Document Title: An Empirical Study to Improve the Scientific Foundation of Forensic Firearm and Tool Mark Identification Utilizing Consecutively Manufactured Glock EBIS Barrels with the Same EBIS Pattern

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Document No.: 244232

Date Received: December 2013

Award Number: 2010-DN-BX-K269

"An Empirical Study To Improve The Scientific Foundation Of Forensic Firearm And Tool Mark Identification Utilizing Consecutively Manufactured Glock EBIS Barrels With The Same EBIS Pattern"

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Final Report

Submitted By:

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2013

This project was supported by Award No. 2010-DN-BX-K269 awarded by the National Institute of Justice, Office of Justice Programs, U. S. Department of Justice. The opinions, findings, and conclusions or recommendations expressed in this publication/program/exhibition are those of the authors and do not necessarily reflect those of the Department of Justice.

Abstract

This research conducted an empirical study to evaluate the reproducibility and uniqueness of striations imparted by consecutively manufactured Glock Enhanced Bullet Identification System (EBIS) barrels with the same EBIS pattern, as well as to determine the error rate for the identification of same gun evidence. The foundation of firearm and tool mark identification is that each firearm/tool produces a signature of identification (striation/impression) that is unique to that firearm/tool, and through the examination of the individual striations/impressions, the signature can be positively identified to the firearm/tool that produced it. The National Academy of Sciences Report questioned the repeatability and uniqueness of striations/impressions left on fired evidence as well as the validity and error rate in firearms identification. The Miami-Dade Police Department has been researching/evaluating Glock barrels since 1994. The Glock EBIS barrel is a polygonally rifled barrel, which has a barcode-like pattern added during the manufacturing process. Consecutively manufactured EBIS barrels with the same EBIS pattern are significant to the study because these barrels will be manufactured with the same EBIS equipment/tools and exhibit a similar pattern. Even though these barrels are consecutively made, their signatures should still be different. Test sets were assembled which included test fired bullets as well as unknowns. Participants were trained firearm and tool mark examiners throughout the United States and internationally. This empirical study established an error rate of less than 1.2 percent.

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EXECUTIVE SUMMARY

In 2009, the National Academy of Sciences (NAS) released a report titled "Strengthening Forensic Science in the United States: A Path Forward." In this report, the NAS questioned the repeatability and uniqueness of striations left on fired firearms evidence as well as the validity and error rate in firearms identification. The goals of this research study were: 1) to conduct an empirical study to evaluate the repeatability and uniqueness of striations imparted by consecutively manufactured barrels; and 2) to determine the error rate for the identification of same gun evidence.

Utilizing an experimental research design, this study analyzed the repeatability and uniqueness of striations on spent projectiles/bullets fired in 10 consecutively manufactured barrels by analyzing their individual striations. One semi-automatic pistol and nine additional consecutively manufactured barrels were utilized. Consecutively manufactured barrels are significant to this study because they were manufactured with the same equipment/tools. Even though these barrels were consecutively made, their signatures should be different if there is no subclass influence. Test sets assembled included known test fired bullets from each barrel as well as unknown (questioned) bullets.

Participants were trained firearm and tool mark examiners throughout the United States and abroad. One hundred fifty test sets were distributed to laboratories in 41 states, the District of Columbia and internationally. The test sets were designed to determine an examiner's ability to correctly identify bullets fired from 10 consecutively manufactured Glock Enhanced Bullet Identification System (EBIS) barrels with the same

EBIS pattern to test fired bullets fired from the same barrels. This empirical study established an error rate of less than 1.2 percent.

The 2009 NAS Report also stated that "some forensic science disciplines are supported by little rigorous systematic research to validate the discipline's basic premises and techniques." In addition, the report stated that forensic science will be improved by collaborative opportunities "with the broader science and engineering communities." The statistical analyses of this research data was performed by a professor from the Department of Statistics at Florida International University. This collaboration with an external agency to analyze the data that was collected ensures that the statistical results are reported accurately and without bias.

This research supports the scientific foundation of forensic firearm and tool mark identification through the evaluation of the repeatability and uniqueness of striations of unknown bullets. This study provides empirical data to strengthen the foundation of firearms identification and quantifies the error rate of identification of same gun evidence from the data collected.

INTRODUCTION

Purpose, Goals and Objectives

The purpose of this research was to conduct an empirical study to evaluate the repeatability and uniqueness of striations imparted by consecutively manufactured EBIS barrels with the same EBIS pattern to spent bullets as well as to determine the error rate for the identification of same gun evidence.

Limited studies have previously been conducted with consecutively manufactured barrels as well as with the Glock EBIS barrel utilizing multiple participants. The goal was to demonstrate whether or not spent bullets could be identified to the firearm that fired them through the comparison of tool marks.

The objective of this research study was to determine if trained firearm and tool mark examiners would be able to identify spent bullets to the firearms that fired them when examining bullets fired through consecutively manufactured barrels utilizing individual, unique and repeatable striations. Also, the study presented herein evaluated the experience level of trained firearm and tool mark examiners and the effect, if any, of their experience level on the results.

Review of Relevant Literature

A review of the relevant literature found articles citing the need for additional data in the field of firearm and tool mark identification. In addition, however, a multitude of studies were also identified where one individual or a small group of individuals correctly identified bullets fired consecutively in various firearms. Some of these studies also examined the repeatability and longevity of a firearm's unique signature by comparing the test fired bullets to the questioned bullets. These research studies have demonstrated that a firearm's unique signature remains identifiable even after several thousand test fires.

Scientific Scrutiny

Saks and Koehler (1991) compared all of the forensic disciplines to DNA. The authors indicated that ballistics and tool marks have eluded the standards of scientific scrutiny. The authors discussed the lack of academic counterparts, conclusions based on unsupported data, and that only a handful of seminal research exists for all forensic disciplines besides DNA.

Saks (1993) noted that forensic science developed through criminal law. The author stated that the crime laboratory analysts lack scientific training, essentially following "recipes" (p.13). Saks discussed that crime laboratories generate little research and that few universities train the crime laboratory analysts. Saks (1994) implied that identification sciences lack statistical data to support identity. He further mentioned that the data available was not suitable for statistical analysis. Saks questioned whether firearms examiners had a reliable foundation to base their opinions.

Moran and Murdock (2002) noted the judicial system was evaluating the scientific basis for tool mark identification. The authors pointed out that the courts will be seeking demonstrative proof for identifications.

Collins (2009) indicated that forensic scientists rely upon their training and experience as their foundation for their conclusions. The author mentioned that the exact chance that two firearms will reproduce the same pattern of striations is unknown; however, "research can, in fact, quantify the margins and establish useful thresholds to help" (p. 5). Saks and Koehler (2008) noted that pattern matching lacked objective standards. They further indicated that there has been a limited amount of research regarding pattern matching.

Faigman (2010) suggested that forensic science (with the exception of nuclear DNA analysis) is not a science. He indicated that the courts allow forensic expertise that is not well validated by contemporary scientific standards. Faigman implied that practitioners are not qualified to carry out good scientific research.

Mnookin (2010) stated that the problem with forensic science is that the claims made are not supported by research. The foundation of forensic science was built on experience, not research. Mnookin is looking for more data to support examiner claims.

Ruger Consecutively Manufactured Gun Barrels

Brundage (1998) conducted an empirical study to determine whether or not firearm and tool mark examiners could properly identify bullets that were fired from consecutively manufactured Ruger gun barrels. Brundage obtained 10 consecutively manufactured 9mm Ruger firearm barrels from Sturm, Ruger & Company. The test sets were sent to 30 firearm and tool mark examiners throughout the United States. All 30 examiners returned their answer sheet; evaluation of the submitted results revealed no incorrect answers. The examiners were able to correctly distinguish the questioned bullets from multiple consecutively manufactured gun barrels. The data collected demonstrated that consecutively manufactured gun barrels differ from each other, producing different signatures. Generally speaking, this data indicated that, on a national level, firearm and tool mark examiners can identify bullets as having been fired through a particular barrel.

