Section A-Research paper

Scope, Analysis and Advancements of Striation Patterns on Bullets

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Abstract

In recent years, advancements in technology have led to the development of more sophisticated techniques for analyzing and comparing bullet striations. These techniques can be used to match a bullet found at a crime scene to a specific firearm with a high degree of accuracy, which can be valuable evidence in criminal investigations. In criminal assault, prevalence or frequencies with which firearms are used has resulted in the development of advanced aspects of criminalistics. Collection of firearms evidence can be classified based on the collection of ammunition, firearms and gunpowder obtained from the scene of crime. Hence for the identification purpose, multipleapproaches are being used such as trace metalcompositionalong with simultaneous comparison or matching of striation marks on bullets. These impressions or striations are like fingerprints of a bullet or a firearm and are unique to the firearm from which it was fired from. Recently, the most reliable instrument used for identification is the comparison microscope, Scanning Electron Microscopy. Once the images of striation are obtained using the SEM, it is then compiled using software like Amira-Avizo or for automated compiling and is transferred to VR. Thus, VR can be used for closer inspection by an expert. The following paper thus goes through the scope, analysis, and the advancements of striation markings on the bullets from traditional to modern techniques and its use in the field of forensic ballistics. This would highly help in increasing the reliability and the accuracy of bullet matching in forensic ballistic cases.

Keywords:

Ballistics, Bullet Striations, Impression evidence, Rifling, Lands and Grooves, Firearms Examination, Virtual toolmark Analysis.

1. INTRODUCTION

Striation markings on bullets are tiny scratches or grooves left on the surface of a bullet as it travels through a barrel. These markings are unique to each barrel, much like a fingerprint, and can be used to trace a bullet back to the firearm that fired it.(B. R, 1976)

Striation markings are created by the rifling in the barrel of a firearm, which imparts a spin to the bullet as it travels down the barrel. The grooves in the rifling cause small scratches on the surface of the bullet as it passes by, creating a distinct pattern of striations. These markings can be used to match a bullet to a specific firearm, as the pattern of striations will be the same for every bullet fired from that same firearm.(Saferstein, 1978)

Forensic scientists use microscopes to examine the striation markings on a bullet in order to match it to a specific firearm. By comparing the markings on a bullet to the markings on a test-fired bullet from a suspect firearm, they can determine whether the two bullets were fired from the same gun. In criminal investigations, striation markings on bullets can provide valuable evidence for linking a suspect to a crime scene or linking multiple crime scenes together. However, it is important to note that striation markings are not always a perfect match and can be affected by factors such as barrel wear and damage, which can alter the pattern of striations over time.

Striations on bullets are formed due to a combination of factors that occur when a bullet is fired from a firearm. When a bullet is fired, it is subjected to a variety of forces and motions, including rotation, translation, and deformation. As the bullet travels down the barrel of the firearm, it encounters imperfections in the bore, such as variations in diameter, rough spots, and other anomalies. These imperfections cause the bullet to deform slightly as it travels, which results in the creation of distinctive marks on its surface.

Additionally, the bullet is rotated by the rifling in the firearm's barrel, which is a series of grooves that impart a spin to the bullet to help stabilize its flight. The bullet's rotation creates a spiral pattern on its surface that is distinct from the marks created by the imperfections in the bore. These marks, together with the deformation caused by the imperfections, are known as striations. As the bullet travels down the barrel, it experiences pressure, friction, and spin. These factors, along with the roughness of the barrel's surface, cause the bullet to be engraved with

microscopic ridges and valleys. These ridges and valleys form the striations or marks on the bullet, which can be compared to the marks on other bullets and the barrel of the firearm in question to determine if they were fired from the same weapon or not.(B. R, 1976)

Striation markings are unique to each firearm and can be used by forensic scientists or forensic ballistic expert to identify the specific firearm that was used to fire a bullet. They can also be used to determine the order of fire in a multiple-shot sequence. By comparing the striations on a bullet to those on test bullets fired from a known firearm, forensic scientists can establish a match and determine the firearm used in a crime. Striations or marks on bullets are formed as a result of the interactions between the bullet and the barrel of the firearm as the bullet is being fired. These marks are unique to each barrel and can be used for forensic purposes to link a bullet to a specific firearm.(Saferstein, 1978)

Virtual reality is an upcoming modern interactive technology in forensic ballistics, which uses interactive crime scene analysis techniques such as realistic bullet trajectory simulation, enhanced visualization of bullet impacts, automated matching of bullet striations, computational ballistics simulations etc, to establish a high-resolution imaging of the bullet evidence and to predict the analysis of bullet behaviour encountered in a crime scene. This technology is highly immersive and allows the user to have immersive experience of virtual toolmark analysis such as bullet in-depth striation characteristics, that are unique to each firearm. Hence it can be a vital resource in the striation marks comparison between the firearms encountered in a crime scene or any situation.

