The Identification of Bullets Fired from 10 Consecutively Rifled 9mm Ruger Pistol Barrels: A Research Project Involving 507 Participants from 20 Countries

By: James E. Hamby, Ph.D., International Forensic Science Laboratory & Training Centre, Indianapolis, IN, David J. Brundage, M.S., Independent Examiner, Nashville, TN and James W. Thorpe, Ph.D., Senior Lecturer (Retired), University of Strathclyde, Glasgow, Scotland

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ABSTRACT

Ten consecutively rifled RUGER P-85 pistol barrels were obtained from the manufacturer and then test fired to produce known test bullets and 'unknown' bullets for comparison by firearms examiners from around the world. This study is a continuation of one originally designed and reported on by David Brundage [1]. The original study was primarily limited to examiners from nationally accredited laboratories in the United States. For this study, the sets were provided to firearms examiners around the world. The RUGER P-85 pistol and the 10 consecutively rifled barrels used for the original study were borrowed from the Illinois State Police. Ammunition was obtained from the Winchester Ammunition Company (A Division of Olin) and 240 tests sets were produced and distributed to forensic scientists and researchers worldwide. A thesis which involved a total of 201 participants – including the original 67 reported on by Brundage – was published by Hamby and Thorpe in 2001 [2]. This paper reports the final conclusions of the research conducted by Brundage, Hamby and Thorpe over a 10 year period [3, 4].

Introduction

Current practices in firearm and toolmark identification training and actual laboratory casework are based on the theory that fired bullets and fired cartridge cases can be identified to the firearm that fired them. A forensic scientist trained in firearm and toolmark identification is often able to specifically identify, or eliminate, a firearm involved in a shooting when that firearm is evaluated in conjunction with recovered evidence. Extensive research has been conducted and published by forensic firearm and toolmark examiners during the past 100+ years to support this theory .

A firearm and toolmark examiner microscopically evaluates fired ammunition components using an optical comparison microscope. For fired bullets specifically, the fine scratches (striae) found on the bearing surfaces are assessed. These striations are considered to be accidental in nature and to arise from randomly occurring imperfections during the manufacture of the gun barrel. Because these imperfections occur at random, the pattern of striations is considered to be unique to a common origin, such as a specific firearm or tool. In the case of a fired bullet, the striations are impressed on the bullet by force and motion as the bullet travels down the barrel of the firearm. Although this specific research project pertains to bullets fired from consecutively manufactured barrels, the same type of analytical techniques and laboratory equipment are used when examining fired bullets, fired cartridge cases and a wide variety of tools – whether from different firearms and tools and/or consecutively manufactured firearms and tools.

Numerous studies have shown that a properly trained firearm and toolmark examiner has the ability to identify fired bullets and fired cartridge cases to the firearm that fired them, even when multiple bullets and cartridge cases have been successively fired. Another area of concern is the examination of bullets and cartridge cases fired by different firearms.

Concerning firearm barrels, it is recognized that striations are caused by imperfections in the rifling tools during the barrel manufacturing process and also can be inherent in the manufacturing process itself. The rifling tools wear during their use and potentially impart a continually changing set of striations, and the machining process itself does not yield identical barrels on the microscopic level. It would be expected that the greatest potential for similarity of striations would be encountered with firearm barrels that are consecutively rifled using the same rifling tool.

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Reproducibility of Striae and Impressed Marks (Consecutive and Non-Consecutive)

The following research articles – listed in chronological order – reflect a very small number of the overall research that has been conducted involving consecutively manufactured components as well as randomly (non-consecutive) manufactured components (barrels, extractors, ejectors, breech faces, knives, etc.).

One of the first recorded identifications of a specific fired projectile to a firearm occurred in 1898 in Neuruppin, Germany. Professor Paul Jeserich, a gifted forensic chemist from Berlin, was requested by the Neuruppin district court to compare a bullet removed from the body of a murder victim to a revolver owned by a suspect [7]. Jeserich test fired the revolver and then carefully produced a series of photomicrographs of the murder bullet and the test fired bullet. When he compared the photographs, he observed abnormalities on the bullets that indicated that both had been fired from the same firearm. His testimony was instrumental in the conviction of the defendant. His other interests, however, precluded his continuing further research into the area of firearm identification.

