11-2004

The Miami Barrel: An Innovation in Forensic Firearms Identification

Thomas G. Fadul Jr.
Lynn University

Follow this and additional works at: https://spiral.lynn.edu/etds

Part of the Social and Behavioral Sciences Commons

Recommended Citation
https://spiral.lynn.edu/etds/245

This Dissertation is brought to you for free and open access by the Student Work at SPIRAL. It has been accepted for inclusion in Student Theses, Dissertations, Portfolios and Projects by an authorized administrator of SPIRAL. For more information, please contact liadarola@lynn.edu.
THE MIAMI BARREL:
AN INNOVATION IN FORENSIC FIREARMS IDENTIFICATION

DISSERTATION
Presented in Partial Fulfillment of the Requirements for the Degree of
Doctor of Philosophy
Lynn University

By
Thomas G. Fadul Jr.

Lynn University
2009
THE MIAMI BARREL

AN INNOVATION IN FORENSIC FIREARMS IDENTIFICATION

Thomas G. Fadul Jr.

Lynn University, 2009

Copyright 2009, by Fadul, Thomas G. Jr. All Rights Reserved

U.M.I
300 N. Zeeb Road
Ann Arbor, MI 48106
ACKNOWLEDGEMENTS

I would first like to thank my wife Katherine and our children Rose Marie, Thomas, Ashley, Irene and Ryan for their support during this entire process. Thank you for understanding and allowing me to have the time required to endure this task. Thank you for the needed quiet time and for allowing me to commandeer our home computer. Your patience through this process was greatly appreciated.

I would like to thank and acknowledge my dissertation committee chairperson, Dr. Adam Kosnitzky for his patience and guidance. Thank you for your tenacious pursuit in driving me to complete the mission. Your support through this process was greatly appreciated. The trips to Panera Bread seemed to have become routine in my life. I also would like to thank and acknowledge my dissertation committee members, Dr. Patrick Halperin, and Dr. Ernest Vendrell. Your efforts were extraordinary, your contributions to this project were significant and greatly appreciated.

Finally, I would like to thank the Miami-Dade Police Department for allowing me an opportunity to complete this research study. Thank you to the Crime Laboratory, specifically the firearm and tool mark examiners, for your support and assistance in this project. Adrian Nunez, Julie Knapp, Timothy Wilmot and Erin Wilson deserve a special thank you. Thank you to Ray Freeman, Retired Firearm and Tool Mark Examiner, for taking the time to train me in the forensic science discipline of firearm and tool mark examinations. Additionally, I would like to thank Retired Senior Police Bureau Commander James Carr and current Senior Police Bureau Commander Stephanie Stoiloff for their encouragement and support.
Abstract