2. Striation analysis techniques and methods

There are several methods to be used in the analysis of striation markings formed on the bullets or cartridge cases which are left by firearms. Forensic Ballistic expert uses some of the following techniques and instruments for the analysis of striation markings left on the bullet:

SEM [Scanning Electron Microscope]:- Ballistics experts often use microscope as the preliminary technique for the in-depth identification or analysis purpose. They help to magnify the already existing impressions on the bullet and examine it by forming a high-resolution image of the impression along with the bullet surface as background with the help of electron beam rather than using visible or any other sources of light spectrum. They try to scan the surface topography of the impression formed on the bullet or cartridge case due to lands and other parts of the firearms such as breach face, chamber marks/ barrel impressions, extractor marks, ejector marks and firing pin marks, with a beam of high powered electrons. SEM is especially used in cases where the bullet or cartridge case completely distorted or damaged, by providing clear images of the impressions from the remaining parts. (Carl Zeiss Microscopy GmbH, 2010)

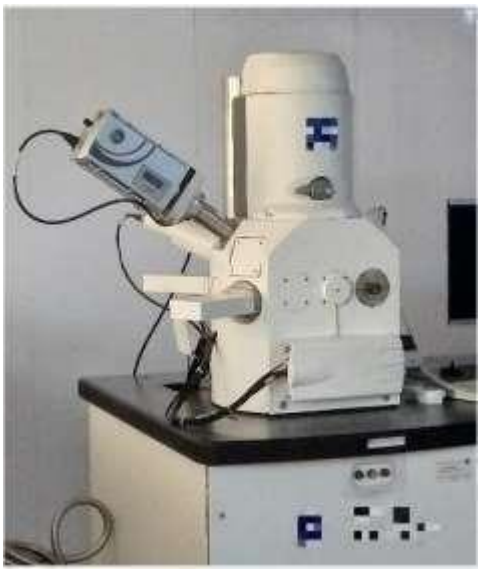


Figure 2.1: Scanning Electron Microscope (Ali, 2020)

Comparison microscope: -Comparison microscopes can also be used for the simultaneous comparison between two bullets that may or may not been fired from the same firearm.They provide a quick and reliable method for determiningif the markings on the bullets or cartridge cases were made by the same firearm. It is sometimes considered as a stereomicroscope with 2 eyepieces to give a 3-dimensional image of the surface topography of the bullet and the impressions dealt on it. Through this microscopic technique, we try to undertake an abreast comparison of 2 or more

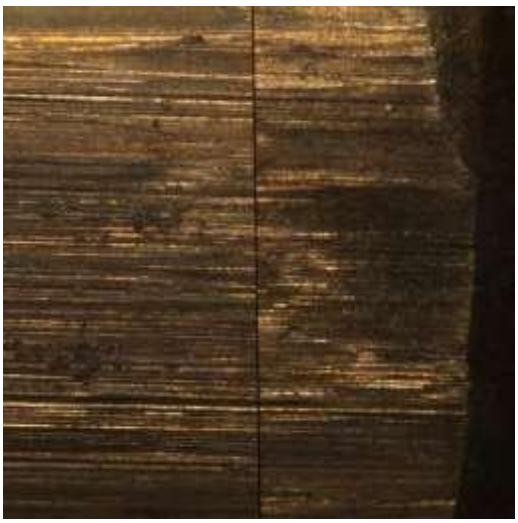


Figure 2.2:Bullet Striation under Comparison Microscope (Mattijssen, Kerkhoff, Berger, & Dror, 2016)

bullets [known standard with a questioned cartridge casing]. To use a comparison microscope, the bullets or cartridge cases are placed on a stage and are viewed through the microscope objectives. This helps us to determine whether the casings are fired from the questioned firearm or not using the marks or impression in detail simultaneously, instead of doing it separately. Thus, markings on the bullets or cartridge cases are then compared and evaluated to determine if they were fired from the same firearm or not to authenticate its source. (Canadian Soc of Forensic Science 63 Kilbarry Crescent, Ottawa, Ontario, K1K OH2 Canada, Canada, 1973)

The comparison microscope is particularly useful when the markings on the bullets or cartridge cases are subtle or difficult to see, as the side-by-side comparison allows for a more accurate evaluation of the markings.

