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The Impact of Latent Print Processing on Firing Pin and Breechface Impressions during Firearm Examination

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**The Impact of Latent Print Processing on Firing Pin and Breechface Impressions during
Firearm Examination**

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science
in Forensic Science at Virginia Commonwealth University.

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Abstract

Latent prints can be a valuable source of forensic evidence when solving a crime. They can verify if a person was at a specific scene, identify unknown individuals to connect them to a scene, and help to corroborate eyewitness accounts. Latent prints, however, are not always visible until they have undergone enhancement or visualization techniques. When fired cartridge cases are suspected of containing latent prints, they are brought in for latent print processing before any firearm analysis is performed. As a result, these cartridges are often coated in various residues or dyes when they arrive for firearm examination. In response, this study aimed to determine the visual impact superglue fuming and dye staining visualization methods have on firing pin and breechface impressions.

Two-hundred cartridges were used in this study. Of these, one-hundred cartridges were 9mm and one-hundred cartridges were .40 Smith and Wesson (S&W) caliber. In controlling for material, fifty cartridges of each caliber were brass cartridges, and fifty cartridges of each caliber were nickel. These cartridges were superglue fumed, and dye stained with either Basic yellow, Rhodamine 6G, or MBD to determine the influence these processing methods had on the visibility of firearm impressions. The visibility of firing pin and breechface impressions was dependent upon which dye stain was used after the cartridges have been superglue fumed, and what caliber and material the cartridges were made out of. With nickel .40 S&W cartridges, the use of MBD would be favorable when compared to Basic yellow or Rhodamine 6G to preserve as much fine detail as possible. Oppositely, the use of Basic yellow or Rhodamine 6G would be preferable to MBD when analyzing brass .40S&W cartridges. All three dye stains could be used when processing nickel 9mm cartridges, as none of them significantly obscured the striations or shearing found on the cartridge. However, when used on the brass 9mm cartridges, all three dye stains significantly concealed the fine details needed to successfully compare the cartridge to potential test fires. It is important to note that cleaning the cartridges with acetone did effectively eliminate the influence of these visualization methods on breechface impressions and recoil action striations.

Overall, this study was an introductory look into the influence latent print processing techniques have on firearm analysis. Moving forward, studies should be conducted using different enhancement techniques, such as black powder, to determine the impact they have on firing pin and breechface impressions. Eventually, a study in which processed cartridges can be entered into NIBIN would be beneficial to determine if NIBIN technology is able to differentiate between latent print dye residue and firearm toolmarks.

Keywords: Breechface impressions, Firing pin impressions, Superglue fuming, Basic yellow, Rhodamine 6G, MBD

Introduction

History of Latent Prints

Latent prints refer to the friction ridge impressions, recovered from a surface, left by residue collected on the fingers and hands. Nehemiah Grew, observing with the use of the microscope, studied the similarities and differences of the veins of plant leaves and the ridges of fingerprints. In 1684, he published descriptions and terminology associated with his findings. [4] Using fingerprints as a means of identification began in the mid-1800's in India, within colonies of the British Empire. Handprints and fingerprints had been used to sign and authenticate documents in India for hundreds of years before British administrators adapted these techniques and brought them back to Europe. [4] There are two qualities that make fingerprints valuable for individual identification: they are permanent and they are unique. Sir William Hershel, a British administrator for the East India Company, is credited with recognizing the uniqueness of fingerprints. As a magistrate, Hershel made this determination after realizing that documents with handprints were more valuable than those with only a signature for identification. Years later, Hershel also noted fingerprint permanence after fingerprinting himself over a period of fifty years and comparing his prints over time. [4]

Latent prints can be a valuable source of forensic evidence when solving a crime. They can verify if a person was at a specific scene, identify unknown individuals to connect them to a scene, and help to corroborate eyewitness accounts. 'Latent', comes from the Latin word 'latere' which means hidden. Latent prints are usually not readily visible to the naked eye and require physical or chemical processing to be made visible. Since these prints can be difficult to detect, various visualization and enhancement techniques have been established over time to help visualize the latent prints left on scene or on various types of evidence.

Latent Print Processing

The main factor to be considered when choosing a visualization method is the surface on which the latent is deposited. There are two types of surfaces to consider: porous and nonporous. Porous substances allow for the transfer of liquid or vapors, such as paper or untreated wood. Nonporous substances are then the opposite and do not allow the transfer of liquid or vapors through their surfaces. These nonporous surfaces include glass and metals. Cyanoacrylate fuming, or superglue fuming, is one technique that can be used to enhance the details of fingerprints and is particularly effective on nonporous surfaces. In warm, high humidity conditions, cyanoacrylate ester molecules are attracted to latent print residues and will polymerize on those residues. [10] When this occurs, a white powdery substance forms in areas of oil deposits. As a result, friction ridge details now become visible to the naked eye. However, often times there is still not enough surface contrast present to achieve quality photographic evidence. To mitigate this, several dye stains have been developed to enhance contrast without destroying the latent print. [3] Following the application of the dye stains, the prints are examined using an alternate light source, which provides enough significant contrast to achieve examination quality photographs. [10] This combination of visualization techniques has been notably successful and is utilized in labs throughout the country.

History of Firearms

The field of firearms examination has constantly evolved over the last 165 years. [5] The origin of firearms extends back all the way to China in 900 AD with the discovery of gunpowder. Historically, the purpose of the charcoal, saltpeter, and sulfur mixture was to propel fireworks into the sky, but the weaponized value of gunpowder soon became apparent. Ammunition came into existence around the 13th century, with a crude weapons design utilizing gunpowder and any

shrapnel material that was available. Development of the cartridge case was a huge advancement in the firearms field. Prior to this, shooting a rifle involved manually loading the muzzle with gunpowder, which was not only tedious but extremely time consuming. [1] In 1845, French inventor Louis Nicolas Auguste Flobert designed a new type of ammunition cartridge. His design, known as rimfire ammunition, was the first type of modern ammunition that inspired the design of cartridges still in use today. In rimfire ammunition, the primer is found inside the outer rim of the cartridge, so when the firing pin hits the rim, the primer will be ignited. [2] Oppositely, as the name indicates, centerfire ammunition holds the primer in the center of the cartridge head. Today, the majority of ammunition produced is centerfire ammunition. [2] Further improvements and dozens of new cartridge designs have been made since the original rimfire and centerfire ammunition, ranging in both style and function. However, despite slight variations among style in firearms, the firing process has remained relatively consistent since the development of firearms.