Hamby (2001) also conducted an empirical study to determine whether or not firearm and tool mark examiners could correctly identify bullets that were fired from consecutively manufactured gun barrels. Hamby obtained the 10 consecutively manufactured 9mm firearm barrels that were utilized in the Brundage study. The test sets were sent to 204 firearm and tool mark examiners, which included the 30 participants from Brundage's 1998 study. Hamby reported that a total of 201 examiners from several countries returned their answer sheets, and that no incorrect identifications were made.

The examiners were able to distinguish the questioned bullets from multiple consecutively manufactured gun barrels. The data collected demonstrated that consecutively manufactured gun barrels differ from each other, producing different signatures. This data also supported the hypothesis that firearm and tool mark examiners, on an international level, can identify bullets as having been fired through a particular barrel with a reasonable degree of scientific certainty.

Hamby and Brundage (2007) continued the quest of the 1998 Brundage study using the 9mm Ruger firearm barrels. A total of 438 examiners from 17 countries participated and no incorrect identifications were made. In the United States, 47 states were represented in this study. Hamby reported an error rate of .001 percent based on the data collected from all 438 participating examiners. According to Nichols (2007), "error rates have been studied and can provide consumers of the discipline with a useful guide as to the frequency with which misidentifications are reported in the community using appropriate methodologies and controls."

In 2009, Hamby, Brundage and Thorpe reported that their 10 consecutively manufactured Ruger barrel research project had a total of 507 participants from 20 countries. As of their publication in 2009, no incorrect answers were reported.

Each study described here independently tested the question as to whether markings imparted to bullets fired through consecutively manufactured barrels are reproducible and identifiable. The results of each study demonstrated that firearm and tool mark examiners can correctly identify same gun evidence. Repeated support of the same hypothesis supports the foundational concepts of firearm and tool mark examination.

Related Research

Miller (2000) conducted research to determine whether or not a trained firearm and tool mark examiner could properly identify bullets that were fired from two consecutively manufactured .44 caliber barrels. Miller found a "significant reproduction of subclass characteristics" (p. 262). Even with the amount of subclass characteristics present, Miller was still able to correctly distinguish the questioned bullets from the consecutively manufactured gun barrels.

Polygonally Rifled Barrels

Haag (1977) obtained one Heckler and Koch P9S pistol with polygonal rifling from the manufacturer for his study. Haag reported that the barrels of Heckler and Koch pistols were hammer forged, which is "a process that involves no cutting as the steel is compressed around the form" (p. 46). Haag indexed the bullets prior to test firing in order to assist with orientation for microscopic examinations. Haag reported that there were some matching striations amongst some of the bullets; however, "others revealed no positive comparison" (p. 46).

Freeman (1978) obtained three consecutively manufactured 9mm caliber Heckler and Koch polygonally rifled firearm barrels. Freeman was able to correctly distinguish the questioned bullets from the consecutively manufactured Heckler and Koch polygonally rifled firearm barrels demonstrating that consecutively manufactured gun barrels differ from each other, producing different signatures. The key limitation reported by Freeman was that one of the Heckler and Koch polygonally rifled firearm barrels used in his study did not mark as well as the other two.

Hall (1983) obtained four consecutively manufactured polygonally rifled Shilen rifle barrels. He was able to correctly distinguish the questioned bullets fired from the consecutively manufactured polygonally rifled Shilen rifle barrels demonstrating that consecutively manufactured gun barrels differ from each other, producing different signatures. Like Miller (2000), Hall (1983) noted that a subclass characteristic was present; however, it would not create a false identification.

Hocherman, Giverts and Shosani (2003) conducted a research study to determine whether or not a firearm and tool mark examiner could properly identify polygonally rifled bullets to the manufacturer of the firearm that it was fired in. Three types of polygonally rifled pistols were obtained which fit two subclass groupings of polygonal rifling profiles. The researchers created known standards (test fired bullets) and question bullets using different Glock, Jerico and Heckler and Koch pistols. Six examiners were used in this study, and they had a 65% success rate in determining the manufacturer. The researchers reported that the 65% success rate was due to a lack of training with polygonal rifling profiles.

The New York Police Department (NYPD) (1996) conducted a research study comparing bullets that were fired through polygonally rifled barrels and conventionally rifled barrels. The main purpose of the study was to determine the suitability of fired bullets for microscopic comparisons. The NYPD fired 10 cartridges through 20 Glock polygonally rifled barrels and 20 Glock conventionally rifled barrels (special order). The NYPD concluded that the ability to identify bullets that were fired through polygonally rifled barrels would be unlikely due to the barrels' inability to reproduce their signatures.

They also found that conventionally rifled barrels produced better microscopic marks for identification than polygonally rifled barrels.

Valdez (1997) examined sets of bullets fired from thirty .40 S&W Heckler and Koch polygonally rifled firearm barrels. He concluded that the difficulty of identifying these bullets was the same as cut rifling. Valdez correctly identified 28 out of 30 sets and reported that the striations appeared to be accidental and unique.

Haag (2003; 2006) introduced bore lapping, a method that utilized a grinding compound to individualize polygonally rifled barrels. He found that placing a couple of drops of a rubbing compound on the nose of a bullet that was fired in the weapon created reproducible, identifiable striations. Northcutt (2010) conducted a research project utilizing a valve-grinding compound to create reproducible, identifiable striations, which supported Haag's findings. In 2009, L. Haag, M. Haag, Garrett, Knell and Patel reported that bore lapping produced identifiable striations.

The Miami Barrel – Enhanced Bullet Identification System (EBIS)

Carr and Fadul (1997) conducted a study to determine whether or not a trained firearm and tool mark examiner could readily identify bullets that were fired from 22 different pistols and five Glock barrels marked with the electronic spark reduction method. Three firearm and tool mark examiners participated in this study. This study found that all of the weapons except Glock and Heckler and Koch marked the bullets in a readily identifiable state. The standard Glock barrels and the five Glock barrels marked with the electronic spark reduction method were listed as not readily identifiable. The inability to readily identify bullets fired in these Glock barrels began the evolution of what would become known as the Miami Barrel.

Fadul and Nunez (2003) found that Glock pulled a single cutter through their polygonally rifled barrel to create the Miami Barrel; this cutter created a subclass characteristic. A study was then conducted on the Miami Barrel to determine whether or not Glock could reproduce identifiable striations that could be readily identifiable. Fadul and Nunez used 22 Miami Barrels manufactured by Glock. Nine firearm and tool mark examiners participated in this study. All nine examiners concluded that the new Miami Barrel was not readily identifiable.

Glock then created a new version of the single cutter used in the Fadul and Nunez (2003) study. Glock called the new cutter the EBIS; however, the barrel itself is still known as the Miami Barrel. Fadul and Nunez (2006) conducted a follow-up study with three new Miami Barrels to determine whether or not these barrels could reproduce identifiable striations that could be readily identifiable. Fadul and Nunez concluded that the new Miami Barrel manufactured with the EBIS was readily identifiable. The key limitation to this study, however, was that only three barrels were examined and a concern was expressed regarding subclass characteristics. The greater concern was that an examiner who is not familiar with these markings will rely on the subclass characteristics alone for a positive identification.

Chin and Sampson (2007) followed up the Fadul and Nunez (2006) study on the Miami Barrel manufactured by Glock to determine whether or not the EBIS reproduced identifiable striations that would allow questioned fired bullets to be identified to known standards. The researchers used four Miami Barrels manufactured by Glock, which incorporated the EBIS. The questioned bullets and known standards were correctly identified. They expressed the same concern as Fadul and Nunez (2006) regarding the subclass characteristics.