Photomicrography: - Photomicrography is an analysis technique which captures digital picture of the impressions embarked on the cases with the aid of a microscope using several photomicrographic techniques, designed to conserve the resultant image produced. Some of the techniques used to produce images include darkfield, brightfield and finally DIC [Differential Interference Contrast] illumination. Each of the techniques are selected based on the image to be produced in cases having differential type of impressions and the type of metal used in the cartridge development.

Figure 2.3: Photomicrography (Abramowitz & Davidson)

When the striation marks or impressions are created well definitely and is clearly visible, Brightfield Microscope Illumination is utilized. Light source in this situation is directly fallen at right angles mostly onto the surface. Darkfield Microscopic Illumination is used in conditions where the impressions formed on the cartridge cases are not clear, well-defined and is difficult to be viewed. Light source is directed at a particular angle to form the dark shadow like background which in turn enhances the outline of the markings thus

enhancing it to be visible and to be captured. DIC [Differential Interference Contrast] is used when the impressions are subtle and difficult to see. A contrast is created between the different parts of striation images by splitting the light source into 2 beams, causing interference between them to help in the production of images.

Once the images are captured, they can be evaluated using assorted Imaging Software, which uses algorithm to measure and compare the striations markings between standard and questioned bullets samples, to match them to a specific firearm in question.

Image Analysis Software: - Involves the digitization and enhanced imaging analysis obtained through various techniques such as DCI, and enhance the accuracy and efficiency of the striation analysis process. The key benefit of using this lies in the formation of more precise measurement and comparison of the striations. It can also in the measuring and comparing of distance, angle, and width of striations or impressions. This can greatly increase the speed and efficiency of the analysis process, which is especially important in the time-sensitive environment of criminal investigations.

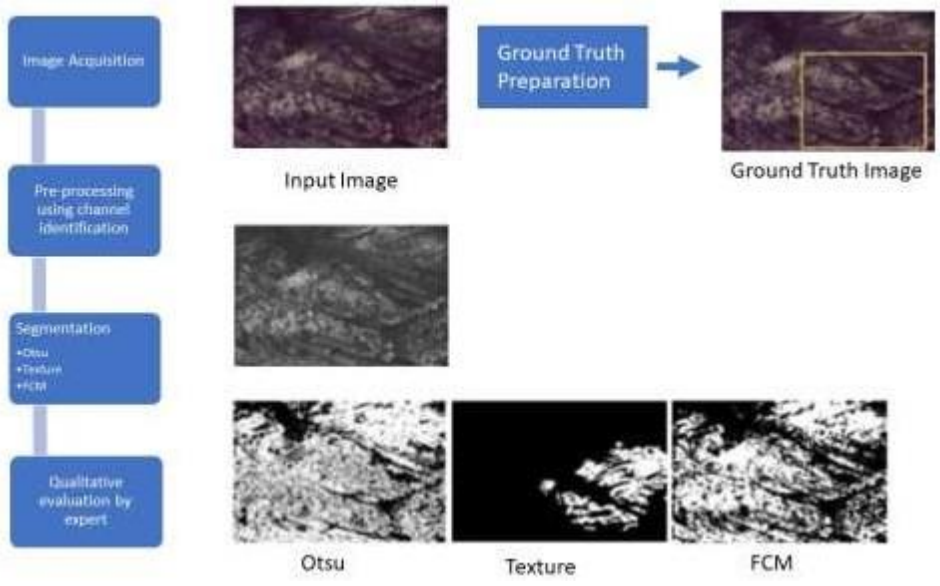


Figure 2.4:Diagrammaticrepresentation of working of an Image Processing Software (Lipi B Mahanta, Kangkana, Rahul, Shauvik and R Suresh, 2019)