Cycle of Fire

Knowledge of firearm firing processes is crucial to understanding the science behind firearm analysis. The basic principles behind the functionality of these weapons not only determines what aspects of the fired cartridges are examined, but also explains the variation and distinctive characteristics that can be present for analysis. Details of the firearm firing process have slight variations depending on the weapon in question and whether the firearm is hammer or striker fired. However, the general process begins when the trigger is pulled and the hammer moves forward to hit the firing pin. Upon impact, the firing pin strikes forward to contact the primer cup. The force of the impact not only causes the priming compound to ignite, but also leaves an impression in the cartridge case. [8] The primer ignition results in an exothermic

chemical reaction, producing a buildup of heat and pressure within the barrel. The pressure within the barrel at this time is so intense, it forcefully pushes the head of the cartridge backwards against the breech face of the weapon, resulting in the impression of breech face markings on the back of the cartridge. [6] It is this chemical reaction and resulting pressure buildup that forces the bullet from the cartridge case and down the barrel, successfully firing the weapon. [8] Since both the firing pin impression and the breech face impression are created during the cycle of fire, they are the two most commonly analyzed impressions used in firearm comparisons.

Firearm Analysis Techniques

Historically, firearm analysis consisted of simple visual inspections, caliber determinations, experimental test fires, or other rudimentary methods of analysis. [5] Advancements in the field began with the development of the comparison microscope. In 1925, Philip O. Gravelle designed the first comparison microscope dedicated to the examination of firearms. Comparison microscopes are essentially composed of two microscopes bridged together, which allows the examiner to view both samples at the same time, side-by-side. In viewing both samples at the same time, the examiner is able to directly compare the markings on two separate cartridge cases in real time. [6] This method of analysis is standard across all laboratories in the United States. However, in recent years there has been an increased push for physical evidence examiners to provide objective methods of analysis. In response, the Bureau of Alcohol, Tobacco, Firearms, and Explosives (ATF) have established the National Integrated Ballistics Information Network (NIBIN). NIBIN is an automated system composed of digital images of bullets and cartridge cases found at crime scenes. The purpose of NIBIN is to provide ballistics comparisons in a timely manner to provide law enforcement with investigative leads. [7, 9] Since NIBIN is an

automated system that analyzes digital images for comparison, its ability to be successful lies in the clarity of the scanned images in the database. Fired cartridge cases are often sent out for latent print processing prior to being inspected by firearms examiners and NIBIN searches. Throughout the process of latent print collection, the cartridge cases in question are handled, fumed with cyanoacrylate, and stained with a dye to improve visually clarity of any resulting prints. As a result, one fundamental question that needs to be answered is whether or not NIBIN will be able to tell the difference between latent print dye residue and firearm toolmarks. For now, this study aims to determine the impact latent print testing has on the visual analysis of fired cartridge cases by firearms examiners.

Materials and Methods

Dye Stain Selection Process

Law enforcement officers from Henrico and Chesterfield PD were contacted to determine the standard evidence collection procedure for fired cartridge cases on crime scenes. Additionally, latent print and firearms examiners from the Virginia Department of Forensic Science were interviewed to ascertain the standard processing techniques for fired cartridge cases in each department respectively. This information was gathered in an effort to mimic realistic and common methods of evidence collection and analysis for the purpose of this study. It was found that the three most locally chosen common dye stains used following a superglue fuming were MBD, Rhodamine G6, and Basic Yellow. These three dye stains are also found in the Virginia Department of Forensic Science Latent Print Procedures Manual. All three of these dye stains were used to determine the impact of latent print dyes on breechface and firing pin impressions.

Cartridge Selection

Two-hundred cartridges were used in this study. Of these, one-hundred cartridges were 9mm and one-hundred cartridges were .40 Smith and Wesson (S&W) caliber. These calibers were chosen because they are two of the most common calibers analyzed in crime laboratories. In controlling for material, fifty cartridges of each caliber were brass cartridges, and fifty cartridges of each caliber were nickel. This categorization led to four distinct sample groups: 9mm nickel cartridges (Federal Premium Full Jacketed Hollow Point, lot number: 6PL2A079A077 & S51P093), 9mm brass cartridges (Federal Champion Full Metal Jacket, lot number: H17B410), 40 S&W nickel cartridges (Federal Premium JHP Hydra-Shok, lot number: Q50X570), and 40 S&W brass cartridges (Federal American Eagle FMJ, lot number: D258V4D259V61). There were two types of firearms used to shoot the ammunition: a Sig Sauer model P229 (serial number: 55B007376) was used to fire the 9mm rounds and a Glock model 23 Gen4 (serial number: RYG485) was used with the 40 S&W ammunition.

Cartridge Sample Collection

Due to Covid-19 restrictions and limited firing range locations, all of the .40 S&W rounds were fired in one day, and all of the 9mm bullets were fired on another day. The .40 S&W rounds were shot on a private lot (3747 Custis Millpond Road, in West Point, Virginia). These bullets were fired outdoors to mimic one type of realistic crime scene conditions and were shot by multiple people. To ensure the collection of representative samples from various types of scenes, the 9mm bullets were fired indoors at the Richmond Police Department Firing Range by two experienced officers. The fired cartridges were collected, and each was placed in an individually labeled coin envelope (Uline 2.5X4.25). To act as a negative control, four cartridges from each caliber and material were randomly selected, packaged, and left unprocessed. This

allowed for inspection throughout the study to prove that firearm impressions do not change throughout time when left alone. Additionally, four other cartridges of each caliber and material were processed using cyanoacrylate fuming and analyzed without the addition of a dye stain. This was done to demonstrate the process of superglue fuming does not change firearm impressions over time. All of the fired cartridges were brought into the laboratory and assigned a number 1-200 to individually identify each cartridge. These identifying numbers were written in permanent ink on the side of each cartridge. All two-hundred cartridges were macroscopically photographed to record the original firing pin and breech face impressions.