Martinez (2008) conducted a study to test the durability of the Miami/EBIS barrel to determine if the EBIS barcode reproduced identifiable striations that would allow questioned fired bullets to be identified to known standards. Martinez used 51 Glock pistols which incorporated the EBIS barrel. A three year window existed between the initial test firing and the final test firing for this research study. Each pistol had at least 250 rounds fired through the barrel, and no more than 10,000 maximum. The Martinez (2008) study reported that 29% of the participants (8 out of 28) with 5 to 10 years of experience reported via survey that there were not enough individual characteristics present to conclude an identification and/or elimination. Additionally, 14% of the participants (4 out of 28) with 5 to 10 years of experience reported identifications and the ability to eliminate. Martinez believed that the identifications were made utilizing the process of elimination.

Fadul (2011) conducted a study utilizing 10 consecutively manufactured Glock Miami/EBIS barrels to further explore the capability of identifying bullets fired through the Glock Miami/EBIS barrels. On a voluntary basis, 150 test sets were created and distributed to laboratories in forty-four states and nine countries. The test set was designed to determine an examiner's ability to correctly identify questioned bullets fired from 10 consecutively manufactured Miami/EBIS barrels to test fired bullets from the same barrels. Fadul reported that 183 participants made 2,734 correct identifications and that 7 participants accounted for 11 errors. Fadul reported an error rate of 0.4 percent.

Fadul also reported that the 10 barrels utilized did not have the same EBIS barcode pattern.

Limited studies have been conducted to identify bullets from consecutively manufactured barrels where the number of participants in the study reached or exceeded one hundred. A larger sample size will provide a more reliable estimate of the true error rate for the identification of same gun evidence by firearm and tool mark examiners.

No study has been conducted to identify bullets from consecutively manufactured Glock EBIS barrels with the same EBIS patterns. The EBIS barrel is a polygonally rifled barrel, which has a barcode-like pattern added to it during the manufacturing process. Previous research included consecutively manufactured EBIS barrels; however, some of the barcode-like patterns were different.

Utilizing barrels with the same EBIS pattern and a larger sample size will provide a more precise error rate calculation for the identification of same gun evidence by firearm and tool mark examiners. Additionally, it will document the reliability, reproducibility, and the individuality of the EBIS barrels.

RESEARCH DESIGN AND METHODS

This study utilized an experimental research design (Christensen, 2004; Creswell, 2005), and was conducted in a crime laboratory setting. Participants compared questioned bullets to known standards that were fired in 10 consecutively manufactured barrels in order to determine whether or not the consecutively manufactured barrels produced different signatures, each with unique striations (tool marks). This research study also established an error rate for the identification of same gun evidence.

Quantitative data was utilized to determine if trained examiners could correctly identify questioned bullets test fired in multiple consecutively manufactured barrels. Additionally, the number of years of experience of the examiners was recorded. This data was used to draw conclusions for the following: 1) whether or not trained firearm and tool mark examiners can identify same gun evidence fired though consecutively manufactured EBIS barrels; and 2) whether years of experience impacts correct identifications. Questionnaire/answer sheets were utilized to collect the quantitative data (see Appendix A).

The proposed outcome in this section is presented with the intention that the findings will be able to answer the research questions.

Research Questions

Q1. Will trained firearm and tool mark examiners be able to correctly identify the firearms that fired the questioned bullets when examining bullets fired through consecutively manufactured barrels with the same EBIS pattern?

Q2. Will firearm and tool mark examiners with less than 10 years of experience reach the same conclusions than those with greater than 10 years of experience when examining bullets fired through consecutively manufactured barrels with the same EBIS pattern?

Research Hypotheses

H1. Trained firearm and tool mark examiners will be able to correctly identify unknown bullets to the firearms that fired them when examining bullets fired through consecutively manufactured barrels with the same EBIS pattern utilizing individual, unique and repeatable striations.

H2. The experience level of firearm and tool mark examiners will not affect identification results when examining bullets fired through consecutively manufactured barrels with the same EBIS pattern.

There is one dependent variable that was examined in this study. The dependent variable is inaccuracy (proportion of incorrect identifications), which was measured by whether or not the questioned bullets could be correctly identified to the consecutively manufactured barrels by using individual, unique and repeatable striations.

There are several independent variables in this study, such as the consecutively manufactured barrels, interval of firing and experience of the examiner. For Q1 and H1, the researchers were interested in studying the effect of the consecutively manufactured barrels on the ability to identify same gun evidence. For Q2 and H2, the researchers were interested in studying the effect of the independent variable of experience, the knowledge and practical wisdom gained through study, observation, experimentation and casework, on the ability to identify same gun evidence. Extraneous variables were controlled as much as possible by utilizing laboratory settings.

For Q1 and Q2, the dependent variable was measured through the average error rate as determined from the *Consecutively Rifled EBIS-2 Test Set* questionnaire/answer sheet using a 1 to 10 point system (1 point for each correct answer, with a maximum point value of 10).

Two hypotheses, H1 and H2, were tested in this study. For H1, the dependent and independent variables measured whether or not consecutively manufactured barrels with the same EBIS pattern produced individual, unique and repeatable striations based on each participant's results. If the tool mark signatures from each of the ten consecutively manufactured barrels could be distinguished from one another by the participants, this would establish that there is no subclass tool mark influence present from the manufacturing process used to form the barrels that affects the ability to identify same gun evidence.

For H2, the dependent and independent variables measured whether or not the years of experience of the participants affected the ability of the examiners to identify same gun evidence based on each participant's results.

Target Population

In this study, the target population represented a subset of the forensic science community, more specifically, firearm and tool mark examiners employed by a national or international law enforcement agency (crime laboratory), or like agency. The Miami-Dade Police Department (MDPD) Crime Laboratory (CL) utilized the membership list for the Association of Firearm and Tool Mark Examiners (AFTE); one of the privileges of membership is access to the membership list. Twelve members of this association currently work in the MDPD CL.

Membership in AFTE is limited to individuals with suitable education, training, and experience in the examination of firearms and/or tool marks. For purposes of this membership, a practicing firearm and/or tool mark examiner is defined by AFTE (2009) as: "(1) An individual who derives a substantial portion of his livelihood from the examination, identification, and evaluation of firearms and related materials and/or tool marks; and (2) An individual whose present livelihood is a direct result of the knowledge and experience gained from the examination, identification, and evaluation of firearms and related materials and/or tool marks."

Every firearms examiner in the United States and internationally who is a member of AFTE had an equal opportunity to be included in this study. Each AFTE member was contacted by the MDPD CL via email inviting them to participate in this study, which included completing demographic questions and participation in an experimental exercise. The test sets utilized in this study were similar to the work that the participants perform on a routine daily basis.

Eligibility-Inclusion Criteria

Participants were required to be firearm and tool mark examiners employed by a national or international law enforcement agency (crime laboratory), or like agency, and must have completed a two year training program. Independent examiners who retired from a qualifying agency were also eligible to participate in this study.

Accessible Population

Accessibility was limited to firearm and tool mark examiners for whom the MDPD CL was able to obtain email addresses by querying the membership list for AFTE. AFTE members with email addresses listed account for 92% of the 2010 AFTE Roster.

Sampling Plan and Setting

The sampling plan for this study utilized an abstract population. Every eligible firearm and tool mark examiner in the United States and internationally who is a member of AFTE, with a functional email address, was invited to participate in this research. The AFTE list identified participants that met the MDPD CL requirements as stated in Eligibility-Inclusion Criteria. The accessible population included approximately 800 firearm and tool mark examiners in the United States and internationally.

To ensure confidentiality, the researchers at the MDPD CL invited firearm and tool mark examiners to participate via email. The survey and test (see Appendix A) were conducted by each participant independently, which strengthened the study's validity (Gall & Borg, 1996).

Instrumentation

This study utilized two methods of instrumentation: a questionnaire that included the participant's demographics, as well as an answer sheet for an experimental exercise. The questionnaire took less than ten minutes to complete. The experimental exercise took approximately two to four hours to complete. These approximate times were based on personal communication and observation of participants from the MDPD CL.