The scientific foundation in 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 examining the individual striations/impressions; the signature can be positively identified to the firearm/tool that produced it. There is no set number of matching striations that are needed for concluding an identification. The inability to identify fired bullets to individual Glock pistols resulted in an in-depth study of Glock’s polygonal rifled barrels, which resulted in the manufacturing of the Miami/EBIS Gun Barrel. This research study provided the scholarly research that was needed to determine if questioned bullets from multiple consecutively manufactured Glock Miami/EBIS Gun Barrels could be distinguished from one and other, as well as the criteria for identification. This particular study explored the measurable differences between the relationship of traditional pattern matching, consecutive matching striations and/or a combination of both techniques through an experimental exercise involving bullets that were fired through consecutively manufactured Glock Miami/EBIS Gun Barrels. In addition, the years of experience of the participants in relationship to the results of the experimental exercise was explored. The results of this study provide firearm and tool mark examiners documentation supporting and validating the theory and hypothesis of the forensic science discipline of firearm and tool mark identification.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACKNOWLEDGEMENTS</td>
<td></td>
<td>ii</td>
</tr>
<tr>
<td>ABSTRACT</td>
<td></td>
<td>iii</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td></td>
<td>vii</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td></td>
<td>viii</td>
</tr>
<tr>
<td>CHAPTER I</td>
<td>INTRODUCTION TO THE STUDY</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Introduction</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Definition of the Problem</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>The Inability to Identify Bullets that are fired in Polygonal Rifled Barrels</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>The Inability to Examine Every Firearm</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>The Lack of Established Criteria for Identification</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Theory of Firearm and Tool Mark Identification</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Definition of Terms</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>Independent Variables</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>Theoretical</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>Operational</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>Mediating Variables</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>Theoretical</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>Operational</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>Dependent Variables</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>Theoretical</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>Operational</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>Purpose of the Study</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>Significance of the Study</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>Assumptions</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>Delimitations</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>Organization of the Study</td>
<td>18</td>
</tr>
<tr>
<td>CHAPTER II</td>
<td>REVIEW OF THE LITERATURE AND THEORETICAL FRAMEWORK</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Review of the Literature</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>An Historical Perspective</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>Theoretical Framework</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>Theory of Identification</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>Pattern Matching</td>
<td>27</td>
</tr>
<tr>
<td></td>
<td>Consecutive Matching Lines (CMS) Theory</td>
<td>29</td>
</tr>
<tr>
<td></td>
<td>Empirical Literature</td>
<td>39</td>
</tr>
<tr>
<td></td>
<td>Instrumentation Studies</td>
<td>39</td>
</tr>
<tr>
<td></td>
<td>Related Studies</td>
<td>44</td>
</tr>
<tr>
<td></td>
<td>Polygonal Rifled Barrels</td>
<td>47</td>
</tr>
<tr>
<td></td>
<td>The Miami Barrel</td>
<td>52</td>
</tr>
<tr>
<td>TABLE</td>
<td>Description</td>
<td>Page</td>
</tr>
<tr>
<td>-------</td>
<td>-----------------------------------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>1</td>
<td>Cronbach Alpha Reliability Coefficients for the Exercise</td>
<td>99</td>
</tr>
<tr>
<td>2</td>
<td>Profile of Firearm and Tool Mark Examiners (Participants)</td>
<td>100</td>
</tr>
<tr>
<td>3</td>
<td>Examination/Comparison of Questioned Unknown Fired Bullets</td>
<td>103</td>
</tr>
<tr>
<td>4</td>
<td>Total Score - Questioned Unknown Fired Bullets</td>
<td>104</td>
</tr>
<tr>
<td>5</td>
<td>Factorial ANOVA of Thirteen Variables: Total Experimental Exercise Scores</td>
<td>105</td>
</tr>
<tr>
<td>6</td>
<td>Method of Participants Versus Examination/Comparison Results</td>
<td>107</td>
</tr>
<tr>
<td>7</td>
<td>Homogeneity of Variances for Method of Participants Versus Examination/Comparison Results</td>
<td>107</td>
</tr>
<tr>
<td>8</td>
<td>ANOVA - Method of Participants Versus Examination/Comparison Results</td>
<td>108</td>
</tr>
<tr>
<td>9</td>
<td>CMS Trained/Non-Trained Versus Examination/Comparison Results</td>
<td>108</td>
</tr>
<tr>
<td>10</td>
<td>Homogeneity of Variances for CMS Trained/Non-Trained Versus Examination/Comparison Results</td>
<td>109</td>
</tr>
<tr>
<td>11</td>
<td>ANOVA - CMS Trained/Non-Trained Versus Examination/Comparison Results</td>
<td>109</td>
</tr>
<tr>
<td>12</td>
<td>Experience Correlated with Skill</td>
<td>110</td>
</tr>
<tr>
<td>13</td>
<td>Homogeneity of Variances for Experience Correlated with Skill</td>
<td>110</td>
</tr>
<tr>
<td>14</td>
<td>ANOVA - Experience Correlated with Skill</td>
<td>111</td>
</tr>
<tr>
<td>15</td>
<td>Gender Correlated with Skill</td>
<td>111</td>
</tr>
<tr>
<td>16</td>
<td>Homogeneity of Variances for Gender Correlated with Skill</td>
<td>112</td>
</tr>
<tr>
<td>17</td>
<td>ANOVA - Gender Correlated with Skill</td>
<td>112</td>
</tr>
</tbody>
</table>
# LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>FIGURE 1</td>
<td>Participant Years of Experience</td>
<td>101</td>
</tr>
<tr>
<td>FIGURE 2</td>
<td>Miami Barrel Error Rate</td>
<td>103</td>
</tr>
</tbody>
</table>
CHAPTER I:
INTRODUCTION TO THE STUDY