Comparison Microscope Photography

All two-hundred cartridges were mounted for observation on a Leica (serial number: MC17010155027) comparison microscope and viewed under 20x magnification. Once in focus, the cartridge was rotated as necessary in order to get the breechface striation markings horizontal to the plane of vision. Once in position, a photograph was taken of the breechface marks using a Leica MC170 HD camera (C-Mount 0.40x lens) attached to the microscope. Leica Microsystems Application Suite technology was used on a Dell (Precision T1700) computer to acquire and save the images. Then, the magnification was increased to 40x and the focus was readjusted. When the firing pin impression was in focus, another photograph was taken. This process was repeated for each individual cartridge.

Superglue Fuming

The remaining 186 cartridges, not including those designated as blank controls, were processed using a Misonix CA-3000 superglue fuming chamber (serial number: CA04430810). A dime sized amount of Evident© cyanoacrylate glue was placed into a 57mm MicroBurst

Fuming Dish. Once the humidity in the chamber reached 70%, the cartridges were processed for seven minutes before the fumes were purged from the chamber. Once removed, all two-hundred cartridges were photographed using the above stated process to document any visual changes in the breechface and firing pin impressions.

Dye Stain Process

The remaining 168 cartridges excluding the blank and superglue fuming controls were separated into three different groups. Fourteen cartridges of each caliber and material were stained in MBD (lot number: 979654 or 313008), fourteen cartridges of each caliber and material were stained in Rhodamine G6 (lot number: 979723 or 506148), and fourteen cartridges of each caliber and material were stained in Basic Yellow (lot number: 979711 or 913001). To dye stain these cartridges, a 50mL beaker was filled with one dye. Each cartridge was held in the dye for two seconds and left to dry on a rack for a week. Once dried, all two-hundred cartridges were photographed to document any visual changes in the breechface and firing pin impressions.

Cleaning Process

All 186 cartridges that had undergone superglue and dye stain processing were cleaned using acetone and a large cotton swab to scrub the surface. Once clean, all two-hundred cartridges were photographed again to document any visual changes in the breechface and firing pin impressions.

Results and Discussion

.40 S&W vs. 9mm Cartridges

One of the most important design factors in this study was the caliber selection. There are various differences between .40 S&W rounds and 9mm rounds, including the type of firearm that can use these calibers for ammunition. As stated previously, a Sig Sauer model P229 was used to fire the 9mm rounds and a Glock model 23 Gen4 was used to fire the .40 S&W rounds. Between these two types of firearms, there are various similarities and some differences between the two that impact both the breechface and firing pin impressions. Glock's possess an elliptical shaped firing pin with a rectangular hole for the pin to pass through. As a result, this design is impressed into the cartridge case of any bullet fired from this particular type of gun (Figure 1).

Additionally, Glock's are recoil action firearms, meaning that during the firing process the barrel drops. This movement between the barrel and the slide results in striations on the cartridge case. These striations are typically most defined markings left behind for examiners to view.

Additionally, firing pin drag can make the right side difficult to analyze, so instead examiners typically focus their examination on the left (Figure 1). Sig Sauer's possess a hemispherical firing pin aperture with a circular hole for it to pass through, which can be seen impressed into the cartridge (Figure 1). These markings and impressions are what examiners will look at when comparing test fires to cartridges left on scene, so it is important to understand what they are and what components of the firearm have caused them.

.40's S&W vs. 9mm firing pin impressions

The differences in firing pin morphology additionally impacts the ease in which firing pin impressions can be examined. The Sig Sauer produces a much larger firing pin impression when compared to the firing pin impression made by the Glock (Figure 2). When compared, there is a much greater visual surface area to evaluate on the Sig's impressions than on the Glock impression. The differentiation in firing pin aperture shape between these two firearms not only

produces differences in impression shape, but also in impression texture. The Glock, with its elliptical shaped firing pin and rectangular pin hole, has more room for material to flow back in during the firing process. This results in shearing within the firing pin impression, a quality that produces more variation in texture which can impact the ability of examiners to recreate the same shearing pattern during test fires. Oppositely, the Sig has a hemispherical firing pin aperture with a circular pin hole. This combination leaves little room for material to flow back in during the firing process, which in turn produces less variation in the texture of the impression. This trend was found to be consistent between both nickel and brass cartridges throughout this study.

Nickel .40 S&W Cartridges

Another important factor analyzed in this study was whether the cartridge material selected impacted the examiner's ability to view firing pin and breechface impressions following specific visualization techniques. As a result of this project, the material and the caliber of the cartridge does influence the ability of the examiner to see the firing pin and breechface impressions depending upon which dye stain is used after the cartridges have been superglue fumed. For nickel .40 S&W cartridges, the use of Basic Yellow and Rhodamine 6G resulted in substantial obscuring of the firing pin and breechface impressions (Figure 3). When these two dyes are applied after superglue fuming, there is a notable loss of fine detail. This loss makes depth determinations of sheering patterns and impressed marks very difficult. However, the use of MBD seems to be less detrimental to the fine details needed to analyze firearms impressions (Figure 3).

Nickel 9mm Cartridges

The microscopic trends found in the 9mm nickel cartridges were different from those found with the nickel .40 S&W cartridges. For the 9mm cartridges, none of the dye stains seemed to greatly impact the ability to visualize striations or other fine details (Figure 4). This result was unexpected, as the 9mm rounds had notably less pronounced striations than those found on the .40 S&W cartridges and therefore were expected to be more difficult to analyze following superglue fuming and dye stain processing.