The experimental exercise was originally utilized by Brundage (1998), redesigned by Hamby (2001) and adapted by Fadul (2011). Over 600 firearm and tool mark examiners have used this instrument (Hamby & Brundage, 2007; Fadul, 2011). The researchers at the MDPD CL modified this instrument by adding the number of years of experience for each firearm and tool mark examiner. The categories of ASCLD/LAB accreditation, AFTE certification, Miami/EBIS barrel and gender were added. Furthermore, the researchers at the MDPD CL added a category for pattern matching and quantitative consecutive matching striations (QCMS). Pattern matching and QCMS are two forms of striated tool mark examination/assessment processes used in the field of firearm and tool mark examination. The categories of "Inconclusive" and "Elimination" were added for the experimental exercise. Additionally, a field was added for "Other Results/Comments."

Data Collection Methods

The researchers did the following:

1. Received National Institute of Justice (NIJ) approval.
2. Sent email to the AFTE membership. Participation was voluntary.
3. Traveled to Glock, Inc. factory, observed the manufacturing process of the EBIS barrel, and recorded the data matrix code for each barrel (for tracking).
4. Obtained 10 EBIS barrels from Glock, labeled 1 through 10.
5. Obtained 1 pistol from the MDPD Firearms Reference Collection.
6. Obtained 9mm Federal cartridges (ammunition/bullets).
7. Utilized the MDPD CL water tank for test firing and retrieval of the bullets.
8. Placed each barrel one at a time in the pistol.
9. Loaded the pistol with five cartridges.
10. Fired the pistol into the shoot tank.
11. Fired five bullets through each barrel to create one test set. (This was repeated 150 times per barrel).
12. Used secure, properly labeled containers to keep each group of five bullets separated.
13. Labeled two of the five bullets with the number of the barrel in which they were fired (1 through 8) to create the test fired bullets (known standards). These known standards were placed in a labeled coin envelope.
14. Labeled remaining three bullets with an alpha character designated by the researchers at the MDPD CL to represent the unknown (questioned) bullets. Different alpha characters were assigned to each barrel.

15. Selected one unknown bullet from barrels 1, 2, 3, 5, 6, 7 and 8 randomly from the containers and placed it in a labeled coin envelope. No unknown bullets from barrel 4 were provided to the participants.
16. Selected one additional unknown bullet from barrel 3 and placed it in a labeled coin envelope.
17. Selected two unknown bullets from barrel 9 to complete the test set of 10 unknown bullets. These two bullets were each placed in a labeled coin envelope. No test fired bullets (known standards) from barrel 9 were provided to the participants.
18. No test fired bullets (known standards) or unknown (questioned) bullets from barrel 10 were provided to the participants.
19. Created 150 test sets and placed each test set in a medium manila envelope.
20. The researchers microscopically examined every 10th set to ensure that the bullets were comparable and identifiable.
21. Mailed test sets to respondents. Each respondent received one test packet through the mail which included the following:
    - One questionnaire/answer sheet
    - 10 unknown bullets
    - 8 sets of test fired bullets (known standards) that were fired through 8 consecutively manufactured barrels.
22. Instructed the participants via the questionnaire/answer sheet to compare the questioned bullets to the known standards, and to place their answers on the questionnaire/answer sheet.

- The participants were also asked to complete the questions that were on the questionnaire/answer sheet.
- The instructions directed the participants to return the questionnaire/answer sheet via mail or fax.

23. Conducted the data collection process for 26 weeks.
24. Utilized an Excel spreadsheet to record and analyze the data collected.
25. Submitted the data to a professor from the Department of Statistics at Florida International University for statistical analyses.

Data Coding

Each participant was assigned a number from 1 to end. There were 10 variables (unknown bullets) which were designated with an alpha character and coded as correct (1), incorrect (2), or inconclusive (3A – 3D; four types are detailed in Summary of Results). The overall correct number was coded 1 through 10 based on the correct number of identifications. Pattern matching was coded as 1, QCMS was coded as 2, utilization of both methods was coded as 3 and no answer was coded as 4. The type of microscope was coded 1 for Leica, 2 for Leeds, 3 for other, or 4 for no answer. Type of lighting was coded 1 for fluorescent, 2 for fiber optic, 3 for LED, 4 for other, or 5 for no answer. Years of experience was coded 1 for less than 10 years and coded 2 for greater than 10 years. Laboratory ASCLD/LAB Accreditation was coded 1 for "yes," 2 for "no" and 3 for no answer. Other accreditations were captured on the questionnaire but were not coded. AFTE certification was coded 1 for "yes," 2 for "no" and 3 for no answer. ABC certification was coded 1 for "yes," 2 for "no" and 3 for no answer. Have you ever encountered the Miami or EBIS barrel in your casework was coded 1 for "yes," 2 for "no" and 3 for no answer. Did you participate in the first Miami Barrel/EBIS study was coded 1 for "yes," 2 for "no" and 3 for no answer. The number of years of training was coded 1 for 2 years or more and 2 for < 2 years. The type of training was coded into 4 groups: 1 for in-house/structured, 2 for National Firearms Examiner Academy, 3 for other, and 4 for no answer. Individuals trained in QCMS were coded 1 for "yes," 2 for "no" and 3 for no answer (see Appendix A).

<u>Descriptive Analysis</u>

Descriptive analysis was used to describe the participants. Descriptive analysis included years of experience, method used (pattern matching/QCMS), accreditation, certification, as well as the type of microscope and lighting used.

<u>Data Analysis Methods</u>

Simple descriptive scores were used to analyze all variables. Statistical analysis was performed utilizing a statistical program, S-PLUS, to answer the two research questions. An independent statistician performed the data analyses.

<u>Definitions</u>

For this research study, the following definitions for confidence interval and error rate will apply.

Confidence Interval

A confidence interval is a range of values used to estimate the true value of a population factor. This study utilized a 95% confidence interval. Typically a 95% confidence interval is computed reflecting the probability that in 95% of the samples tested, the interval should contain the true value of the population factor (Butler, 2005).

Error Rate

An error rate is a calculated value that represents the comparison of the number of wrong responses with the total number of responses. The error rate for each participant was defined as the proportion of questions answered incorrectly over their total number of responses. For example, if a participant answered 3 out of the 10 questions incorrectly, their error rate is 0.3.

An average error rate is calculated by dividing the sum of the error rates per respondent by the total number of respondents. For example, if there are four participants and two of the participants answered 1 out of 10 questions incorrectly, one of the participants answered 3 out of 10 incorrectly, and one answered none of the 10 questions incorrectly, then the average error rate would be calculated as follows: $[(2 \times 0.1)+(1 \times 0.3)+(1 \times 0.0)] / 4 = 0.13$. An average error rate calculation was used for this study. An average error rate calculation was used by the researchers because it is illustrative of the error rate across all participants rather than solely based on number of responses.

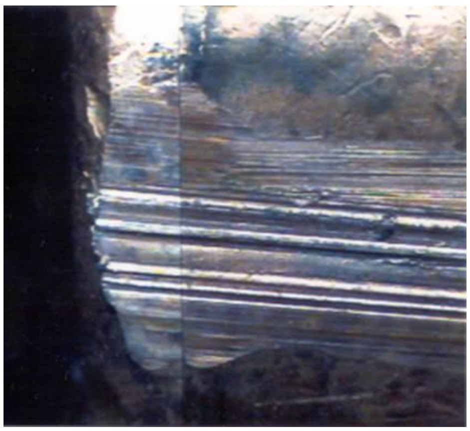
<u>Manufacturing Process of EBIS Barrels</u>

Standard issue Glock barrels are polygonally rifled. EBIS barrels are essentially standard issue, polygonally rifled Glock barrels with an added manufacturing step. All Glock barrels are drilled, reamed, honed and cold hammer forged on a mandrel. The mandrel is a negative of the polygonal rifling profile. The cold hammer forging operation marks the end of the machining process for a standard issue Glock barrel.