In the United States in 1907, the first recorded examination of multiple firearms in conjunction with fired cartridge cases involved inspectors at the US Army's Frankford Arsenal. The arsenal staff examined 279 service rifles and 33 fired cartridge cases from a shooting incident. The rifles were test fired and the test cartridge cases examined in conjunction with the evidence cartridge cases. The staff reported that they were able to identify some of the cartridge cases to the rifles. Their conclusions are an excellent example of early cartridge case identification [8, 9, 10].

Additional research continued in this forensic field during the next 25 years by early self-trained examiners such as Sydney Smith, Robert Churchill, Dr. Calvin Goddard and others. Four heavily reported criminal events permanently established the discipline of firearm and toolmark identification in both the United Kingdom and the United States. These cases involved the assassination of the Sidar in Egypt, the murder of Constable Gutteridge in England, and the Sacco-Vanzetti murder case and St. Valentine's Day Massacre in the United States [11, 12, 13]. The ability of these pioneer examiners to identify both fired bullets and fired cartridge cases to a specific firearm was instrumental in establishing firearm and toolmark identification as one of the forensic sciences.

Numerous studies support the contention of uniqueness where multiple bullets and/or cartridge cases are fired from one firearm. An excellent article by Bonfanti and De Kinder [14], discusses several scientific studies (some of which are mentioned in this article) that have been conducted where fired bullets and/or cartridge cases have been examined after test firings from consecutively manufactured firearms. In other instances, research has been conducted to evaluate fired components from a large number of firearms.

Two excellent articles and a presentation by Ronald Nichols [15, 16, 17] comprise a comprehensive review of the literature that pertains to firearm and toolmark identification criteria. Additional articles such as ones by Grzybowski, Murdock, Moran, Biasotti and others [18, 19, 20] offer a valuable compendium of reference materials that discuss scientific methods, reliability and the validity of the field of firearm and toolmark identification.

Numerous historical articles have been published [21, 22, 23, 24] which also provide various references concerning the field of firearm and toolmark identification. Other researchers such as Biasotti, Murdock, Moran, Thompson and many others have conducted extensive research and published their findings [25, 26, 27, 28, 29, 30, 31]. Due to space limitations, and the nature of this specific research project, only a few references are provided below.

In 1930, a rod of steel (barrel blank) was bored and rifled at an U.S. Government arsenal. The barrel stock was rifled and then cut into six pieces to form six short barrels. A bullet was test fired from each of the six barrels and scribed with a secret marking. Colonel Goddard was given the six scribed bullets and six barrels for evaluation and examination. In this blind study, Goddard correctly associated the scribed bullets to the appropriate barrel [32].

In 1957, Flynn reported on a study in which the Chicago Police Department (CPD) Crime Lab examined a total of 100 consecutively manufactured chisels that had been finished using a grinding process. He reported that a total of 5,050 total comparisons were made during the experiment with no misidentifications [33].

In 1958, Kirby fired 900 lead bullets from a .455 caliber revolver and was able to identify that all of the cartridge cases had been fired in the same weapon [34]. However, he was only able to identify the first thirty bullets as being fired from the revolver because the patterns of striations on the bullets were affected by the barrel becoming leaded during the test.

In 1970, Lutz used two consecutively rifled and machined revolver barrels for a 38 Special caliber Smith & Wesson Model 10 revolver. Three different types of bullet configurations, including lead bullets, were test fired and examined. Of those participating in the examination of the test fired bullets, none had difficulty differentiating between the proper barrels [35].

In a study conducted in 1972, a total of 501 full metal jacket (FMJ) projectiles were fired from an M16A1 223 caliber assault rifle [36]. The assault rifle was selected from the Laboratory Weapons Reference Library (WRF) while the ammunition used was from the Laboratory's Ammunition Reference File (ARF) [32, 33]. The 501 cartridges were fired – using the full automatic mode - as fast as the 20 round magazines could be changed and every hundredth projectile collected in a cotton recovery box. It was possible to microscopically identify all the bullets as having been fired by the same rifle.

In 1972, Murdock compared bullets fired from four crowned, button-rifled barrels with bullets fired from the same barrels after they had been recrowned. Although he observed some changes in the rifling, he could still associate the proper bullet to the specific barrel. Another set of test fired bullets was compared to the first set after the barrels were recrowned a second time with a similar result. This study demonstrated that the crowning process had minimum effect on identifying fired bullets [37].

