechanism. The barrel incorporates the chamber. Usually, a magazine that fits into the pistol's grip contains cartridges. The next round enters the chamber after the spent cartridge is forced out by the gun's action. Automatic, semi-automatic, repeating, and single-shot are among the different actions that handguns can have.

2.2 CLASSIFICATION OF FIREARMS

1. Barrel Bore characteristics classification
2. Functional mode
3. Calibre based classification
4. Loading
5. Handling Mode classification

2.3 FIREARM PARTS

A Firearm has three main parts ;

a) Barrel
b) Action
c) Stock

The Barrel of a firearm provides space for the expansion of gases . It has a chamber to house the catridge in most of the firearms (revolvers excluded) . The chamber is on the back of the barrel .

The Action consist of the mechanism of loading , firing , extraction and ejection of the catridges , the magazine and the safety devices ,if any . The arrangements for the location of constituent parts vary in different firearms .

The Stock of the firearm holds the other parts in position and provides support for firing purposes . In automatic and semi- automatic pistols, the stock also carries the magazine .

2.4 . FIREARM FORENSICS

Examining firearms, ammunition, and the consequences of their use during criminal investigations is the focus of the crucial field of firearm forensics, commonly referred to as forensic ballistics. Examining and analyzing firearms, ammunition, and associated ballistic evidence in criminal investigations is the focus of this specialized area of forensic science. Identifying firearms, examining the behavior of bullets and cartridge cases, and connecting firearms to crimes, victims, or suspects are the main objectives. In addition to supplying vital evidence for criminal justice and legal proceedings, this branch is essential in the investigation of gun-related offenses.

This field combines knowledge of firearms with scientific techniques to answer key investigative questions like:

- What type of firearm was used?
- Was a particular gun used in the crime?
- How many shots were fired?
- From what distance and direction was the gun fired?
- Can the shooter be identified or linked to the weapon?

2.5 .FIREARM IDENTIFICATION

Examining firearms, ammunition, and the effects of their use in criminal investigations is the main emphasis of the crucial discipline of firearm forensics, often known as forensic ballistics. In order to link firearms to crimes, victims, or suspects, this particular branch of forensic science focuses on analyzing firearms,

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ammunition, and associated ballistic evidence. Identification of firearms, analysis of bullet and cartridge case behavior, and provision of vital evidence for criminal justice and legal actions are the main goals. This discipline is crucial to the investigation of crimes involving firearms[324]. Firearm identification under ballistics involves examining microscopic marks lest on bullets and cartridge cases by a firearm during firing , allowing forensic experts to potentially link a weapon to crime . Forensic firearm examination is the forensic process of examining the characteristics of firearms or bullets left behind at a crime scene. Specialists in this field try to link bullets to weapons and weapons to individuals.

Any firearm discovered during an investigation could yield critical evidence if it undergoes thorough examination. Forensic firearm analysis can uncover specific details, such as serial numbers and potential fingerprints present on the weapon's surface. By examining the unique striations imprinted on a bullet by a rifle barrel, forensic experts can link discharged ammunition to a specific firearm. These striations result from the rifling within gun barrels, which rotates the bullet as it is fired to enhance accuracy. While bullet striations are distinctive to each firearm, the microscopic patterns within the barrel can vary significantly with each shot. As a result, the number of bullets discharged from a firearm retrieved at a crime scene is usually constrained by forensic ballistics specialists[325].

Using comparison microscopes and cutting-edge 3D imaging technologies, evidence gathered from a crime scene can be compared to known samples from a seized weapon. Uploading striation photos to national databases enables comparisons with other images to ascertain whether a particular weapon has been connected to more than one crime scene[326]. Identifying a firearm usually entails the following steps:

1. Toolmarks are examined: Due to the unique features of its barrel, firing pin, extractor,and other components, each handgun leaves a unique mark on bullets and cartridge cases.

2. Ammunition Analysis: This entails determining the caliber, bullet type, and any additional distinctive characteristics, including rifling impressions.