Brass .40 S&W Cartridges

The brass .40 S&W cartridges had opposite results to those of the nickel .40 S&W cartridges when it came to the use of MBD. The use of Basic yellow or Rhodamine 6G mildly impacted the ability to analyze the fine details of the breechface impressions and striations. Despite this mild interference, the breechface impressions found on these cartridges were still largely visible for analysis (Figure 5). However, the use of MBD seemed to have a greater hindrance on the ability to visualize any breechface impressions or striations resulting from the recoil action of the Glock (Figure 5). MBD, while having almost a mild impact on the nickel cartridges, was the most detrimental to the markings on the brass .40 S&W rounds.

Brass 9mm Cartridges

The brass 9mm cartridges were found to have the opposite results as those found in the nickel 9mm cartridges. Basic yellow, Rhodamine 6G, and MBD all completely obscured the breechface impressions and striations that were on the cartridge (Figure 6). These results were expected, as the Sig Sauer model P229 does not leave prominent striations from recoil action on the cartridges like the Glock model 23 does.

Conclusions

When fired projectiles or cartridges are brought into the lab for analysis, any items suspected to have fingerprints will be sent off for latent print processing before firearms analysis. This processing is done in order to obtain any latent prints that may be present on evidence before it is handled in the lab, which could obliterate any usable prints. As a result, fired cartridges are often coated in various residues or dyes when they arrive for firearm examination. In response, this study aimed to determine the visual impact superglue fuming and dye staining visualization methods had on firing pin and breechface impressions. Additionally, these visualization methods were tested against cartridges of different calibers and materials that are commonly found in casework in order to determine the influence these factors have on firing pin and breechface impressions.

The results of this study varied greatly depending upon the material and caliber of the cartridge. Despite these variations, this data can still be incredibly useful in terms of which visualization and processing methods would be the least hindering with downstream analyses such as firearm analysis. With nickel .40 S&W cartridges, the use of MBD would be favorable when compared to Basic yellow or Rhodamine 6G to preserve as much fine detail as possible. Oppositely, when dealing with brass .40 S&W, the use of Basic yellow or Rhodamine 6G would be preferable to the use of MBD, as MBD is found to obscure recoil action striations and breechface impressions more so than the other two dye stains. (Table 1) For 9mm cartridges, the main factor to be considered when choosing a visualization technique is the material composition of the cartridge. All three dye stains could be used when processing nickel 9mm cartridges, as none of them significantly obscured the striations or shearing found on the cartridge. However, when used on the brass 9mm cartridges, all three dye stains significantly concealed the fine details needed to successfully compare the cartridge to potential test fires. (Table 1) It is

important to note that cleaning the cartridges with acetone did effectively eliminate the influence of these visualization methods on breechface impressions and recoil action striations. However, the cleaning processes was not always successful in cleaning the firing pin impression. In cases where the firing pin impression is the only location on the cartridge that can be clearly analyzed, these processing and visualization techniques may become a hindrance to firearms analysis.

This study was mainly an introductory look into the impact of a few latent print processing methods on firearm analysis. From here, numerous variations can be made to develop a more complete insight into how these techniques can impact downstream analyses. Studies should be conducted using different enhancement techniques, such as black powder, to determine the impact they have on firing pin and breechface impressions. Eventually, the hope would be to develop a study in which processed cartridges can be entered into NIBIN to determine if the technology will be able to differentiate between latent print dye residue and firearm toolmarks.