In 1973, an U. S. Army Captain was shot and killed while standing in his tent in a bivouac [encampment] area. The assailant fired a 223 (5.56mm) caliber M16A1 assault rifle at the Captain's shadow in the tent. Investigators seized a total of 47 M16A1 assault rifles from personnel in the bivouac area. The rifles, along with the fired bullet components recovered during the autopsy, were forwarded to the US Army Criminal Investigation Laboratory at Fort Gordon, Georgia. Special Agent John G. Ward, Sr., senior firearms examiner for the laboratory, test fired the 47 rifles and microscopically compared the test-fired bullets to the evidence bullet fragments. Ward was able to identify the rifle used to shoot and kill the Captain. The suspect, a disgruntled soldier, was found guilty of murder [38].

Butcher & Pugh reported on a study in 1975 which involved the examination of test marks made by ten consecutively made bolt cutters as well as ten randomly selected bolt cutters – all with ground working surfaces (blades). The study showed no more than 29% matching striae for known non-matches (KNM) and between 87% and 93% matching striae for known matches (KM). The implication of this research suggests that there is no risk of misidentification by a competent examiner [39].

Ogihara, and others, conducted an extensive research study in 1977, by examining 5000 bullets and cartridge cases fired by an U.S. Army issue M1911A1, 45 (11.45mm) ACP caliber semiautomatic pistol [40]. The researchers used standard 45ACP caliber FMJ military ammunition for the project and collected every tenth fired bullet and cartridge case for examination. The firearm used for the project was part of the National Research of Police Science Institute's (NRIPS) Weapons Reference Library and the ammunition was provided by the U.S. Army Criminal Investigation Laboratory – Pacific (USACIL-PAC) – now closed. This study involved firearm and toolmark examiners from three forensic laboratories and required a substantial amount of time to effect the comparisons for the bullets and cartridge cases. Using standard microscopic techniques, the researchers were able to identify all of the bullets and cartridge cases as having been fired by the same pistol.

In 1978, Watson published an article discussing the uniqueness of two consecutively manufactured knives. His research revealed that no carryover of individual markings was found to exist between the two knives and that the knives could be individually identified [41].

Cassidy reported on a study in 1980 where he examined the individuality of striated marks produced by consecutively broach cut tongue and groove pliers. His examination and observations of the jaw teeth and their test marks revealed no subclass marks and that the striated marks produced are individual to the tool that made them [42].

For a comprehensive study in 1981, Murdock obtained three consecutively button-rifled 22 caliber (5.56mm) barrels each from three different manufacturers. The nine barrels were machined to fit one bolt-action rifle. Thirty lead bullets were fired from each of the nine barrels and compared to each other. His research determined, as in other studies, that the first few bullets fired from each barrel were not identifiable to each other. The remaining bullets, from each barrel, were identifiable to each other and could be distinguished from those fired from the other barrels [43].

In 1982, Tuira compared two consecutively manufactured Buck brand knives that were used to cut inflated tires. His microscopic observations of the resulting toolmarks determined that the toolmarks were significantly different [44].

In a study by Hall in 1983, four barrels in 308 caliber (7.62mm) with polygonal rifling were used. Two of the barrels were consecutively rifled while the other two were randomly taken from the production line. Hall reports that he encountered no difficulties in identifying bullets fired in any of the barrels. He used three different brands of ammunition with the first five bullets fired from each barrel used for stabilizing the pattern of striations. The bullets, fired after the first five, were identifiable to each other and could be distinguished from those fired in any other barrel. Hall observed some change in striae when comparing bullets that were sequenced further apart from each other, but this did not preclude identification [45].

In 1983 Shem and Striupaitis fired 501 bullets and cartridge cases using a Raven Model P-25 25 (6.25mm) Auto caliber semiautomatic pistol. The researchers collected every 10th fired bullet and cartridge case for examination. They concluded that, although changes were occurring in the bullet striae and breechface marks, it was possible to identify bullet 1 to 501 as well as cartridge case 1 to 501 [46].