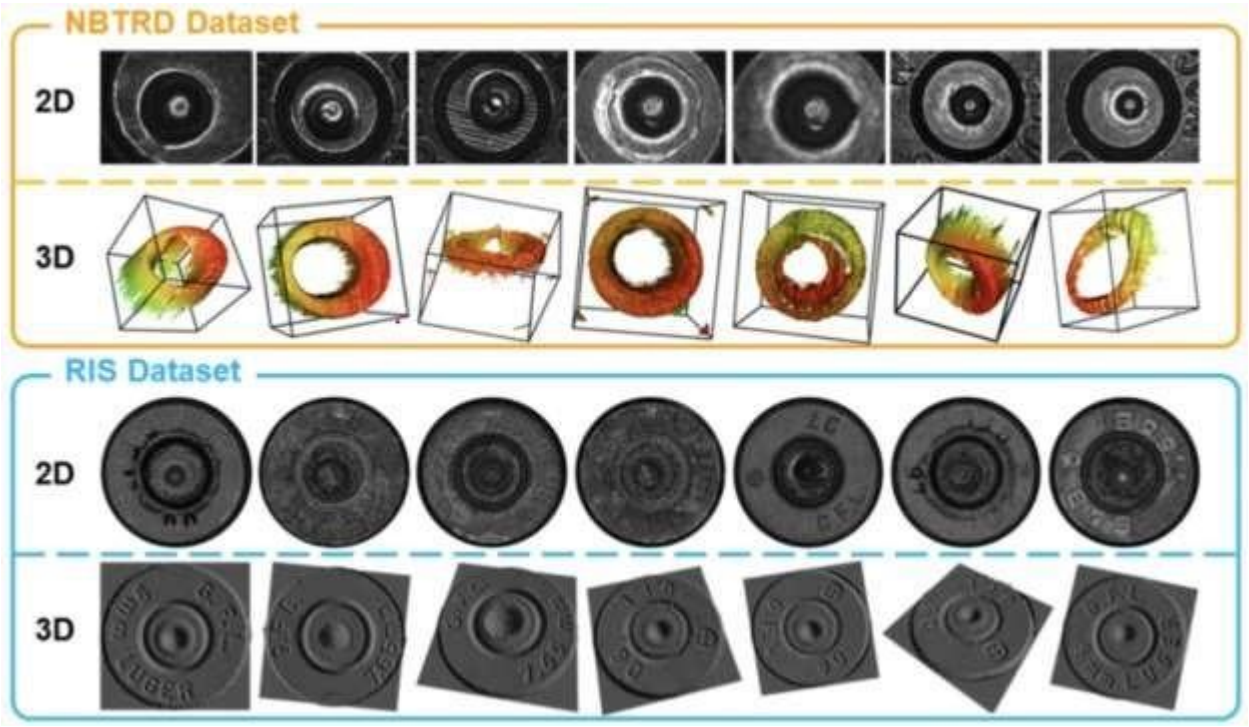
In addition to that, the imaging software can also provide advanced visualization capabilities, such as the ability to create 3D models of striations or to simulate the firing of a bullet. These features can be incredibly useful in helping to reconstruct the events of a crime or in demonstrating the results of a striation analysis in court. Other examples of software programmes used to aid the process of stria analysis caused on the bullets include MicroScribe, Ballistic Explorer and LEADE [Law Enforcement Automated Ballistic Evidence Database]. It is always significant to observe that the Image Software to be used in the stria analysis of the bullets must be in aggregation with the expertise of a skilled or trained analyst or a firearm examiner.

Stereo-Optical Comparator: - 3-dimensional pictures of the striation marks are produced onto a screen using lights and mirror technology enrolled in the instrument, leading to the production of accurate measurements and comparison of depressions on the surface of the bullet can be carefully studied.

In addition, a stereo-optical comparator can also provide advanced visualization capabilities, such as the ability to view the striations in 3D, to rotate the image for better viewing, and to make measurements from multiple angles. This can greatly aid in the interpretation of the striations and in the comparison of different bullets. Comparison of multiple images simultaneously helps to consume less time in the analysis of striations within different bullets, which is very much recommended in time-sensitive environment

Fig 2.5: 2D and 3D images obtained in Stereo-optical Comparator (Luca, Oliver, Salvatore L, Antonino

or situations.



Apart from these techniques, a toolmark database is also used as a standard database to scan, classify and identify the striations on a bullet with any previous data stored that may be similar to it. The databases can be used to match the markings to a specific firearm by comparing the markings on the bullets or cartridge cases to the known tool marks in the database.

3. Importance of Striation Analysis in Criminal Investigations

Striation analysis is a crucial tool in criminal investigations, particularly in firearms-related cases or in forensic ballistics. This technique involves the examination and comparison of the unique markings or striations left on a bullet when it is fired from a gun. These markings are used to identify the make, model, and even the specific gun that may have fired the bullet.