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Appendix

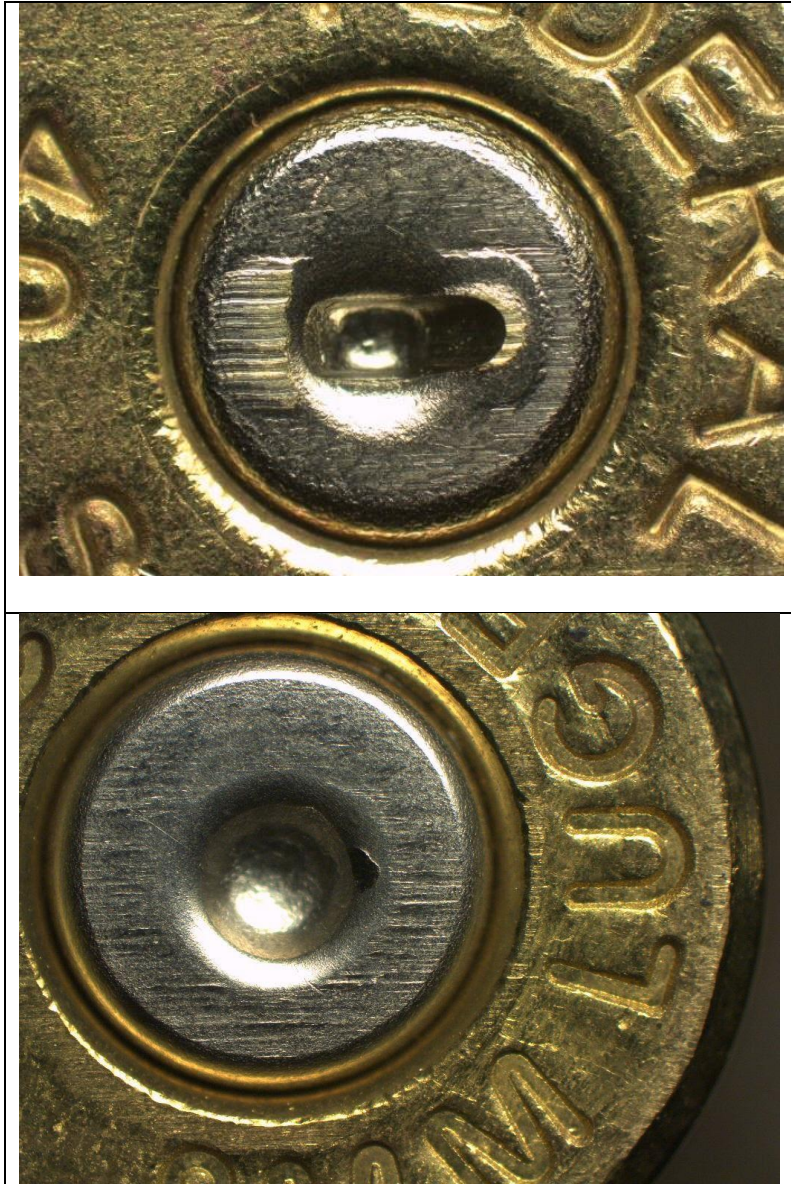


Figure 1. The image on top is from brass .40S&W cartridge 51 at 20x magnification. The elliptical shape of the firing pin, in addition to the rectangular shape of the hole in which the pin passes through can be seen. Additionally, firing pin drag can be seen on the right side of the firing pin impression. The image on the bottom is from brass 9mm cartridge 7 at 20x magnification. The hemispherical firing pin aperture and circular hold for the pin to pass through can be seen.

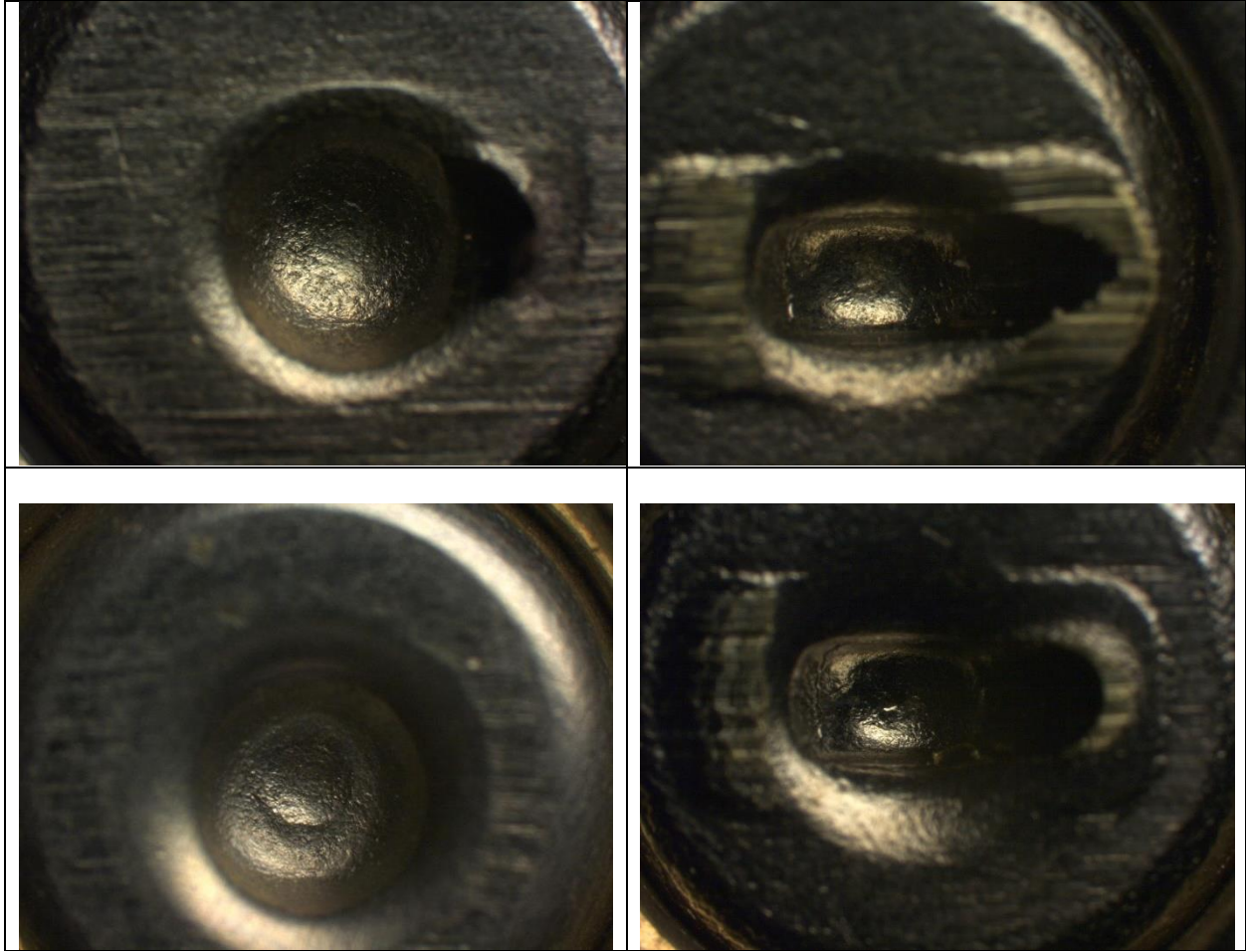


Figure 2. The image on the top left is nickel 9mm cartridge 102 at 40x magnification. The image on the top right is nickel .40 S&W cartridge 154 at 40x magnification. When compared, the Sig Sauer leaves a much firing pin surface area impression to analyze when contrasted against the firing pin impression produced by the Glock. The image on the bottom left is brass 9mm cartridge 1 at 40x magnification. The image on the bottom right is brass .40 S&W cartridge 51 at 40x magnification.