Introduction

The use of firearm violence is a global issue which affects every city, state, and nation. The threat that a criminal may go free or undetected threatens our environment. Between 1976 and 2005, there were approximately 565,000 reported homicide victims (Fox & Zawitz, n.d., Table 1). The homicide rate grew 10% during the 30 year time span (Fox & Zawitz, n.d.). The Federal Bureau of Investigation’s (FBI) Uniform Crime Reporting Program estimated that there were approximately 595,000 homicides between 1976 and 2005 (U. S. Department of Justice, 2006).

According to the U.S. Department of Justice Crime Statistics, “74% of males and 48% of females stated the individual(s) who robbed them was a stranger” (2008, ¶ 3). Firearms were used in “48%” of those robberies, compared to 85% for homicides (2008, ¶ 11). Additionally, firearms were used in “7%” of rape cases and “22%” in aggravated assault cases (2008, ¶ 11).

In Florida, homicides increased “7%” in 2007, as compared to 2006. In that same time frame, robberies increased “12%” (FDLE, 2008a, p. 1). The use of firearms in homicides increased “12%”, and the use of firearms in robberies significantly increased “25%” (FDLE, 2008a, p. 1). The use of firearms increased “21%” in forcible rape cases, “46%” in forcible sodomy cases and “29%” in forcible fondling cases (FDLE, 2008a, p. 1).

In Broward County, Florida, homicides increased “21%” from 2006, as compared to 2007 (FDLE, 2008b, p. 1). Robberies increased “10%” (FDLE, 2008b, p. 1). The use
of firearms in Broward County homicides increased "14%", and the use of firearms in robberies significantly increased 21% (FDLE, 2008b, p. 1). This increased use of firearms in criminal activity has resulted with increased ballistic evidence.

Ballistic evidence is submitted to crime laboratories for examination. Firearm and tool mark examiners have the responsibility to examine the firearms and related ballistic evidence. Their conclusions help convict the guilty and exonerate the innocent. The hypothesis in 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 examining the individual striations/impressions; the signature can be positively identified to the firearm/tool that produced it.

Firearm and tool mark examiners base their identifications on individual matching striations, their length, width, spatial relationship, surface contour and the number of these lines that are present. These striations are a result of minute imperfections on a cutting tool that cuts the lands and grooves into a barrel of a firearm (FBI, 1941; Hatcher, 1935; Mathews, 1973). The lands and grooves are what cause the bullet to spin when it takes flight. When a bullet travels through a gun barrel, the bullet is scored by the minute imperfections that resulted in the manufacturing process, and appear on the bullet as striations (fine microscopic lines). For example, run a rake through sand and you will create lines such as those that would be on a bullet.

There are approximately eight million firearms manufactured in the world today (Maclnnis, 2007, ¶ 2). How can it be determined to a scientific certainty that any one firearm/tool fired a questioned bullet, or made the questioned impression to the exclusion of all other firearms/tools? Many crimes go unsolved, unlike the television version of
CSI-Miami (CSI), where every case is solved in a one hour time frame. Because of CSI, public scrutiny has increased for all crime laboratory examinations. The work is glamorized in the CSI show, when in essence, it is tedious and stressful. Firearm and tool mark examiners bare a tremendous amount of responsibility to make correct and timely conclusions.

**Definition of the Problem**

High profile police involved shootings in Miami, Florida enraged the community, and attracted mass media attention (Epstein, 1993, October 7; Epstein, 1994, June 16; Epstein, 1994, July 14; Epstein, 1994, August 25). The Miami-Dade Police Department (MDPD) Crime Laboratory Bureau examined the evidence in these shootings and was unable to positively identify which officer’s Glock pistol fired the fatal shots. MDPD’s inability to identify the fired bullets to an individual Glock pistol prompted political pressure within the community, as well as within the police community.