To create an EBIS barrel, a standard Glock polygonal barrel is further processed after the cold hammer forging operation. This additional machine imparts a barcode-like pattern on the surface of the lands within the interior of the barrel. The machine does this by inserting a rod outfitted with two carbide steel cutting wheels situated 180˚ from each other (Photograph 1). The rod can make up to fifteen passes for a barrel with six lands and grooves. Each land can have up to five channels cut into its surface. Because there are two cutting wheels situated 180˚ from each other, opposite lands are imparted with the same barcode-like profile. Photograph 2 illustrates the EBIS pattern on two fired bullets.

The barrels are placed on a holder to guarantee the start position and the rod is inserted from the chamber end. The rod tool with the cutting wheels remains stationary while the barrel turns. Channels are cut on the surface of opposite lands from chamber to muzzle as the barrel rotates around the tool following the rate of twist of the rifling. After one pass is made, the barrel rotates to a groove and the tool is extracted. The tool then positions itself for the next pass. According to Glock personnel, the tool does not go down the surface of a land perfectly straight during rotation, and they have no control of this action. Each barrel is inspected with a bore scope to ensure that the barcode pattern was imparted. The EBIS barcode pattern is imparted prior to hardening. Five hundred barrels can be imparted with an EBIS barcode pattern before the carbide steel cutting wheels have to be changed.

Photograph 1: EBIS tool with carbide steel cutting wheel.



Photograph 2: Photomicrograph of the EBIS pattern on two fired bullets.

Internal Validity Strengths

- The quantitative data was internally valid due to the procedures set forth to assemble the tests.
- All the test materials were assembled in a crime laboratory setting.
- All unknown bullets and known standard bullets were labeled with a number (known standard) or letter (unknown bullets).
- Secure containers were used to keep the unknown bullets separated into groups.

- The researchers at the MDPD CL microscopically examined every 10th test set to ensure that the bullets were comparable and identifiable.
- The questionnaire/answer sheet used has been documented in previous studies, and the sheet is a standardized format.

Internal Validity Weaknesses

- The validity of this study was dependent upon the accuracy of the assembly of the tests.
- Communication between participants could have threatened the internal validity.
- The possibility exists that the unknown bullets and known standards failed to mark clearly. Since every set was not microscopically examined to ensure that the bullets were comparable and identifiable, some sets may have contained bullets that were not suitable for identification.

External Validity Strengths

- The external validity strength of this research project was that all testing was conducted in a crime laboratory setting.
- Participants utilized a comparison microscope.
- The participants were trained firearm and tool mark examiners.
- The training and experience of the participants strengthened the external validity.
- The number of participants exceeded the minimum sample size needed to be statistically significant.

External Validity Weaknesses

- The researchers assumed that the participants followed appropriate AFTE procedures, as listed in the AFTE Procedures Manual, FA-IV-13, Microscopic Comparison (2001).

- The researchers had no control over the equipment used by the participants.
- The training and skill level as well as the experience of the participants could have been an external weakness.
- The researchers had to assume that a participant's laboratory policy could allow for eliminations based on individual characteristics instead of an inconclusive result.

RESULTS

In this section, the examination of research questions, hypotheses testing, and other findings related to this study were analyzed to evaluate the repeatability and uniqueness of striations imparted to consecutively manufactured barrels as well as to determine the error rate for the identification of same gun evidence. This experimental exercise was designed to measure accuracy. The participant's ability to perform the experimental exercises was evaluated against reported data and demographic characteristics.

For participant performance relating to accuracy and methods utilized, a mass email was sent out to the membership of the AFTE. A total of 201 examiners representing 125 crime laboratories in 41 states, the District of Columbia, and 4 international countries completed the *Consecutively Rifled EBIS-2 Test Set* questionnaire/answer sheet. Thirty-six of the 201 participants did not meet the two year training requirement for this study. This resulted in a data-producing sample of 165 participants.

The firearm and tool mark examiners that responded to the *Consecutively Rifled EBIS-2 Test Set* questionnaire/answer sheet represented 82% of the states in the United States that conduct firearm and tool mark examinations.

The questionnaire/answer sheet utilized for this study allowed the participants to record their answer by circling the appropriate known test fired bullet sets designated by a numerical number 1 – 8 on the same line as the alpha designator of the unknown bullet. The questionnaire/answer sheet also allowed the participants to record inconclusive and/or elimination. Additionally, the participants were provided a field for other results/comments.

The statistician utilized the statistical analysis program S-PLUS for this study. Nonparametric tests, namely the Wilcoxon Signed Rank and the Wilcoxon Rank Sum tests were used for the analysis. These tests were also followed up by procedures based on large sample approximations to the distribution of the average error rate(s). The Wilcoxon Signed Rank test is a nonparametric alternative to the paired Student's t-test while the Wilcoxon Rank Sum test is used for comparing two independent samples. The tests are used when sample populations cannot be assumed to follow distributional assumptions. Quite often these tests are based on ranks. As an example, when comparing two independent pools of data from two different populations (i.e. individuals having greater than 10 years of experience versus individuals having less than 10 years of experience), one would first combine the two pools of data and rank their tested values (number of incorrect responses, for example) from the lowest to the highest. The lowest observation gets rank 1, the next one rank 2, etc. After ranking the combined pool, one would then separate the data back to their original population and sum up the ranks of each data set. If the results from the two populations are roughly similar, there should be no significant difference in the sum of the ranks (adjusted for sample size). A difference between the sums of the ranks would indicate that the participants from one population performed differently than the other population.

In 2009, the National Academy of Sciences issued a report entitled "Strengthening Forensic Science in the United States: A Path Forward." This report stated that "some forensic science disciplines are supported by little rigorous systematic research to validate the discipline's basic premises and techniques" (p. S-16). In addition, the report stated that forensic sciences will be improved by collaborative opportunities "with the broader science and engineering communities" (p. S-16). The statistical analyses of this research data were performed by Dr. Sneh Gulati, a professor from the Department of Statistics at Florida International University. This collaboration with an external agency to analyze the data that is collected ensures that the statistical results are reported accurately and without bias.

Instrument Parameters

Each participant received a total of eight pairs of known test fired bullets labeled Barrel 1 through Barrel 8 and ten unknown fired bullets labeled with an alpha character. The participants examined and compared the ten unknown fired bullets to the eight pairs of known test fired bullets, and were asked to determine which barrels were used to fire the ten unknown fired bullets.

The researchers utilized an "open set" design where the participants had no expectation that all unknown tool marks should match one or more of the unknowns, as illustrated in Table 1.

Table 1

Open Set Design

Barrel #	Known Standards (Test Fired Bullets)	Unknown Bullets (Questioned)
1	Provided	C
2	Provided	H
3	Provided	A, F
4	Provided	None
5	Provided	D
6	Provided	I
7	Provided	E
8	Provided	B
9	Not Provided	G, J
10	Not Provided	None

Main Analyses

The first research question asked whether trained firearm and tool mark examiners would be able to identify the firearms that fired the unknown bullets when examining bullets fired through consecutively manufactured barrels. Answering the first research question is equivalent to testing whether the average error rate is zero against the alternate that the average error rate is greater than zero. The overall average error rate was [(156 x 0.0) + (6 x 0.1) + (3 x 0.2)] / 165 = 0.007 and the standard deviation was 0.032. All analyses in the study were conducted through nonparametric methods. The Wilcoxon Signed Rank Test was used to answer the first question. With a significance level of 0.05, the p-value was 0.0027, which indicates that the average error rate is significantly different from zero. A 95% confidence interval for the average error rate, based on the large sample distribution of the sample average error rate, is between 0.002 and 0.012. Using a confidence interval of 95%, the error rate is no more than 0.012, or

1.2%. Inconclusive results were not counted in the calculation of the overall average error rate.