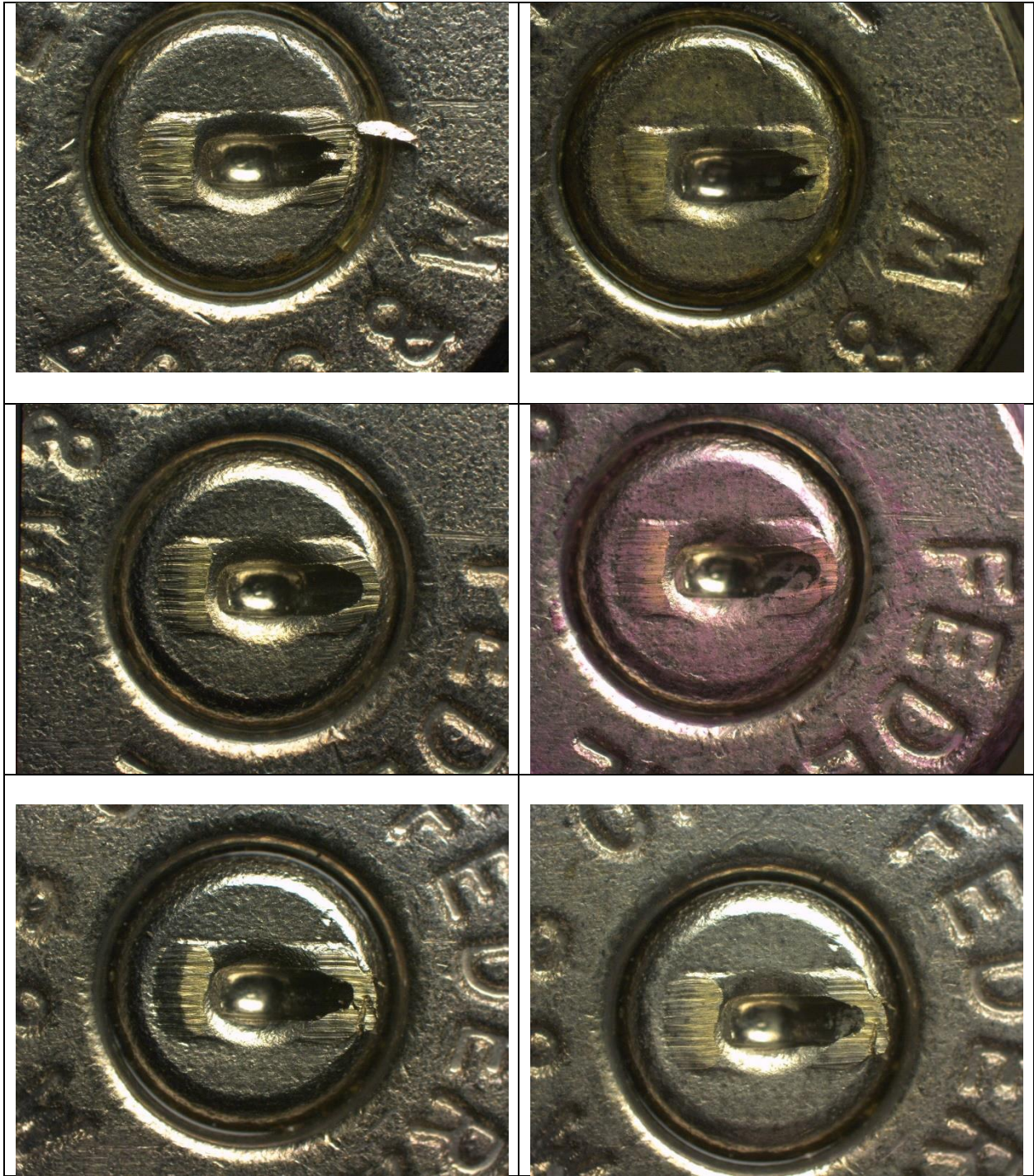


Figure 3. The top row is nickel .40 S&W cartridge 162 at 20x magnification. The left column shows the cartridge in its original state, the right column shows the cartridge after being superglue fumed and stained with basic yellow. The middle row is nickel .40S&W cartridge 174 at 20x magnification. The image in the middle right is superglue fumed and stained with Rhodamine 6G. The bottom row is nickel .40S&W cartridge 191 at 20x magnification, with the image on the right having been superglue fumed and stained with MBD.