3. Firing Test: To match the distinctive markings from a suspect weapon with those discovered at a crime scene, forensic specialists frequently test-fire weapons.

No two firearms, even ones of the same make and model, leave identical traces on bullets or cartridge cases, according to the fundamental tenet of firearm identification. The distinctive microscopic flaws within the gun's barrel and firing mechanisms create these marks, which are referred to as toolmarks. Forensic specialists can ascertain whether a specific firearm was used in a crime by examining these markings using methods like comparative microscopy.

2.5.1 . Fingerprint recovery

The most frequent method for recovering fingerprints off weapons is cyanoacrylate fuming, also referred to as superglue fuming. Instead of just eliminating the fumes, this method distributes them evenly by placing firearms under a specially made fume hood. In a container, liquid superglue is heated until it becomes a gas. The oils that fingerprints leave behind are adhered to by the flowing fumes, making the prints appear white. Fingerprint powder can be applied to the resulting white prints to improve visibility by making them stand out more against the weapon's surface. Despite the prevalence of fuming techniques for fingerprint recovery from firearms, the process can be difficult because of the textured grips and overall state of the recovered weapons.

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Fingerprint databases like the Integrated Automated Fingerprint Identification System (IAFIS) can process retrieved fingerprints. It is also possible to test different areas of the recovered weapon for touch DNA left by the person who handled it. However, there are a number of problems with the minimal amounts of DNA that can be recovered, including contamination and anomalies in analysis like allele drop-out and drop-in.

2.5.2 . Serial number recovery

- Examining serial numbers is one type of tool mark analysis. Serial numbers became commonplace when the Gun Control Act of 1968 was passed, requiring all weapons made in the United States or imported into the country to have a unique serial number. Many rifles had serial numbers that were either not unique or that manufacturers frequently used on other firearms before this restriction was implemented.
- If a found weapon's serial numbers have been altered or deleted, forensic examiners may attempt to recover them. The two primary methods for restoring serial numbers are chemical restoration and magnetic particle analysis. Since magnetic particle inspection is a nondestructive process, it need to be carried out first.
- Chemical restoration can be utilized as the following stage in the forensic investigation process if magnetic particle examination is unsuccessful.

The serial number can assist investigators in tracing the history of a weapon and potentially identifying its owner if it is successfully restored. Investigators can use firearm databases, such as INTERPOL's Firearm Reference Table and the National Crime Information Center in the United States, to track firearms that have been lost, stolen, or involved in other illegal activities.

2.5.3 Magnetic particle inspection

The primary purpose of magnetic particle inspection is to identify defects or abnormalities in magnetic materials. In firearms, this method can also be utilized to reveal serial numbers that may be hidden beneath damaged surfaces. To conduct this examination, examiners first position the handgun within a magnetic field. The magnetic field is affected by the imperfections in the metal, including any concealed serial numbers. When a solution containing ferrous particles is applied to the magnetized surface of the weapon, these particles are attracted to the distorted areas of the magnetic field, collecting in those specific locations. If fluorescent particles are added to the ferrous solution, using UV light can enhance the visibility of any uncovered serial numbers.

2.5.4 .Chemical Restoration

Chemical restoration is one kind of chemical milling. Usually, material is gradually removed by chemical grinding until the required shape is achieved. Throughout the serial number restoration process, tiny pieces of metal are meticulously eliminated until the metal variations that correspond to the original serial number are visible. This is made feasible by the fact that stamping the numbers disturbs the grain boundary structure underneath the metal's surface. However, chemical restoration is only effective at shallow levels and requires just partial obscuration of the serial number.

The initial step in the restoration process conducted by examiners involves sanding the area where the serial number was previously located. This sanding not only obscures the serial number but also removes any remaining material. Following this, the examiner meticulously works to reveal the serial number once again, employing a chemical agent, typically an acid. The specific chemical used is dependent on the material of the weapon. For instance, magnetic metals are treated with Fry's Reagent, a combination of hydrochloric acid, cupric chloride, and distilled water. In contrast,

non-magnetic, non-aluminum materials require a different approach.