In 1984, Matty and Johnson examined the concentric marks produced by Smith & Wesson firing pins. Subclass characteristics were found and determined to be a result of the lathe mounted cutter being much harder than the firing pins. The researchers also determined that areas of the firing pins that contain random breaks in the striated lines due to metal tearing or areas that show wear can be used for identification [47].

Matty conducted a study in 1984 involving three consecutively made breechfaces from Raven semiautomatic pistols. His observations were that the concentric toolmarks on the breechfaces could be individualized and that the toolmarks were not subclass [48].

In 1985, Matty reported on a project involving the examination of three individual barrels produced from one button-rifled barrel blank. He noted some subclass characteristics in the groove impressions but not in the land impressions. He also determined that the striae changed significantly during the first few test firings [49].

In 1985, Van Disk reported on his examination of fifty steel marking stamps made from the same hob (die). The marking stamps were examined for subclass marks. Van Disk determined that unique defects from the hobbing process could be used to correctly identify each stamp [50].

Uchiyama conducted a study in 1986 where he examined the breechface marks produced by 25 Auto caliber Browning, Raven and Titan semiautomatic pistols. He determined that subclass characteristics were significant and informed examiners to be cautious when examining these types of firearms [51].

In 1986, Dr. Gross - then head of the Bundeskriminalamt (BKA) firearms section - reported on a high profile murder case that had occurred in Germany in 1984 & 1985. The case involved test firing some 7,862 similar type pistols with the test fired items submitted for examination. The examiners identified test fired components from pistol number 3,704 [52].

In 1992, Schecter and others test fired a 223 caliber (5.56mm) GALIL rifle 7,100 times, using a variety of 223 caliber ammunition. The researchers microscopically examined the fired cartridge cases specifically for the ejector marks because the ejector on a GALIL rifle is part of the rifle and is not removable. Schecter and others were able to identify the ejector marks on the casings with a spread in excess of 7,050 firings [53].

In 1992, Hall performed a series of tests in which consecutive test cuts in lead were made with bolt cutters. Hall reported that lead is a suitable material for test marks and that cuts in shackles may or may not change the tool depending upon the hardness of the shackle [54].

In 1994, Thompson reported on a follow-up study of the article by Matty on Raven breechfaces. He obtained four breechfaces from Phoenix pistols (formerly Raven) and compared them to determine the nature of their marks. His examination confirmed the findings of Matty that breechfaces possess unique identifying marks [55].

Brown & Bryant, in 1995, reported on a study of multi-barreled derringers in which it was assumed that the barrels were rifled consecutively. In one instance, one set of derringer test fires showed some good correspondence in the groove impressions (gross marks), but showed little correspondence in the land impressions [56].

In 1996, Thompson examined the manufacturing process of Lorcin pistol breechfaces. He noted that Lorcin breechfaces were produced by stamping and then painted over - as opposed to being machined - and that false identifications could be possible if the only marks considered were from the breechface [57].

In 1998, Tulleners and Guisto obtained a Thompson Center Contender button rifled barrel which was sectioned one inch at a time after each test firing. A total of six sections were removed from the barrel. The bullets test fired from each sectioned barrel were compared to each other to determine how much the Consecutive Matching Striation (CMS) count had changed. Striae on the bullets were found to be significantly altered from one barrel section to the next. The results obtained from adjacent barrel sections were apparently comparable to the results Biasotti had obtained from different, uncut barrels [58].

Tulleners and Hamiel reported on a study in 1999 where the potential for subclass characteristics in Smith & Wesson revolver barrels was discussed. The article points out that a firearm and toolmark examiner should be careful when examining the groove impressions on fired bullets from barrels that have been rifled using broach rifling techniques [59].

In 2000, Miller reported on a study where he pushed bullets through two consecutively broached 44 caliber barrels. He examined the test bullets using the Biasotti/Murdock conservative CMS criteria for identifications and reported that there were no misidentifications [60].

Rosati reported on a study in 2000 involving the examination of four bunters that were produced using Electrical Discharge Machining (EDM). The bunters were used by Remington for the manufacture of 45 Auto caliber cartridge cases. Rosati's examination confirmed the random nature of marks from the EDM process on headstamp characters [61].

In 2000, Lopez and Grew conducted a study involving firearm bolt faces machined with an end mill. The study warns that a misidentification is possible unless the identification is based on breechface wear or machining "chatter" marks on the breechface [62].