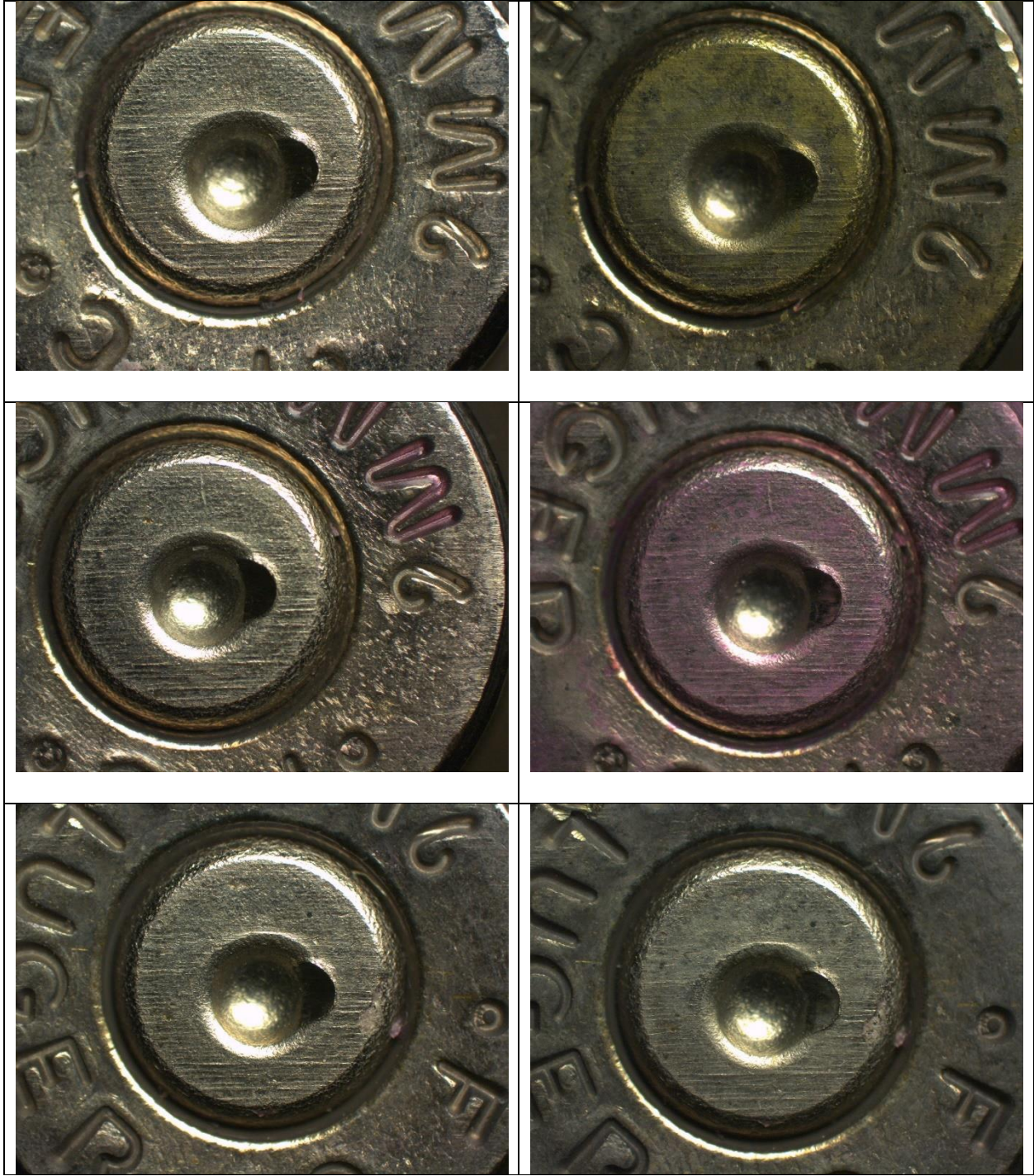


Figure 4. The top row is nickel 9mm cartridge 118 at 20x magnification. The left column shows the cartridge in its original state, the right column shows the cartridge after being superglue fumed and stained with basic yellow. The middle row is nickel 9mm cartridge 134 at 20x magnification. The image in the middle right is superglue fumed and stained with Rhodamine 6G. The bottom row is nickel 9mm cartridge 140 at 20x magnification, with the image on the right having been superglue fumed and stained with MBD.

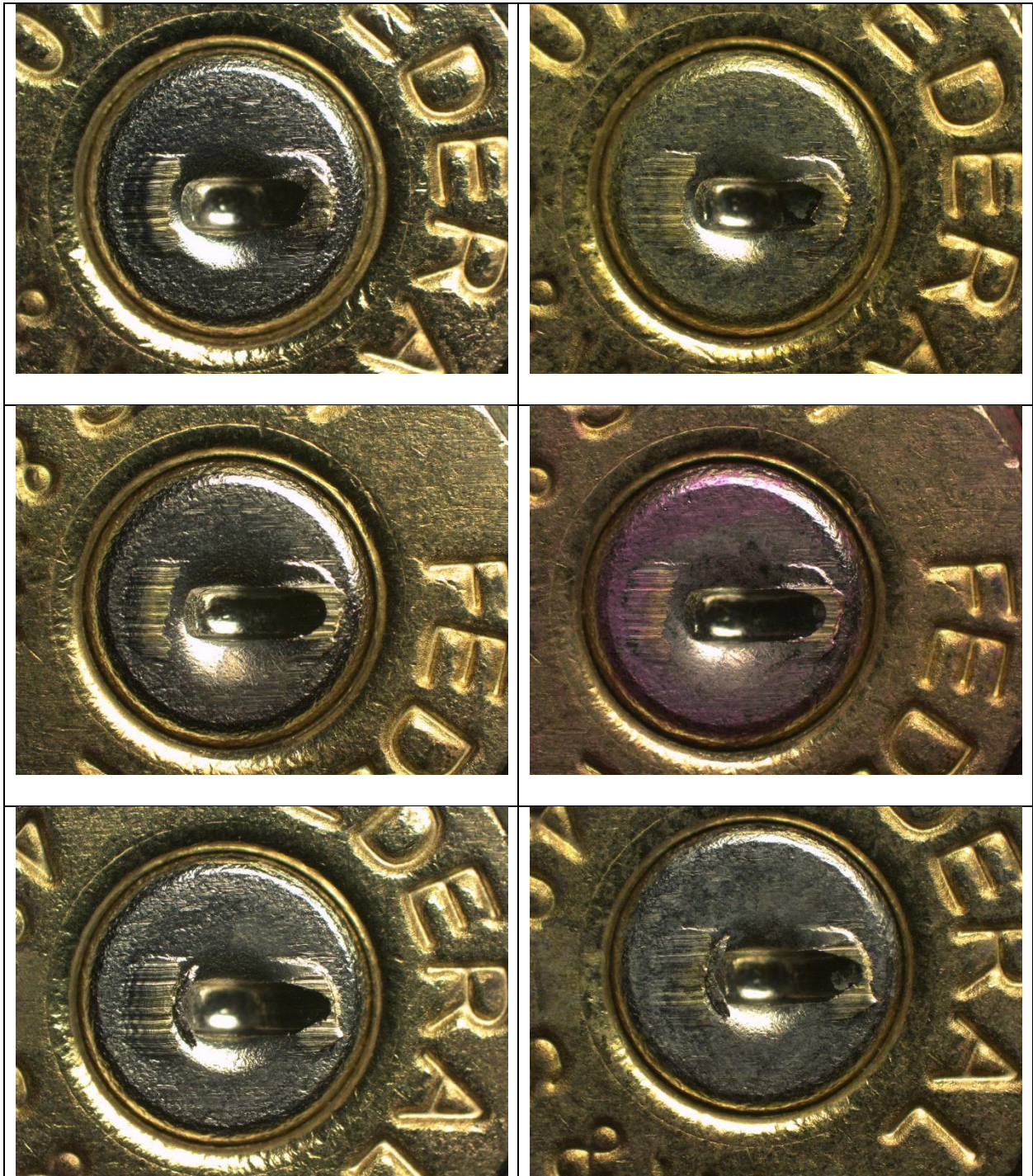


Figure 5. The top row is brass .40 S&W cartridge 63 at 20x magnification. The left column shows the cartridge in its original state, the right column shows the cartridge after being superglue fumed and stained with Basic yellow. The middle row is brass .40S&W cartridge 84 at 20x magnification. The image on the right is superglue fumed and stained with Rhodamine 6G. The bottom row is brass .40S&W cartridge 91 at 20x magnification, with the image on the right having been superglue fumed and stained with MBD.