2.5.5 .Examination Of Cartridges

Examining the cartridges A magnified picture of two test-fired cartridges shows that their striations match. It is possible to compare spent cartridges from the same firearm to samples taken from the crime scene or examine them for physical evidence like fingerprints. To examine the cartridge, one must look for distinctive tool marks made by the firing pin and, in semi-automatic and fully automatic rifles, the ejector. It is possible to match and compare these indications to known exemplars that were fired from the same weapon with identical parts. Examiners can view the questioned cartridge and the known exemplar concurrently while analyzing the marks on the cartridge using a comparison microscope, which helps them look for identical tiny marks made during fire.

Because putting ammunition into a magazine or chamber can leave recoverable impressions, cartridges are regularly inspected for fingerprints. Although it is not common, fingerprints that can withstand shooting have been recovered from cartridges found at crime scenes. Cartridges go through cyanoacrylate fuming to increase the likelihood of retrieving usable prints. In order to compare them with known samples, usable prints are photographed and uploaded to fingerprint databases like IAFIS. Cartridges can also be swabbed to detect the DNA trace left by the magazine's loader. The incredibly low amounts of recoverable DNA, however, pose difficulties akin to those that arise when swabbing a handgun for DNA evidence.The implementation of firing pin microstamping has advanced due to developments in microscopic stamping technology. When a cartridge fires, the microstamp etched into the firing pin is transferred to the cartridge casing. This allows investigators to link casings found at a crime scene to a specific firearm, as each firing pin has a unique serial number. Although California passed legislation requiring microstamping on all newly sold firearms, this practice has ceased as of 2025. Gun manufacturers have strongly opposed the regulation and the concept of microstamping in general, citing concerns about its reliability and the lack of evidence that it effectively helps to prevent or solve crimes.

2.5.6 Examination of bullets

Rifling pattern for a Remington rifle showing a clockwise (right-handed) twist.

Class characteristics

- By examining the general features of the recovered projectile, a preliminary study of a bullet can rule out a variety of firearms. Many firearms can be quickly ruled out as being unable to fire that particular type of bullet by evaluating the fundamental characteristics of the fired ammunition. Furthermore, the combination of several class features linked to particular manufacturers can frequently be used to deduce the weapon's make and model. The caliber of the bullet, the rifling twist, and the lands and grooves are the three main class features of all bullets. The type of barrel that fires the bullet is directly related to these characteristics.The raised and recessed patterns created during the rifling operation are known as lands and grooves. While the twist indicates the direction of the rifling's striations—clockwise for right-handed people and counterclockwise for left-handed people—the caliber relates to the barrel's diameter. Although certain barrels, including those made by Colt's Manufacturing Company, use left-handed twists, most barrels are made with a right-handed twist. To determine whether a bullet came from a particular firearm, weapon barrels that match the class criteria of recovered bullets can be further inspected for unique features.
- The barrel's diameter is referred to as the caliber. The twist, which can be

either clockwise (for right-handed people) or counterclockwise (for left-handed people), shows which way the rifling inside the barrel has exited the grooves. Barrels made by Colt's Manufacturing Company usually have a left-handed twist, but the majority have a right-handed twist. To ascertain whether a bullet came from a particular weapon, weapon barrels that have the same class characteristics as recovered bullets can be examined further for unique features.

3.0 The Role of Firearm Identification

1. **Role In Criminal Investigations**

Firearm identification is a crucial aspect of forensic ballistics and plays a significant role in criminal investigations for several reasons. One of its primary purposes is to link a firearm to a crime scene. Forensic experts examine tool marks on bullets or cartridge casings, including rifling impressions, striations, and firing pin impressions. By comparing these markings to known impressions from the firearms of suspects or from test-fired ammunition, they can establish a connection between a specific firearm and a crime scene. This analysis can determine whether a firearm found with a suspect or retrieved from another location was used in the crime. It can also confirm if the firearm in the suspect's possession is the same one used in the offense.