In 2001, Hamby reported on the microscopic examinations of four 9mm cartridge cases that were test fired in 617 Glock Model 17 & 19 semiautomatic pistols. Hamby microscopically examined the cartridge cases against each other to validate that uniqueness and individuality exist among the fired cartridge cases. The observations were that each casing could be identified to the specific firearm [63].

In February 2001, at the American Academy of Forensic Sciences Meeting in Seattle, Washington, Brett Doelling presented the results of research that he had conducted involving multiple bullets fired from the same firearm. Doelling test-fired 4,000 cartridges using a 9x18mm caliber Makarov semiautomatic pistol. Every 100th bullet was collected and examined microscopically. Doelling concluded that although the markings continued to change, the 4000th bullet was identifiable to the 1st bullet [64].

In 2001, Miller, using a test set containing bullets from the Hamby & Brundage Ruger ten barrel test, reported that he had identified some very minor subclass characteristics but not sufficient to cause a misidentification. He also applied the conservative CMS Criteria which resulted in no misidentifications [65].

Eckerman reported on a study in 2002 in which toolmarks made by consecutively manufactured and belt- sanded chisels were examined for the possibility of subclass marks. Eckerman's examinations revealed that the marks were found to be individual to each chisel [66].

Lee reported on a study in 2003 where she used five consecutively manufactured screwdrivers to test the reproducibility of marks produced at various angles with both pushing and pulling motions. The toolmarks from each of the screwdriver blades were found to be individual to tool that produced them [67].

In 2003, Thompson & Wyant visited a knife production facility where they observed the actual production of 10 consecutively manufactured knife blades. The researchers produced a number of test sets containing known and unknown knife cuts using those 10 consecutively manufactured knife blades. The test sets were provided to firearm and toolmark examiners for examination. This test – the Knife Identification Project (KIP test) – demonstrated the ability by the majority of participants to successfully differentiate toolmarks made by consecutively manufactured knife blades [68].

Bunch and Murphy reported in 2003 on a study in which 10 consecutively manufactured Glock semiautomatic pistol slides were obtained from the factory in Austria. The manufacturing process of the 10 slides - which contain the breechface - was observed and the slides then used to produce test fired cartridge cases for a comprehensive validity study by examiners in the FBI Laboratory's Firearms-Toolmark Unit (FTU). Using breechface marks, the examiners were able to correctly identify cartridge cases fired by each of the different slides [69].

Vinci, and others, conducted an extensive study in 2004 that involved 2500 cartridges fired by a 45 (11.45mm) ACP caliber Springfield Armory semiautomatic pistol. The researchers examined every 100th fired cartridge case to evaluate sequential changes in both class and individual characteristics and reported that it was possible to identify all 2500 cartridge cases as having been fired by the recently produced pistol [70].

In 2005, Clow reported on an extensive research study that utilized 10 consecutively manufactured knife blades in a stabbing motion to determine if the marks produced were unique, reproducible and identifiable in pig cartilage. The toolmarks were found to be unique to each knife blade, reproducible and potentially identifiable in cartilage [71].

Smith reported on a research study in 2005 that was designed to test the accuracy of examinations by trained firearm and toolmark examiners who use pattern recognition as a method for identification. Eight FBI examiners took the test which consisted of both bullets and cartridge cases. No false positives or false negatives were reported [72].

In 2005, Collins reported on an empirical study involving the uniqueness of impressed toolmarks. He used twenty worn hammers to produce a series of test toolmarks and examined the marks to determine if they could be considered unique. His conclusions were that the marks could be considered unique [73].

In 2008, Gouwe, Hamby and Norris reported on a experiment that involved a total of 10,000 fired 40 S&W caliber cartridge cases using a Glock Model 22 firearm. The researchers microscopically examined every 10th cartridge case and determined that sufficient individual markings were present on the fired cartridge cases to identify cartridge case 1 to cartridge case10,000 [74].

Experimental Design

During the past eighty years, a significant volume of research has involved the evaluation of test fired bullets and cartridge cases. The research cited in this paper has included test firing a firearm numerous times to evaluate changes in microscopic characteristics observed on the fired components and also the test firing of consecutively rifled firearms to determine if bullets could be identified to the barrel from which they were fired. In every research project involving the examination of consecutively manufactured tools – including bullets from consecutively rifled barrels – the results have established that properly trained firearm and toolmark examiners have the ability to identify toolmarked surfaces to the correct tool. Despite the wealth of research, there are still challenges to this type of evidence in the courts system.