The second research question asked whether trained firearm and tool mark examiners with less than 10 years of experience would reach the same conclusions as those with greater than 10 years of experience when examining bullets fired through consecutively manufactured barrels. Nonparametric tests on the error rate between the two populations of experience (< 10 years = 1; > 10 years = 2) were conducted. Again, inconclusive results were not counted. The Wilcoxon Rank Sum test (nonparametric test) was utilized due to the possible lack of normality. The p-value was 0.9735 with a significance level of 0.05. The high p-value indicates that the examiners with less than 10 years of experience will not reach different conclusions than the examiners with greater than 10 years of experience. As found in Table 2, there was no significant difference in the error rate between the two populations.

Table 2

Comparison Of Error Rates Based On Years Of Experience

	YRS EXP = 1	YRS EXP = 2
$\overline{X}$	0.008	0.007
s	0.036	0.029

Additional Analyses

Certification and accreditation were evaluated to determine if they affected the error rate. Thirty-five of the 165 participants reported that they were AFTE Certified. Three of these 35 AFTE certified participants reported a total of four errors, resulting in an error rate of 0.011 for AFTE Certified participants. One hundred forty-five participants reported that their laboratory was accredited (134 ASCLD/LAB with 133 from the United States), 4 - FQS (all from the United States), 7 - AFFSAB and NATA. Seven of these 145 participants reported nine errors, resulting in error rates of 0.006 (overall) and 0.007 (United States) for participants working in an accredited laboratory. See Table 3 for certification/accreditation acronym description.

The method (QCMS and pattern matching) utilized by the participants was also evaluated. Thirty-six of the 165 participants reported that they used both QCMS and pattern matching. Two of the 36 participants reported three errors, resulting in an error rate of 0.008 for participants utilizing both QCMS and pattern matching. One hundred fifteen of the 165 participants reported that they used only pattern matching. Seven of the 115 participants reported a total of nine errors, resulting in an error rate of 0.008 for participants utilizing only pattern matching. No participant reported using QCMS by itself. Fourteen of the 165 participants did not list the method utilized.

Table 3

Certification/Accreditation Acronyms

ABC	American Board of Criminalistics
AFFSAB	Australasian Forensic Field Sciences Accreditation Board
AFTE	Association of Firearm and Tool Mark Examiners
ASCLD/LAB	American Society of Crime Laboratory Directors / Laboratory Accreditation Board
FQS	Forensic Quality Services
NATA	National Association of Testing Authorities (Australia)

Inconclusive Results

Inconclusive responses were not used to calculate the overall average error rates for this research because they were not considered errors. According to Peterson and Markham (1995), inconclusive responses are neither incorrect nor correct and may indeed be the most appropriate response in a situation in which the sample, lab policy, and/or examiner capabilities do not permit a more definitive conclusion.

Summary of Results

The first research question asked if trained firearm and tool mark examiners would be able to correctly identify the firearms that fired the unknown bullets when examining bullets fired through consecutively manufactured barrels with the same EBIS pattern. The dependent variable (inaccuracy) and the independent variable (consecutively manufactured barrels) were measured by whether or not the unknown bullets could be correctly identified to the consecutively manufactured barrels by using individual, unique and repeatable striations (proportion of incorrect identifications). The analysis of the data revealed that the error rate was significantly greater than zero, albeit less than 1.2% based on a 95% confidence level.

The second research question asked if trained firearm and tool mark examiners with less than 10 years of experience would reach the same conclusions as those with greater than 10 years of experience when examining bullets fired through consecutively manufactured barrels with the same EBIS pattern. The dependent variable (inaccuracy) was compared against the independent variable of years of experience. The analysis of the data revealed that there were no significant differences between the two groups and their ability to identify same gun evidence.

Demographic variables analyzed included certification, accreditation and method used for examination. These demographics were evaluated to determine if they affected the error rate. With a significance level of 0.05, certification, accreditation and method did not significantly affect the error rate. Note: These results should be interpreted with caution due to the large number of zero error rates. Zero error rates can lead to a large number of ties in the non-parametric test which can lead to misleading results for small samples. Since the current study has a large sample size, however, the results should not be affected.

The first hypothesis states that trained firearm and tool mark examiners will be able to correctly identify unknown bullets to the firearms that fired them when examining bullets fired through consecutively manufactured barrels with the same EBIS pattern by utilizing individual, unique and repeatable striations. The findings of this research study support the hypothesis that trained firearm and tool mark examiners can correctly identify same gun evidence with an average error rate of 0.007 (0.7%). With a significance level of 0.05, the p-value was 0.0027, which indicates that the average error rate is significantly different from zero. A 95% confidence interval for the average error rate, based on the large sample distribution of the sample average error rate, is between 0.002 and 0.012. Using a confidence interval of 95%, the error rate is no more than 0.012, or 1.2%.

The second hypothesis states that the experience level of firearm and tool mark examiners will not affect identification of same gun evidence when examining bullets fired through consecutively manufactured barrels with the same EBIS pattern. The findings of this research study support this hypothesis. Based on this study, the experience level of the firearm and tool mark examiner did not affect the firearm and tool mark examiner’s examination/comparison conclusions when examining bullets fired through consecutively manufactured barrels. With a significance level of 0.05, the analysis of the data revealed that there were no significant differences between the two groups of examiners.

The findings of this research study support the theory in firearm and tool mark identification that, assuming no subclass influences, each firearm/tool produces a signature of identification (striation/impression) that is unique to that firearm/tool. Through examination of the individual striations/impressions, the signature can be positively identified to the firearm/tool that produced it. Such tool mark identifications are made to a practical certainty. These identifications are not absolute because it will never be possible to examine every firearm or tool in the world, a prerequisite to making absolute determinations. The conclusion that “sufficient agreement” exists between two tool marks (test and questioned) for identification means that the likelihood that another tool (firearm) could have made the questioned tool mark is so remote as to be considered a practical impossibility.

Practical impossibility currently cannot be expressed in mathematical terms. As a result of extensive empirical research and validation studies such as this one that have been conducted in the field of firearm and tool mark identification, as well as the cumulative results of training and casework examinations that have been either performed or peer reviewed by a trained firearm and tool mark examiner, an opinion can be justifiably formed that it is a practical impossibility that another firearm will be found that exhibits as much individual microscopic agreement with test tool marks as the questioned tool marks that have been identified.

There were a total of 1,650 unknown fired bullets examined by the participants. There were 1,496 correct answers, 12 incorrect answers and 142 inconclusive answers. The 12 incorrect answers were made by 9 participants. Two of the participants identified unknown bullets G and J (no known standard provided) to barrel 4 (no unknown bullets provided), which accounted for 4 of the 12 errors. Additionally, three participants from the same laboratory made the same error in misidentifying questioned bullet B. Due to these results, the researchers recalled this test set for examination. There were no packaging errors and bullet B was identifiable.

Sixty-nine participants had inconclusive results for unknown bullets G and J which accounted for 138 of the 142 inconclusive results. Standards from the barrel that fired unknown bullets G and J were not provided to the participants. The following illustrates the definition of an inconclusive answer for this research study. Inconclusive was coded as (3). A further breakdown of inconclusive responses is detailed here:

- **Inconclusive** response (3A): This designation means that the correct barrel number was not circled, and the Inconclusive answer was circled instead. This inconclusive response could have been selected for any of the unknowns. When specifically relating to Unknowns G and J, the Inconclusive answer was circled, and the test taker did NOT identify Unknowns G and J as having come from one firearm (22 participants, 42 of 46 inconclusive responses were for G and J).
- **Inconclusive** response (3B): <u>Relating only to Unknowns G and J</u>. The Inconclusive answer was circled, and the test taker DID identify Unknowns G and J as having come from one firearm (39 participants, 78 inconclusive responses).