The inability to identify fired bullets to an individual Glock pistol has raised questions nationally. The New York Police Department (1996) reported that that the Los Angeles Police Department identified approximately 5% of Glock bullets. Albany, New York reported that they also identified approximately 5% of Glock bullets (NYPD, 1996). Furthermore, the FBI’s Firearm and Tool Mark Unit Chief reported that it was very difficult to identify fired bullets to the Glock pistol that fired them (NYPD, 2006).

The issue is the capability of identifying a particular tool (firearm) to a specific tool mark (striated impression on a fired bullet). More specifically, the issue of being able to identify a bullet as having been fired in a particular firearm to the exclusion of all other firearms in the world comes into question. There is no set number of matching
striations that are needed when identifying two tool marks as having been produced by one tool/firearm. A set number needs to be established (Miller, 2000; Miller & McLean, 1998). Tool mark identification is not objective; it appears to be subjective in nature. A major research problem exists because it is impossible to examine every tool/firearm manufactured in the world. What is sufficient agreement?

The lands and grooves of the Miami Barrel are rounded, where as the barrels in the Brundage study (1998), were conventionally square. The question is, does the cutting tool used in the Miami Barrel change enough from barrel to barrel in order to allow examiners to distinguish between them, and if so, can Miller’s (1998, 2000) criteria for identification be applied?

Three issues have been identified as problem areas, which need further research and study. The issues are the inability to identify bullets that are fired in polygonal rifled barrels; the inability to examine every firearm; and, the lack of established criteria for identification.

The Inability to Identify Bullets that are fired in Polygonal Riffled Barrels

The first issue addresses the inability to identify bullets that are fired in polygonal rifled barrels. High Profile police involved shootings in the Miami, Florida enraged the community, and attracted mass media attention (Epstein, 1993, October 7; Epstein, 1994, June 16; Epstein, 1994, July 14; Epstein, 1994, August 25). The Miami-Dade Police Department (MDPD) Crime Laboratory Bureau examined the evidence in these shootings and was unable to positively identify which officer’s Glock pistol fired the fatal shots.

The inability to identify fired bullets to an individual Glock pistol is an issue throughout the United States. The New York Police Department (1996) reported that that
the Los Angeles Police Department identified approximately 5% of Glock bullets. Albany, New York reported that they also identified approximately 5% of Glock bullets (NYPD, 1996). Furthermore, the FBI’s Firearm and Tool Mark Unit Chief reported that it was very difficult to identify fired bullets to the Glock pistol that fired them (NYPD, 1996).

The problem area of identifying fired bullets that have been fired through polygonal rifled barrels is that the polygonal rifling has rounded shoulders, and is smoother than the conventional rifling which utilizes square shoulders. The polygonal rifling does not mark the bullets as well as the conventional rifling.

Freeman (1978) conducted a study utilizing consecutively manufactured Heckler and Koch polygonal rifled firearm barrels. Freeman noted that one of the Heckler and Koch polygonal rifled firearm barrels used in his study did not mark as well as the other two. Hall (1983) conducted a study on consecutively manufactured polygonal rifled Shilen rifle barrels. Hall found that the polygonal rifled Shilen rifle barrels produced subclass characteristic. Subclass characteristics could pose a major issue, and possibly a wrong conclusion for the uninformed firearm and tool mark examiner.

The New York Police Department (NYPD) (1996) conducted a research study and concluded that the ability to identify bullets that were fired through polygonal barrels would be unlikely. They also found that conventionally rifled barrels produced better microscopic marks for identification than polygonal barrels.

Carr and Fadul (1997) conducted a study and found that conventionally rifled barrels produced signatures on fired bullets that were readily identifiable. Furthermore,
they found that Glock and Heckler and Koch polygonal rifled barrels did not produce signatures on fired bullets that were readily identifiable.