The importance of striation analysis in criminal investigations lies in its ability to provide strong evidence linking a bullet or cartridge to a specific firearm. This evidence can be used to connect a suspect to a crime scene or to rule out suspects. For example, if a bullet recovered from a crime scene is found to have striations that match those of a gun owned by a suspect, this can provide compelling evidence linking the suspect to the crime.(Saferstein, 1978)

In addition, striation analysis can also be used to determine the number of firearms involved in a crime. This information can be critical in understanding the dynamics of the crime and in developing a theory of the case. Moreover, striation analysis can also provide information about the distance from which a shot was fired and the angle of the shot, the direction of twist of the rifling, which can be important in reconstructing the events of a crime. This information can be used to determine the location of the shooter and to help establish the sequence of events.

Overall, striation analysis is a powerful tool in criminal investigations, providing crucial evidence linking a bullet or cartridge to a specific firearm and helping to reconstruct the events of a crime. As technology advances and new techniques are developed, the importance of striation analysis in criminal investigations is likely to grow even further.

4. Role of Computer Simulations and 3D Modeling in Striation Analysis [VR & AR]

Computer simulations and 3D modelling have played a significant role in the advancement of striation analysis of bullets. These tools allow for the creation of virtual representations of bullets, firearms, and striations, which can be used to simulate and analyse the firing of a bullet and the formation of striations.It can also provide advanced visualization capabilities, such as the ability to view the striations in 3-dimension and to rotate the image for better viewing. This can greatly aid in the interpretation of the striations and in the comparison of different bullets.(Lu, Wu, Yang, & d, 2013)

Computed techniques such as VirtualReality helps in the striation analysis of bullets by providing a range of benefits that have greatly enhanced the accuracy, speed, and efficiency of the analysis process. One of the main benefits of using Virtual Reality in striation analysis is that they provide a more complete and accurate representation of the firing of a bullet and the formation of striations. This information can be used to help reconstruct the events of a crime, to validate the results of a striation analysis, and to demonstrate the results of a striation analysis in court. For example, a computer simulation of a bullet firing from a firearm/gun can be used to determine the exact trajectory of the bullet and the orientation of the firearm at the time of the shot. This information can then be compared to the physical evidence collected at the crime scene to validate the results of the analysis.

Another advantage lies in the fact that it can enhance the accuracy and efficiency of the analysis process. By allowing for the simulation of various scenarios and the testing of different theories, VR can greatly reduce the time and effort required to perform a striation analysis. For example, a combination of virtual and augmented reality can be used to test different theories about the origin of a bullet and its striations, eliminating the need to physically test each theory. They also provide advanced visualization capabilities, such as the ability to view the striations in 3D and to rotate the image for better viewing. This can greatly aid in the interpretation of the striations and in the comparison of different bullets. For example, a 3D model of a bullet and its striations can be rotated to provide a better view of the striations and to make precise measurements and comparisons.(Gorisse, Christmann, Amato, Richir, & Simon, 2017)

One of the softwares which could be used in such scenarios is Amira-avizo. Amira-avizo has 3D visualization capabilities and analysis capabilities. The software could be used to export a 3D model, created using any one of techniques discussed above and the said 3D model can be used with augmented or virtual reality headset for analysis.

Hence it can be viewed that Computed Techniques have greatly impacted the field of striation analysis of bullets, providing a range of benefits that have greatly enhanced the accuracy, speed, and efficiency of the analysis process. As technology continues to advance, it is likely that computer simulations such asVirtual Reality and Augmented Reality will play an even greater role in striation analysis and other areas of criminal forensics, providing more accurate and reliable results for criminal investigations.

5. Advancements from Traditional to Modern Striation Analysis Techniques

Striation analysis is a technique used to identify the source of a bullet and to link it to a specific firearm. Over the years, the techniques used for striation analysis have evolved, with the introduction of new technologies and advancements in the field. A comparison of traditional and modern striation analysis techniques can provide a better understanding of the evolution of this important field.

Traditional striation analysis techniques, also known as manual or microscopic techniques, involved the use of a microscope to manually compare the striations on a bullet to those on a known or suspect firearm. This process was time-consuming and required a great deal of skill and experience, as the striations were typically small and difficult to see. In addition, the results of the analysis were subjective and could be influenced by the interpretation of the analyst.

Modern striation analysis techniques, also known as automated or digital techniques, use advanced technology to automate the process of comparing striations. These techniques include the use of image analysis software, spectrographic analysis, stereo-optical comparators, and computer simulations and 3D modelling. These tools provide greater accuracy and efficiency in the analysis process, and allow for the automation of many of the steps involved in manual striation analysis.