2. **Identification of the Shooter:**

While fingerprints and DNA are the most common forms of personal identification, firearm identification allows law enforcement to trace bullets and cartridge cases back to the specific firearm, which can help link a suspect to a shooting incident, even if the shooter's identity is not immediately known.

3. **Establishing Connections Between Different Crime Scenes:**

If the same firearm or ammunition is used in multiple crimes, firearm identification can establish a pattern or link between otherwise unrelated crimes. This can lead investigators to connect serial shootings or identify a suspect responsible for multiple criminal incidents.Ballistic fingerprinting (or the creation of a database of ballistic marks) can make it easier to match bullets and cartridges from different locations, potentially solving previously unsolved crimes.

4. **Providing Courtroom Evidence:**

   - Firearm identification plays a critical role in criminal trials, where expert testimony about ballistic evidence can strengthen a case against a suspect or, conversely, help exonerate someone who has been wrongfully accused.
   - Forensic ballistics experts analyze and present ballistic evidence, such as matching a bullet or cartridge case to a specific firearm, in court as critical evidence of guilt or innocence.

5. **Reconstructing the Event:**

   - Forensic firearm identification can help reconstruct the events of a crime. By analyzing the ballistic evidence, experts can determine things like the distance from which the firearm was fired, the trajectory of the bullet, and even the type of firearm used.
   - This analysis aids investigators in determining how the crime occurred and helps establish timelines or corroborate witness testimony.

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6. **Public Safety and Crime Prevention:**
    - Identifying firearms used in crimes can assist in preventing further criminal activity. Tracking firearms used in multiple crimes or illegal weapons trafficking can lead to the dismantling of criminal networks.
    - Firearm identification also helps authorities understand patterns of violence, which can inform policy decisions, law enforcement strategies, and public safety initiatives.

4.0 PRINCIPLES OF FIREARM IDENTIFICATION

The **Principles of Firearm identification** fall under the broader field of **forensic ballistics**, where firearms and ammunition are analyzed to determine if a particular weapon was used in a crime. This process is also called **Firearm forensics** or **Toolmark identification**.

1. **Every Firearm is Unique**

Bullets and cartridge cases will have slightly varied marks from even two guns of the same manufacture and type. These variations result from:
• Imperfections in manufacturing
• Damage and wear
• Adjustments
The gun's "fingerprint" is made up of these tiny traces.

2. **Firearms Leave Marks on Ammunition**

Because the bullet and cartridge case come into touch with the gun's internal components when it is fired, it leaves distinctive toolmarks on them.These include:

A. Firing Pin Impressions

- The shape and depth of the mark from the firing pin striking the primer can help identify the firearm.

B. Breechface Marks

- The rear of the cartridge case is forced against the breechface, leaving unique patterns.

C. Extractor and Ejector Marks

- Semi-automatic and automatic firearms often leave identifiable marks as the cartridge is ejected.

D. Chamber Marks

- Scratches caused by the cartridge case expanding against the walls of the chamber.

E. Rifling Marks on the Bullet

- The lands and grooves inside a barrel spin the bullet, leaving **striations** that match the barrel's rifling.

3. **Comparison Microscopy**

Experts in forensics analyze and contrast bullets and casings side by side using a comparison microscope. They're searching for traits that fit both individual and class:

Class Characteristics:

- Caliber
- Number of lands/grooves
- Direction and twist of rifling
- Width of lands/grooves

Individual Characteristics:

- Unique, microscopic imperfections from manufacturing or wear

4. **Ballistics Databases**

• To store and match firearm evidence, agencies employ databases such as NIBIN (National Integrated Ballistic Information Network).
• You can enter a fired bullet or casing into the system to see whether it fits any other crimes.

5. **Scientific Validity and Consistency**

Firearm identification is based on the assumption that:

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"No two firearms produce the same unique set of marks on ammunition."