Hocherman, Giverts and Shosani (2003) found that firearm and tool mark examiners had a 65% success rate in determining the manufacture of the firearms in which polygonal rifled bullets were fired in. Giverts, Springer, and Argaman (2004) found that the Integrated Ballistics Identification System, which is a computerized database, lacked the ability to search and match unknown fired polygonal bullets.

The Miami Barrel is a polygonal rifled barrel that was developed by Glock Inc. for use in Glock Pistols. Limited testing has been conducted with the barrel; however, no tests have been completed utilizing consecutively manufactured barrels. Additionally, no set number of consecutive matching lines has been established for polygonal rifled barrels.

The lands and grooves of the Miami Barrel are rounded, where as the barrels in the Brundage study (1998), were conventionally square. The problem area is whether or not the cutting tool used in the Miami Barrel changes enough from barrel to barrel in order to allow examiners to distinguish between them, and if so, can Miller’s (1998, 2000) criteria for identification be applied?

**The Inability to Examine every Firearm**

The inability to examine every firearm/tool in the world is an issue. The hypothesis in 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 examining the individual striations/impressions; the signature can be positively identified to the firearm/tool that produced it.
The hypothesis "as it pertains to the comparison of tool marks enables opinions of common origin to be made when the unique surface contours of two tool marks are in "sufficient agreement" (AFTE Glossary, 2001, p. 129). Sufficient agreement is the "significant duplication of random tool marks as evidenced by the correspondence of a pattern or combination of patterns of surface contours. The statement that sufficient agreement exists between two tool marks means that the likelihood another tool could have made the mark is so remote as to be considered a practical impossibility" (AFTE Glossary, 2001, p. 129).

A major research problem exists because it is impossible to examine every tool/firearm manufactured in the world. Firearm and tool mark examiners base their identifications on individual matching striations, their length, width, spatial relationship, surface contour, and the number of these line that are present. These striations are a result of minute imperfections on a cutting tool that cuts the lands and grooves into a barrel of a firearm (Hatcher, 1935; Mathews, 1973). How do we know that these matching striations are individual to a specific tool/firearm?

Several studies (Brundage, 1998; Hamby, 2001; Miller, 2000a; Hamby & Brundage, 2007) were conducted relating to firearm and tool mark identification; however, the key limitations of these studies were that not all firearm barrels or tools could be tested. The logistics involved to conduct such a test on all firearm barrels and tools is practically impossible. All of the firearm and tool mark examiners in the world were not able to participate. Additionally, we do not know if the examiners that did participate actually made an identification; or, if they guessed correctly. The environment of the participants was not controllable, nor do we know the study
conditions. The researchers were not able to identify or control extraneous variables at the other laboratories.

There are millions of firearms and tools in the world today (Maclnnis, 2007). How can it be determined to a scientific certainty that any one firearm/tool fired a questioned bullet, or made the questioned impression to the exclusion of all other firearms/tools? Can research be generalized for the forensic science discipline of firearm and tool mark examinations?

**The Lack of Established Criteria for Identification**

The forensic science discipline of firearm and tool mark examinations has no established criteria for identification. The traditional method of pattern recognition is historically based. Firearm and tool mark examiners have been utilizing pattern recognition since the inception of the discipline (Howitt, Tulleners, Cebra & Chen, 2008). Pattern recognition in firearm and tool mark examinations is based upon pattern recognition of microscopic lines and impressions.

The method of pattern recognition is dependent upon the firearm and tool mark examiner’s training and experience. Under this method, firearm and tool mark examiners base their identifications on individual matching striations, their length, width, spatial relationship, surface contour, and the number of these lines that are present.

Pattern recognition is subjective in nature because there is no way to quantify the firearm and tool mark examiner’s conclusion. Presently, there is no set number of matching striations that are needed when identifying two tool marks as having been produced by one tool/firearm. There is no set number required in other forensic science disciplines. In fingerprint identification, “there is no valid scientific basis for requiring a
minimum number of ridge characteristics which must be present in two fingerprints in order to establish positive identification” (Olson, 1978, p. 27). Additionally, there is no set number of characteristics required in shoe impression evidence (Bodziak, 2000), and tire impression evidence (Nause, 2001).