- **Inconclusive** response (3C): Relating only to Unknowns G and J. No answer was circled, but the test taker DID identify Unknowns G and J as having come from one firearm (2 participants, 4 inconclusive responses).
- **Inconclusive** response (3D): Relating only to Unknowns G and J. The Elimination answer was circled, but the test taker DID NOT identify Unknowns G and J as having come from one firearm (7 participants, 14 inconclusive responses).

Table 4 illustrates the number of incorrect and inconclusive results.

Table 4

Incorrect and Inconclusive Results: Unknown (Questioned) Bullets

	Unknown Bullets (Questioned)	**Incorrect Responses**	**Inconclusive Responses**
n = 165			
	A	0	2
	B	4	0
	C	0	0
	D	0	0
	E	2	1
	F	1	1
	G	2	69
	H	1	0
	I	0	0
	J	2	69
Total	**10**	**12**	**142**

The error rate for this research study was computed on an individual level for each participant and then averaged across all participants.

CONCLUSIONS

This research study provides relevant information to the forensic science community and to the forensic science discipline of firearm and tool mark identification. This research study utilized multiple participants (n = 165) to examine fired bullets from consecutively manufactured barrels in order to determine an error rate for identification of same gun evidence. The results of this study support the hypothesis that trained firearm and tool mark examiners can identify fired bullets to the correct consecutively manufactured barrel utilizing individual (no subclass influence), unique and repeatable striations.

Consecutively manufactured barrels represent the best possibility for the production of two firearms that could produce non-distinguishable markings since the same tools and machining processes are utilized back-to-back on one barrel after another. This process thus represents a situation where the most similarity should be seen between barrels. If there were ever any chance for duplication of individual marks, it would occur during the manufacture of consecutively manufactured barrels. The results of this research study, as well as past studies, indicate that sufficient empirical evidence exists to support the scientific foundation of firearm and tool mark identification. Once the specter of subclass influence is eliminated, each firearm/tool produces a signature of identification (striation/impression) that is unique to that firearm/tool. Through the examination of the individual striations/impressions, the tool mark signature can be positively identified to the firearm/tool that produced it (Freeman, 1978; Hall, 1983; Brundage, 1998; Miller, 2000; Hamby; 2001; Hamby & Brundage, 2007; Hamby, Brundage & Thorpe, 2009; and Fadul, 2011).

Data also revealed no significant differences in the error rate between identifications made by firearm and tool mark examiners with < 10 years of experience (0.008, $n = 75$) as compared to identifications made by examiners with > 10 years of experience (0.007, $n = 90$) when examining bullets fired through consecutively manufactured barrels. These results indicate that a trained firearm and tool mark examiner with two years of training, regardless of experience, will correctly identify same gun evidence.

The most significant finding in this study was the low error rate for the examination of unknown bullets and identification to the firearms that fired them when examining bullets fired through consecutively manufactured barrels utilizing individual, unique and repeatable striations. The error rate of the participants was 0.007.

Finally, this research study addressed concerns that were raised by the 2009 National Academy of Sciences Report entitled "Strengthening Forensic Science in the United States: A Path Forward." The National Academy of Sciences Report questioned the repeatability and uniqueness of striations left on fired evidence used to identify same gun evidence as well as questioned the error rate of firearms identification. Based on this research study, firearm and tool mark examiners demonstrated a very low error rate when comparing bullets fired in consecutively manufactured barrels.

Limitations

The researchers noted the following limitations to this study:

- The researchers assumed that the participants followed appropriate AFTE procedures, as listed in the AFTE Procedures Manual, FA-IV-13, Microscopic Comparison (2001).
- Each participant was administered the experimental exercise at their own crime laboratory via mail, and the researchers had no observable control.
- The researchers had to assume that each participant independently completed the experimental exercise with no outside assistance.

- The researchers had no control of the equipment that participants utilized for the experimental exercise.
- The researchers had to assume that the equipment utilized was appropriate, properly maintained and properly functioning.
- The researchers had no control over the training, skill level or experience of the participants.
- The instrument for the experimental exercise was individually administered utilizing the United States Postal Service according to the email response of the participants.
- While the researchers personally mailed the experimental exercise to one participant per crime laboratory, that participant in turn maintained control of the exercise.
- The researchers had no control of the development and maintenance of standards utilized by the participants' laboratories.
- The researchers had no control over participants' laboratory policies regarding inconclusive results, such as whether or not eliminations were allowable based on individual characteristics.
- The study did not follow actual case practice of technical review.

Recommendations for Future Research

Future research is needed in the forensic science community in the area of multiple consecutively manufactured barrels. Research has been conducted on multiple consecutively manufactured barrels (Freeman, 1978; Hall, 1983; Brundage , 1998; Miller, 2000; Hamby; 2001; Hamby and Brundage, 2007; Hamby, Brundage and Thorpe, 2009;

and Fadul, 2011); however, the present research study was the first investigation to utilize multiple participants to examine fired bullets from consecutively manufactured Glock EBIS barrels with the same EBIS pattern in order to determine an error rate. Participants from 125 crime laboratories in 41 states, the District of Columbia, and four international crime laboratories participated in this study; however, additional participants from the remaining crime laboratories and states should be sought out. Future research should include a re-test of the original participants to examine repeatability of the results.

Future research should continue to analyze the repeatability and uniqueness of striations/impressions, as well as examine the reproducibility of the EBIS pattern of other calibers of Glock firearms. Further studies should also continue to incorporate "open set" designs where the participant has no expectation that all unknown tool marks should match one or more of the knowns.

Additional empirical research will continue to support the scientific foundation of forensic firearm and tool mark identification through the evaluation of the uniqueness of striations/impressions and the determination of error rates for the identification of same gun evidence from the additional data. Fundamental research will continue to improve the understanding of the accuracy, reliability and validity of the forensic science discipline of firearm and tool mark identification.

ACKNOWLEDGMENTS

Thank you to the Miami-Dade Police Department Crime Laboratory Firearm and Tool Mark Examiners:

- Chris Barr
- Jorge Bello
- Yamil Garcia
- Angela Garvin
- George Hertel
- Julie Knapp
- John Mancini
- Magen Roberts
- Jill Therriault
- Tim Wilmot

DISSEMINATION OF RESEARCH FINDINGS

South Florida Firearm and Tool Mark Examiners 4th Annual Discipline Meeting, Presentation, February 7, 2013, Fort Pierce, FL.

International Forensic Research Institute (IFRI), 2nd Annual Forensic Science Symposium at Florida International University, Presentation, March 14, 2013, Miami, FL.

ASCLD 40th Annual Symposium, Presentation, May 7, 2013, Durham, NC.

AFTE 2013 44th Annual Training Seminar, Presentation, June 27, 2013, Albuquerque, NM.

REFERENCES

Association of Firearm and Tool Mark Examiners Procedures Manual. Version: July 9, 2001. Association of Firearm and Tool Mark Examiners Member’s Page. <http://www.afte.org/MembersArea/promanual.shtml>.

Association of Firearm and Tool Mark Examiners Page. Association of Firearm and Tool Mark Examiners. 16 June 2009 <http://www.afte.org/Membership/membership.htm>.

Brundage, D. (1998). The identification of consecutively rifled gun barrels. *AFTE Journal*, *30*(3), 438 – 444.

Butler, J. (2005). Forensic DNA typing, (2nd ed.). Burlington, MA: Elsevier Academic Press.

Carr, J., & Fadul, T. (1997). The Miami barrel. *AFTE Journal*, *29*(2), 232 – 233.

Chin, J., & Sampson, B. (2007, May). *Glock, Inc., Enhanced Bullet Identification System (EBIS) Barrels*. Paper presented at the meeting of the Association of Firearm and Tool Mark Examiners Annual training seminar, San Francisco, CA.

Christensen, L. (2004). Experimental methodology, (9th ed.). Boston, MA: Pearson.