5.0 METHODS OF FIREARM IDENTIFICATION

Forensic examiners employ the Methods of Firearm Identification to ascertain whether a given bullet or cartridge case was fired from a particular firearm. These techniques integrate tool mark comparisons, microscopic examination, and scientific principles.

1. Microscopic Examination

• The most often used approach.
• Examines two things side by side using a comparison microscope (often the evidence vs a test-fired bullet or shell).
• Examiners search for tool marks that match:

Bullet rifling striations, breech face marks, extractor and ejector marks, and firing pin impressions

Comparison Microscopes:

These devices make it easier to compare tool marks by enabling examiners to observe an unknown bullet or cartridge case and a known standard that was shot by the suspect weapon at the same time.

Microscopic Examination:

In order to assess whether the tool marks are comparable enough to conclude that the ammo was shot from the suspect weapon, examiners carefully compare them.

2. **Class and Individual Characteristic Analysis**

A. Class Characteristics

General features shared by a group of firearms.

- Caliber
- Number of lands/grooves
- Twist direction
- Width of lands and grooves

B. Individual Characteristics

These are unique microscopic marks left on ammunition by the components of firearm. They are caused by manufacturing imperfections of wear and tear.

- Microscopic, random imperfections are unique to a specific firearm. Arise from:
  - Manufacturing variations
  - Use and wear over time
  - Damage or intentional alterations

These are critical for making **identifications**.

3. **Test Firing (Exemplar Comparison)**

- Investigators fire the suspect firearm into a **water tank** or **ballistic gel** to recover bullets without distortion.
- The test bullets are then compared to the crime scene bullet under a comparison microscope.

4. **Toolmark Identification Techniques**

Firearms are considered a type of tool, and they leave toolmarks on ammunition. Examiners use:

- **Striation matching** (on bullets)
- **Impression matching** (on cartridge cases)
- **Pattern matching** using microscopy and digital enhancement

5. **Automated Ballistics Identification Systems (ABIS)**

Notable systems:

- **NIBIN (National Integrated Ballistic Information Network)** – U.S. system operated by ATF.
- **IBIS (Integrated Ballistic Identification System)** – Global system that supports automated comparisons.

These systems use digital imaging and algorithms to match bullets and casings across large databases. Final confirmation is always done by a human examiner.

6. **Measurement and Imaging Techniques**

- **3D imaging and surface topography**: Captures minute details of toolmarks.
- **Scanning electron microscopy (SEM)**: Provides high-magnification surface details.
- **Digital photography**: Enhances and documents findings for court presentations.

6.0 . LEGAL ASPECT OF FORENSIC BALLISTICS

- **Admissibility in Court**:
  - Governed by legal standards like **Daubert** (in the U.S.) or similar frameworks globally.
  - Evidence must be **relevant**, **reliable**, and **legally obtained**.
- **Chain of Custody**:
  - Every piece of ballistic evidence must have a documented and unbroken chain of custody.
  - Failure can lead to inadmissibility in court.
- **Search and Seizure Laws**:
  - Firearms and ballistic evidence must be collected legally (with proper warrants or exceptions).
- **Right to Cross-Examine**:
  - Defense has the right to challenge the forensic ballistic expert's methods, qualifications, and conclusions.

7.0 CONCLUSION

In criminal investigations, the evidence provided by firearms, ballistics, and ammunition is often overlooked. Law enforcement actions typically stop at the point of seizure or recovery. However, materials linked to confiscated or recovered firearms can also serve as crucial evidence for a variety of other offenses, such as illegal production and firearm trafficking. Since "every firearm tells a story," firearms and ballistics play a vital role in criminal investigations. Firearm identification is essential in forensic ballistics because it provides important information that connects firearms to specific crimes, offenders, and crime scenes. By closely examining the unique tool marks that weapons leave on bullets and cartridge cases, forensic specialists can establish undeniable links between a suspect's weapon and criminal activity. This expertise enhances the judicial system by offering significant evidence that aids in solving crimes and upholding the integrity of court cases.

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