Tool mark identification is not objective; it appears to be subjective in nature. According to some researchers (Miller, 2000; Miller & McLean, 1998), a set number needs to be established to make the firearm and tool mark examiner’s conclusion objective. The theory of consecutive matching lines (CMS) was introduced to the firearm and tool mark profession in an attempt to quantify examiner conclusions and to make the results objective. The works of Biasotti (1959) and Biasotti and Murdock (1984) suggested that a quantitative number could be used by a firearm and tool mark examiner to explain a conclusion that was reached through pattern recognition. The major limitation of their work was the variance in the total number of matching lines.

Based on Miller and McLean’s (1998) study, tool mark identifications could be overlooked solely on the absence of consecutive matching lines. According to Miller’s (2000b) study, he was unable to place an arbitrary number on the number of total matching lines. Based on Miller’s (2000b) study, and employing his criteria of consecutive matching lines, no bad/wrong identifications would be made. However, one may fail to make an identification, resulting in a false elimination. Miller (2001) concluded that there would be no erroneous identifications applying the CMS theory; however, the possibility to exclude a positive identification exists. Both studies (Miller, 2000b; & Miller 2001) suggest a major limitation, which is the exclusion of a positive identification.
Neel (2007) completed a comprehensive statistical analysis to support the CMS theory; however, he found the lack of CMS could result in an inability to make an identification that would have been made through pattern recognition. One researcher (Nichols, 2003), states that it is possible to exclude a positive identification using the theory of consecutive matching lines. He stated that if the impressions did not meet the criteria of the theory, then it would not be an identification.

Line counting and the CMS theory is a phenomenon that originated on the West Coast. It provides an objective approach with numerical numbers; however, the absence of CMS could lead to a missed identification. Most of the examiners that the researcher knows use pattern matching. They base their identifications on the pattern recognition of individual matching striations, their width, length, special relationship, surface contour, and the number of these lines that are present. They do not count lines; they make mental observation. It is subjective and is based on the training and experience of the examiner. Hence, the problem of criteria for identification exists.

**Theory of Firearm and Tool Mark identification**

The theory in 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 examining the individual striations/impressions; the signature can be positively identified to the firearm/tool that produced it. Most examiners base their identifications on individual matching striations, their width, length, special relationship, surface contour, and the number of these lines that are present. It is subjective and is based on the training and experience of the examiner.
The lands and grooves inside the barrel of a firearm cause the bullet to spin when it takes flight. When a bullet travels through a gun barrel, the bullet is scored by the minute imperfections that resulted in the manufacturing process, and appear on the bullet as striations, which are fine microscopic lines (Mathews, 1973). These striations are a result of minute imperfections on a cutting tool that cuts the lands and grooves into a barrel of a firearm (FBI, 1941; Hatcher, 1935; Mathews, 1973). For example, run a rake through sand and you will create lines such as those that would be on a bullet.

According to Houts (1956), "it is impossible for two barrels made by the same manufacturer on the same machine, one right after the other, to be identical" (p. 292). He also emphasized that through use, the barrels obtain additional individual characteristics and/or irregularities that are unique to themselves. Houts (1956) described the individual characteristics and/or irregularities as the barrels signature.

The hypothesis "as it pertains to the comparison of tool marks enables opinions of common origin to be made when the unique surface contours of two tool marks are in sufficient agreement" (AFTE Glossary, 2001, p. 129). Sufficient agreement is the "significant duplication of random tool marks as evidenced by the correspondence of a pattern or combination of patterns of surface contours. The statement that sufficient agreement exists between two tool marks means that the likelihood another tool could have made the mark is so remote as to be considered a practical impossibility" (AFTE Glossary, 2001, p. 129).

Empirical studies (Brundage, 1998; Hamby, 2001; Hamby & Brundage, 2007; Miller, 2000a) have clearly documented, as well as validated the theory and hypothesis of the forensic discipline of firearm and tool mark examinations. The major limitation of all
of these studies was that the conclusions were reached based on the examiner's training and experience, making them subjective conclusions. No criteria for making an identification was presented by the researchers.