City of New York Police Department. (1996). *Ballistics comparison of polygonal and conventionally rifled Glock, Inc., barrels.* (Communication No. 65/96). New York: Dominic Buccigrossi.

Collins, J. (2009). Stochastics – The real science behind forensic pattern identification. *Crime Lab Report*, retrieved from www.crimelabreport.com.

Creswell, J. (2005). Educational research: Planning, conducting, and evaluating quantitative and qualitative research (2nd ed.). Upper Saddle River, NJ: Pearson.

Fadul, T. (2011). An empirical study to evaluate the repeatability and uniqueness of striations/impressions imparted on consecutively manufactured Glock EBIS gun barrels. *AFTE Journal 43*(1), 37 – 44.

Fadul, T., & Nunez, A. (2003). The Miami barrel saga continues. *AFTE Journal, 35*(3), 290 – 297.

Fadul, T., & Nunez, A. (2006). Glock, Inc.'s new EBIS barrel: The finale to the Miami barrel. *AFTE Journal*, *38*(2), 96 – 100.

Faigman, D. (2010, August). The Scientific Foundations of Forensic Science. Paper presented at the NIJ Impression and Pattern Evidence Symposium, Clearwater Beach, FL.

Freeman, R. (1978). Consecutively rifled polygon barrels. *AFTE Journal, 10*(2), 40 – 42.

Gall, M., & Borg, W. (1996). Educational research (6th ed.). White Plains, NY: Longman.

Haag, L. (1977), Heckler & Koch polygonal rifling. *AFTE Journal, 9*(2), 45 – 47.

Haag, L., (2003, May). Identifiable Bullets from Glocks in 60 Seconds. Paper Presented at the meeting of the Association of Firearm and Tool Mark Examiners Annual training seminar, Philadelphia, PA.

Haag, L. (2006). RE: Glock's new EBIS barrel by Fadul and Nunez [Letter to the editor]. *AFTE Journal, 38*(3), 189.

Haag, L., Haag, M., Garrett, L., Knell, J., & Patel, M. (2009). Bore lapping compounds and their effect on traditional firearms identification. *AFTE Journal, 41*(3), 232 – 245.

Hall, E. (1983). Bullet markings from consecutively rifled Shilen DGA barrels. *AFTE Journal, 15*(1), 33 – 53.

Hamby, J. (2001). *Forensic firearms examination.* Unpublished doctoral thesis, University of Strathclyde, Glasgow, Scotland, U.K.

Hamby, J., & Brundage, D. (2007, May). *The Identification of Consecutively Rifled 9mm Pistol Barrels*. Paper presented at the meeting of the Association of Firearm and Tool Mark Examiners Annual Training Seminar, San Francisco, CA.

Hamby, J., Brundage, D. & Thorpe, J (2009). The identification of bullets fired from 10 consecutively rifled 9mm Ruger pistol barrels: A research project involving 507 participants from 20 countries. *AFTE Journal (41)*2, 99 – 110.

Hocherman, G., Giverts, P., & Shosani, E. (2003). Identification of polygonal barrel sub-family characteristics. *AFTE Journal, 35*(2), 197 – 200.

Martinez, C. (2008, May). *Glock's Signature Barrel – Durability of the EBIS Markings.* Paper presented at the meeting of the Association of Firearm and Tool Mark Examiners Annual Training Seminar, Honolulu, HI.

Miller, J. (2000). An examination of two consecutively rifled barrels. *AFTE Journal, 32*(3), 259 – 270.

Mnookin, J. (2010, August). Show me the Data. Paper presented at the NIJ Impression and Pattern Evidence Symposium, Clearwater Beach, FL.

Moran, B., & Murdock, J. (2002). Joseph Ramirez vs. State of Florida – Supreme Court Decision December 20, 2001. *AFTE Journal (34)* 2, 215 – 226.

National Academy of Sciences. <u>Strengthening Forensic Science in the United States: A Path Forward.</u> Washington, D.C.: The National Academies Press, 2009.

Nichols, R. (2007). Defending the scientific foundations of the firearms and tool mark identification discipline: Responding to recent challenges [Abstract]. *Journal of Forensic Sciences, 52*(3), 586 – 594.

Northcutt, A. (2010), "Glock barrel modification: a feasible method to facilitate the identification of fired bullets. *AFTE Journal*, *42*(2), 108 – 119.

Peterson, J., & Markham, P. (1995). Crime Laboratory Proficiency Testing Results, 1978-1991, II: Resolving Questions of Common Origin. *Journal of Forensic Sciences, 40*(6), 1009-1029.

Saks, M. (1993). The Unknown Validity of forensic Science (draft). College of law, University of Iowa. 1 – 21.

Saks, M. (1994). Implications of the Daubert Test for Forensic Identification Science. *Shepard's Expert & Scientific Evidence,* (1)3, 427 – 434.

Saks, M., & Koehler, J. (1991). What DNA Fingerprinting Can Teach the Law About the Rest of Forensic Science. *Cardozo Law Review, (13)*2-3, 361 – 372.

Saks, M., & Koehler, J. (2008). The Individualization Fallacy in Forensic Science Evidence. *Vanderbilt Law Review, (61)*1, 199 – 219.

Valdez, S. (1997), Bullet identification from H & K USP polygonal barrels. *AFTE Journal,* 29(3), 307 – 309.

Appendix A:

Survey Instrument (Questionnaire/Answer Sheet)

Miami-Dade Police Department
Crime Laboratory

9105 NW 25th Street, Miami, Florida 33172
(305) 471-2050

Firearm & Toolmark Unit

Answer Sheet: Consecutively Rifled **EBIS-2** Test Set Test Number: __________

Name: **ANONYMOUS** Male or Female? (Please circle one) Date:_________________

Years Experience:_____________Years Training:___________Type of Training:________________________

Brand & Model of Microscope:_________________________Type of Lighting:__________________________

QCMS Trained? Yes No Did you use Pattern Matching, QCMS or Both for this test?_________________

Is your Laboratory ASCLD/Lab Accredited? Yes No Other Accreditatation? ____________________

AFTE Certified? Yes No ABC Certified? Yes No Other Certification? __________________

Have you ever encountered the Miami or EBIS Barrel in your case work? Yes No If yes, How many times?_____

Did you participate in the First Miami Barrel / EBIS Study? Yes No

Please microscopically compare the known test shots from each of the 8 barrels with the 10 questioned bullets submitted. Indicate your conclusion(s) by circling the appropriate known test fired set number designator on the same line as the alpha unknown bullet. You also have the option of Inconclusive and Elimination. This test does not have to be done all at one time, but sufficient time to adequately examine this material is necessary. Although the bullets have been scribed on the nose, you may elect to confirm the 'identifier' on the nose and re-scribe it on the base of the bullet.

Unknowns **Knowns** (Barrels 1 through 8)

A. 1…...2…….3..….4…….5…….6..…..7…....8…....Inconclusive……Elimination

B. 1…...2…….3..….4…….5…….6..…..7…....8…....Inconclusive……Elimination

C. 1…...2…….3..….4…….5…….6..…..7…....8…....Inconclusive……Elimination

D. 1…...2…….3..….4…….5…….6..…..7…....8…....Inconclusive……Elimination

E. 1…...2…….3..….4…….5…….6..…..7…....8…....Inconclusive……Elimination

F. 1…...2…….3..….4…….5…….6..…..7…....8…....Inconclusive……Elimination

G. 1…...2…….3..….4…….5…….6..…..7…....8…....Inconclusive……Elimination

H. 1…...2…….3..….4…….5…….6..…..7…....8…....Inconclusive……Elimination

I. 1…...2…….3..….4…….5…….6..…..7…....8…....Inconclusive……Elimination

J. 1…...2…….3..….4…….5…….6..…..7…....8…....Inconclusive……Elimination

Other Results/Comments: ____

Adapted from the Indianapolis-Marion County Forensic Services Agency with the permission of Dr. James E. Hamby