Brundage's original research study was expanded to examine the ability of numerous firearm and toolmark examiners on a worldwide scale to associate bullets fired from consecutively manufactured gun barrels as well as to provide test sets for training use within the participant's own laboratory. (Originally, the 67 participants were comprised of 30 official examiners that were from ASCLD/LAB Accredited Laboratories, 30 unofficial examiners that were from non-accredited laboratories, and 7 examiners that were requested to conduct a pre-test evaluation of the test sets prior to distribution. At that time, all 67 participants were from laboratories in the United States)

This experiment was undertaken to address some of the following issues:

1 - To determine if a firearm and toolmark examiner has the ability to correctly associate test fired bullets to the correct consecutively rifled gun barrels;

2 - To expand the test data base from the original 67 participants to participants in laboratories worldwide;

3 - To provide test sets of known bullet pairs and unknown test bullets from the 10 consecutively rifled barrels for laboratories to use in their organizational training programs;

4 - To evaluate the issue of subclass characteristics on bullets fired from consecutively rifled barrels;

5 - To provide information to counter various legal challenges concerning the ability of firearm and toolmark examiners to identify bullets to firearms;

6 - To provide examiners with examples of best known non-match (KNM) bullets.

Materials and Methods

1. Pistol: One Ruger P-85 9mm Luger caliber semiautomatic pistol, serial number: 302-06291 with one 15-cartridge capacity magazine. The same magazine was used during the test firing sequence.

2. Barrels: Ten consecutively rifled 9mm caliber barrels manufactured by Ruger for the Ruger P-85 pistol. The barrels were marked 11 through 20, hereafter referred to as barrel numbers 1 through 10.

3. Ammunition: Winchester 9mm caliber NATO, 124 grain FMJ ammunition, lot number: Q4312, Headstamp: WCC96.

4. Recovery system: One locally manufactured and vented 800 gallon water recovery tank, located in the firearm section of the Indianapolis-Marion County Forensic Services Agency (IMCFSA), Indianapolis, Indiana.

5. Ear and eye protection for test firing, electric engraver unit for scribing test bullets.

6. Envelopes of different sizes, computer labels for labeling the test envelopes, padded packaging materials, pill boxes for collecting test fired bullets, and shipping containers.

Methods (Test Construction)

Each test set included a control set and an unknown set of bullets. In the control set, it was known which barrel fired the bullet and was comprised of two bullets fired from each of the 10 barrels. The unknown set of fifteen bullets was comprised of at least one bullet from each barrel and no more than three bullets from any one barrel. A total of 240 such test sets were prepared.

Prior to test firing the ammunition to prepare the test sets, the pill box containers were appropriately marked to indicate both barrel number and sequence of seven shots. For example, a container marked 1/1 would indicate barrel 1, test sequence 1, while a container marked 7/239 would indicate barrel 7, test sequence 239. Test firing commenced on July 8, 1999 and concluded on August 10, 2000 and was carried out by Hamby, Brundage, and Mickey French, all qualified firearm and toolmark examiners then employed at the IMCFSA. Production of the test ultimately involved shooting some 16,800 cartridges; 1,680 from each of the 10 consecutively manufactured barrels. All 16,800 fired cartridge cases were test fired using the same slide installed on the Ruger P-85 semiautomatic pistol.

Seven cartridges were test fired for each test sequence. The test fired bullets were retrieved from the water recovery tank and placed, along with the recovered cartridge cases, into a pill box designed to maintain them. After the test firing was complete for a group of test sets, the marked pill boxes were combined into 'groups' by barrel and firing sequence number. This process allowed for the same relative amount of barrel wear because the bullets were test fired during the same sequence. For example, every barrel – one through ten – and sequence 74 were assembled into one test set, 1/74, 2/74, 3/74, etc.