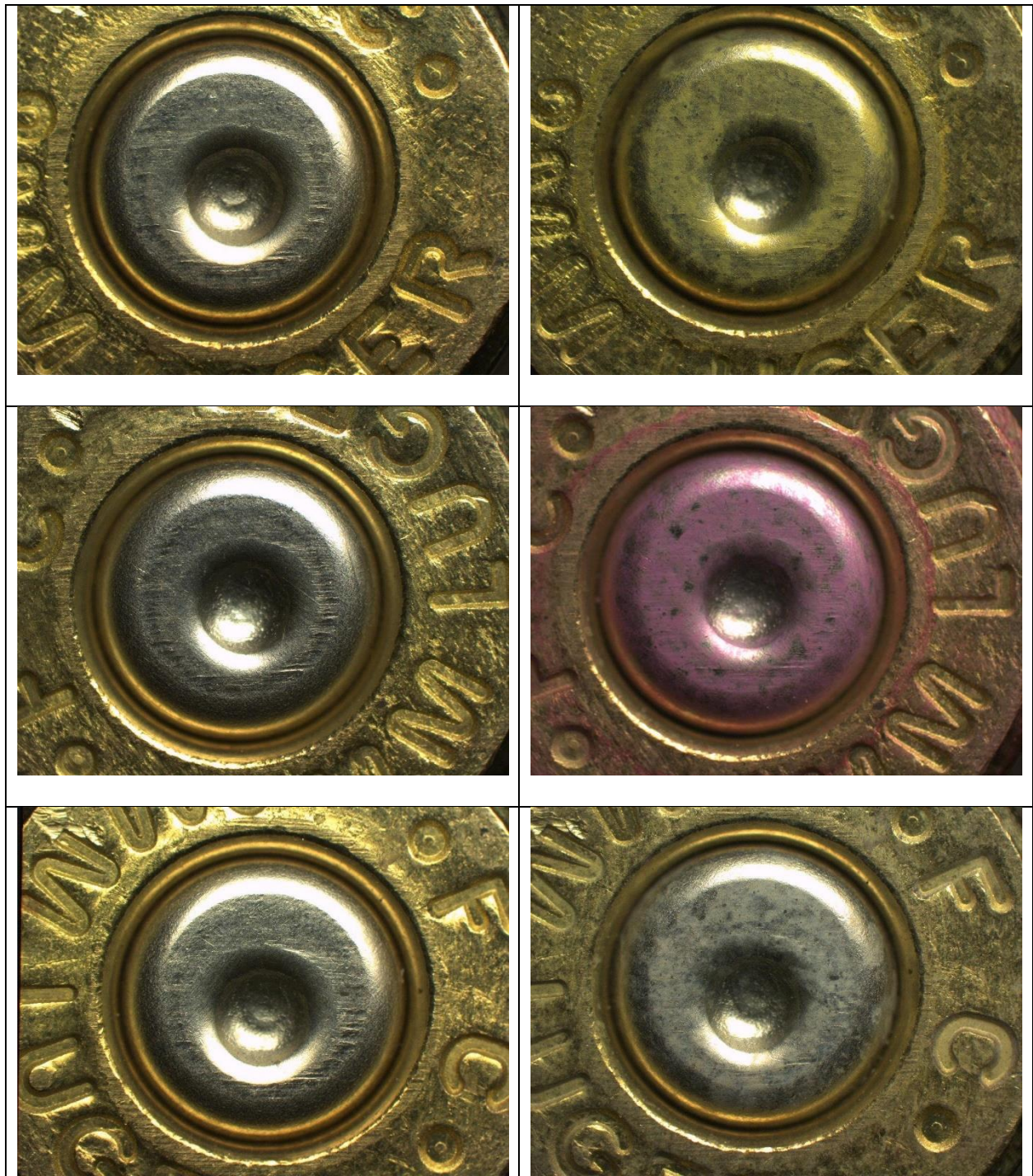


Figure 6. The top row is brass 9mm cartridge 10 at 20x magnification. The left column shows the cartridge in its original state, the right column shows the cartridge after being superglue fumed and stained with basic yellow. The middle row is brass 9mm cartridge 27 at 20x magnification. The image on the right is superglue fumed and stained with Rhodamine 6G. The bottom row is brass 9mm cartridge 44 at 20x magnification, with the image on the right having been superglue fumed and stained with MBD.

Cartridge Caliber/Material	Recommended for use?		
	Basic yellow	Rhodamine 6G	MBD
Nickel .40 S&W	No	No	Yes
Nickel 9mm	Yes	Yes	No
Brass .40 S&W	Yes	Yes	Yes
Brass 9mm	No	No	No

Table 1. The table listed provides a summation of the results found in this study by recommending which dye stains would be best suited for analysis on these cartridges based on their material composition and caliber.

Vita

Brittany Baird Harrington was born in Minneapolis, Minnesota before moving to Plymouth, Wisconsin for high school. She attended the University of Wisconsin Oshkosh for her undergraduate degree. In her time at Oshkosh, she earned a Bachelor of Science degree with an emphasis in healthcare science, a dual minor in psychology and neuroscience, and a certificate in LGBTQ studies. Brittany graduated from the University of Wisconsin Oshkosh Honor's College in 2019 and is currently pursuing her master's degree in Forensic Science at Virginia Commonwealth University, anticipating graduation in May 2021. While at VCU, Brittany has worked as a laboratory teaching assistant for both introductory biology and genetics. Following graduation, Brittany hopes to pursue a career as a forensic firearms analyst.