One of the key differences between traditional and modern striation analysis techniques is the level of accuracy. Modern techniques provide more precise and accurate results, due to the use of advanced technology and the automation of many of the steps involved in manual striation analysis. In addition, modern techniques provide greater consistency in the analysis process, reducing the potential for subjectivity and interpretation of errors caused during the analysis part.

Another difference between traditional and modern techniques is speed and efficiency. Modern techniques are significantly faster and more efficient than traditional techniques, as they automate many of the steps involved in the analysis process. This results in a greatly reduced time required to perform the analysis, and allows for the analysis of larger numbers of bullets and firearms.

In conclusion, the comparison of traditional and modern striation analysis techniques highlights the significant advancements that have been made in this field. Modern techniques provide greater accuracy, consistency, speed, and efficiency in the analysis process, and are now widely used in criminal investigations and forensic analysis.

6. Limitations and Challenges in Bullet Striation

Bullet striation analysis is a critical tool in criminal investigations, used to identify the source of a bullet and link it to a specific firearm. Despite its importance, bullet striation analysis is not without limitations and challenges, which can impact the accuracy and reliability of the results.

One of the main limitations of bullet striation analysis is the subjective nature of the results. The interpretation of the striations is dependent on the experience and skill of the analyst and can be influenced by factors such as the quality of the striations, the lighting conditions, and the analyst's ability to see the striations clearly. This can lead to inconsistencies in the analysis process and potential errors in the results.Another limitation is the potential for striations to be altered or damaged, which can impact the accuracy of the analysis. Striations can be altered by factors such as corrosion, wear and tear, and impact with other objects. In addition, striations can also be damaged during the recovery of the bullet, which can further impact the accuracy of the analysis.There are challenges faced in bullet striation analysis such as the potential chances for firearms to be altered or modified, which can impact the accuracy of the analysis. For example, firearms can be modified to change the appearance of the striations, making it difficult to accurately link the bullet to the firearm. This can result in incorrect results and false leads in criminal investigations.

The comparison of striations can be difficult and time-consuming, particularly in cases where there are large numbers of bullets and firearms to analyse. This can be particularly challenging in cases where the striations are of low quality or difficult to see, which can impact the accuracy and speed of the analysis.Finally, the availability of advanced technology and training for bullet striation analysis can also be a challenge, particularly in smaller law enforcement agencies or jurisdictions with limited resources. This can result in limited access to the latest technology and techniques, which can impact the accuracy and reliability of the results.

7. Conclusion

Automated techniques, such as image analysis software, spectrographic analysis, stereo-optical comparators, and computer simulations and 3D modeling, are becoming increasingly popular

and are expected to continue to evolve, providing even more advanced and sophisticated tools for bullet striation analysis.The integration of machine learning and artificial intelligence (AI) into the analysis process, the development of advanced imaging technologies, and the increasing use of databases and information management systems, are shaping the future of the field and will play a significant role in shaping the future of criminal investigations. Despite these advancements, the field of bullet striation analysis is not without limitations and challenges, such as the subjective nature of the results, the potential for striations to be altered or damaged, the potential for firearms to be altered or modified, the difficulty and time-consuming nature of the comparison process, and the availability of advanced technology and training.

In terms of implications for criminal forensics, bullet striation analysis continues to play a critical role in criminal investigations, providing valuable information and evidence that can help to solve crimes and bring perpetrators to justice. The continued development of new technologies and advancements in the field of bullet striation analysis will further enhance its usefulness and importance in criminal forensics, leading to even more accurate and reliable results.

Despite all the advancementsin the analysis of striation marks on the bullets, there are still areas where improvements are needed in deep closure. Some of these include standardizing of analysis process of striation marks by developing uniform protocols or procedures to be followed by all the analysts, development of new technologies such as machine learning, advanced imaging technology and AI Algorithms to enhance the accuracy and reliability of the analysis of striation marks. There must be standardized protocols for the management of data, that has been obtained during the analysis process, to ensure that the data is stored safely, analysed and is being shared in a reliable and consistent manner to the analyst. Ongoing training and opportunities for education or knowledge pertaining to the need of striations in forensic ballistics must be provided to help the analyst to be up-to-date with the latest innovations paving to the field. Making improvements in the following areas would help to further enhance the accuracy and reliability of bullet striation analysis in the upcoming years.

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