The sets of 20 'known' bullets were scribed on the base with the barrel number from 1 to 10. The 15 'unknown' bullets were scribed on the base with an alpha designator from A through Z. To ensure a random letter process and to preclude using the same alpha character twice while scribing the 'unknown' bullets, a set of 3x5 cards were marked A through Z. The 26-card set was shuffled just before scribing the 15 'unknown' bullets and the first 15 alpha characters selected were utilized for marking the bullets. Once the test fired bullets were marked, they were placed into coin envelopes that were previously labeled as depicted below:

KNOWN TWO (2) TEST BULLETS FIRED FROM
BARREL #10

QUESTIONED ONE (1) UNKNOWN FIRED
BULLET – MARKED 'J'

The test sets were individually packaged according to the sequence of the test set being fired and continued until all 240 test sets were completed. A 10% random sampling of the 240 prepared sets was conducted before the sets were shipped to participants. This random sampling, using an optical comparison microscope, validated that it was possible to identify the 15 'unknowns' to the 'known' bullets.

Each completed test set was sealed in a manila envelope with instructions for completing the examination. The answer sheet requested additional information from the participant, such as years of experience, years and type of training, type of comparison microscope used and membership in forensic organizations. It may be, if the error rate was non-zero, that this could be correlated with training, experience and/or type of microscope. The test materials and answer form were all packaged in a padded envelope for shipment. When the answer form was received from a participant, the answers were evaluated using the test set answer key. A letter of acknowledgement and the answer key were mailed to the participant for later use within their laboratory.

Distribution of Tests

In the expanded study, notices of the tests availability were widely distributed. A letter announcing the availability of the test sets was distributed at the Annual AFTE Training Seminars held in Virginia, Missouri and California in 1999, 2000 and 2001. The test sets were also distributed at the 2000, 2001 and 2002 Shooting, Hunting, Outdoor, Trade (SHOT) Shows. An announcement concerning the availability of the 10 barrel test was also published in the AFTE Journal and the authors contacted a number of individuals – in laboratories in the United States and overseas – to solicit participation in the project. To date, all 240 test sets have been distributed to forensic laboratories, universities and researchers around the world.

Results and Discussion

Test Series	No. Examiners Reporting All Correct Results	No. Inconclusive Results (Examiners, bullets)		No. Incorrect Results
Brundage	66	1	1	0
Hamby	436	4	7	0
Combined Totals	502	5	8	0

A total of 507 responses have been received from individuals that participated in the two studies. In the original Brundage study, one laboratory reported an inconclusive result in that they were unable to associate an unknown bullet with the known bullets due to damage to the projectile. While they reported their finding on one of the 15 bullets as "inconclusive", it would perhaps have been more appropriate to have been reported as "unsuitable". In the expanded study by Hamby & Thorpe, two examiners felt that there were insufficient individual characteristics on two of the bullets due to tank rash [75]. In another instance, two firearm and toolmark examiner trainees were unable to correctly associate 5 of the unknown bullets (1 for one trainee, 4 for the second trainee). In each instance, the participants reported their findings as inconclusive and at no time were misidentifications reported.

In addition to individuals examining the test sets using optical comparison microscopy, five test sets were examined using 'ballistics' imaging equipment. The test sets were examined using the following systems with correct answers reported by the participants. This information indicates that these systems – when properly used – can provide appropriate data:

- Intelligent Automation's SciClops™ - Dr. Ben Bachrach (Maryland, United States);
- Automated Land Identification System (ALIS) - Mr. Tsuneo Uchiyama (Tokyo, Japan);
- Integrated Ballistics Identification System (IBIS) ™ – Mr. Robert Thompson (California, United States);
- BulletTRAX-3D™ - Forensic Technology Scientists (Montreal, Canada) (2 sets)

Evaluation

The majority of participants reported that the examination of the test set required between seven and nine hours. The shortest amount of time reported was three hours while the longest time required for two participants was 30 hours.

In this type of testing, once a bullet is ascribed to a barrel, that bullet is not re-examined; this is sampling without replacement. Normally the probability of achieving a correct result by pure chance is calculated using the hypergeometric theorem. However, this situation is complicated by having up to three separate bullets ascribed to one barrel in a test set and the exact probability will vary depending where in the sequence of fifteen test bullets the additional bullets occur. Therefore, a simpler calculation was used. If an examiner took an "unknown" bullet and attributed it at random to a barrel then there would be a probability of 0.1 that the attribution would be correct. In the survey, each examiner attributed 15 bullets to the 10 barrels correctly and the probability of achieving this by chance is 1 in 10 (-16).

Background information provided from the questionnaires provided insight (shown below) about 435 individuals responding to the survey as the data wasn't available for the original 67 participants or for the individuals using the SciClops™ and BulletTRAX-3D™ imaging systems. Responses were obtained from 20 countries on four continents. Participants from the following countries contributed to this worldwide research project: Australia, Barbados, Belgium, Botswana, Canada, China, Germany, Greece, Jamaica, Japan, Saudi Arabia, Netherlands, New Zealand, Norway, Switzerland, South Africa, Trinidad & Tobago, United Arab Emirates, United Kingdom and the United States. In the United States, responses were received from examiners in 49 states and the territories of Guam and Puerto Rico.

The median number of years of experience in the field, for the 435 respondents participating in the project was 10.5 years, with the amount of time spent in training 1.8 years. Two of the participants were in training and had a less than three months experience each while one individual was a graduate student in a forensic science program. The majority, in excess of 95%, of all responding participants indicate that they were trained under an 'on the job' (OJT) training scheme while a few examiners stated that their training was formal. The larger laboratory systems such as the Federal Bureau of Investigation (FBI) and the Illinois State Police (ISP) – as well as some other laboratories - conduct more formal training than some smaller laboratories. It should be noted, however, that the majority of forensic laboratories around the world utilize a combination of training methods which includes the AFTE Training Manual, specific OJT training, formal instruction, tours of manufacturing facilities, etc. A recent web based firearm and toolmark examiner training program – sponsored by the National Institute of Justice (NIJ) and prepared by the National Forensic Science & Technology Center (NFSTC) under contract to NIJ – was released for use by examiners worldwide at the 2008 AFTE Annual Training Seminar in Honolulu, Hawaii. The majority of the program was written by experienced firearm and toolmark examiners – all members of the Association of Firearms and Toolmark Examiners - and closely follows the AFTE Training Manual [76].

When asked about the Specialized Firearms Techniques School offered by the Federal Bureau of Investigation, a total of 65 participants responded that they had attended the school. Since the National Firearms Examiner Academy (NFEA) was established in 1999, a total of 88 firearm and toolmark examiners have successfully completed the course. Of those attending the NFEA, a total of 21 firearm and toolmark examiners participated in this research project.

Conclusions

A total of 507 responses were received for this worldwide research project, including the 67 responses from firearm and toolmark examiners who participated in the original study by Brundage. The project was designed to determine if trained firearm and toolmark examiners could identify 15 'unknown' fired bullets to the correct one of 10 consecutively rifled barrel. In only two instances of the 7,605 'unknown' fired bullets examined, respondents considered three of the bullets as unsatisfactory for microscopic examination due to damage. Two firearm and toolmark examiner trainees were simply unable to ascribe five of the 'unknown' fired bullets to the 'known' samples. The remaining 7,597 'unknown' fired bullets were correctly identified by participants to the provided 'known' bullets. The fact that there were no actual errors shows that the test procedure used to ascribe bullets fired from consecutively rifled barrels is reproducible on a worldwide basis.

In a Daubert Hearing (a legal challenge in the United States), an examiner could state something like the following: "A long term internationally administered validity test using consecutively rifled barrels, a condition widely considered the most likely to produce errors, was completed by 507 different participants (502 examiners, 5 using instrumentation) and resulted in 7,597 correct identification conclusions and no false positive conclusions".

This study shows that there are identifiable features on the surfaces of bullets that can link them to the barrel that fired them. Although one would expect bullets fired from consecutively rifled barrels to display subclass characteristics, <u>the issue of subclass characteristics was not an issue</u> for the 502 individuals who participated in this research project. Based on the results of this research, having fired bullets in good condition and properly trained firearm and toolmark examiners, the identification process has an extremely low estimated error rate. In circumstances where bullets are deformed or fragmented, the comparison process may be more difficult and the error rate may increase. This study also shows that various statements made about the inability of examiners to associate fired bullets to consecutively rifled barrels were incorrect.

It should be noted that 502 participants – excepting those utilizing 'ballistics' imaging equipment – conducted the examinations using conventional optical comparison microscopy. Results of this study have provided the forensic science community with additional supportive documentation in the field of firearm and toolmark identification, especially as it pertains to the identification of bullets fired from consecutively rifled barrels.

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