**Definition of Terms**

**Independent Variables**

**Theoretical.** The independent variable is the examination and comparison of the questioned bullets to the known standards, which were fired in the 10 consecutive manufactured Glock Miami Barrels.

**Comparison** is defined as "the process of ascertaining whether two or more objects have a common origin" (Saferstein, 2001, p. 63).

The **barrel** is defined as the "part of a firearm through which a projectile or shot charge travels under the impetus of powder gasses, compressed air, or other like means" (AFTE Glossary, 2001, p. 9).

A **bullet** is defined as "a non-spherical projectile for use in a rifled barrel" (AFTE Glossary, 2001, p.24). **Bullet engraving** is defined as "the rifling impression on a fired bullet" (AFTE Glossary, 2001, p. 24). For the purpose of this paper, the source of the questioned bullet (fired through 1 of the 10 Barrels) will be unknown, and the source of the known standard (test fired bullet) will be known.

**Firearms Identification** is defined as "a discipline of forensic science which has as its primary concern to determine if a bullet, cartridge case or other ammunition component was fired by a particular firearm" (AFTE Glossary, 2001, p. 58).

A **Firearm and Tool Mark Examiner** is a scientist who has the training and experience to work in the forensic discipline of Firearms Identification (Saferstein, 2001).
Glock is the last name of Gaston Glock who was an engineer that formed his own company, Glock Inc., and the manufacturer of the Glock Pistol (Kasler, 1992).

Identification is defined as the act of identifying (Thornton and Peterson, 2002). For the purpose of this paper, Identification shall mean identifying two items as being produced by a common origin.

Miami Barrel is defined as a Glock polygonal rifled barrel that contains modifications which resulted due to the Miami-Dade Police Department’s inability to identify fired bullets to the shooting office’s weapon (Carr & Fadul, 1997).

Operational Firearm and tool mark examiners will be able to examine and compare fired bullets utilizing pattern matching and line counting techniques.

Pattern matching will be accomplished by comparing individual matching striations, their length, width, spatial relationship, and the surface contour of two bullets.

Line counting will be accomplished by counting consecutively matching lines of two bullets. An identification must have one group of six consecutive matching lines, or two groups of three consecutive matching lines.

Mediating Variables

Theoretical. The mediating variable is the firearm and tool mark examiner’s ability to identify questioned bullets to the barrel that produced them.

Training is defined as “the acquisition of knowledge, skills, and competencies as a result of the teaching of vocational or practical skills and knowledge that relate to specific useful competencies” (Wikipedia, n.d.).
Experience is defined as “practical knowledge, skill, or practice derived from direct observation of or participation in events or in a particular activity” (Merriam-Webster, 2008, ¶2).

Operational. The ability of the firearm and tool mark examiners will be measured by their training and years of experience.

Dependent Variables

Theoretical. The dependant variable will measure whether or not the questioned bullets could be distinguished between consecutively manufactured gun barrels. Additionally, the dependent variable will measure whether or not line counters failed to make identifications.

Consecutive matching striations (CMS) is defined as “a numerical threshold that allows one to distinguish between what constitutes an identification from a non-identification or inconclusive” (Nichols, 2003, p. 303).

The theory of identification “as it pertains to the comparison of tool marks enables opinions of common origin to be made when the unique surface contours of two tool marks are in “sufficient agreement” (AFTE Glossary, 2001, p. 129).

A theory of consecutive matching lines (CMS) was introduced by seminal and empirical studies (Biasotti, 1959; Biasotti & Murdock, 1984; Miller, 2000b; Miller, 2004; Miller & McLean, 1998). They determined that a set number of consecutive matching lines could be used to make an identification, and that a quantitative number would make conclusions an objective opinion.

The theory of pattern matching is dependent upon the firearm and tool mark examiner’s training and experience. Under this method, firearm and tool mark examiners
base their identifications on individual matching striations, their length, width, spatial relationship, surface contour and the number of these lines that are present.

Operational. Firearm and tool mark examiners will use the theory of pattern matching or the theory of consecutive matching lines to compare questioned bullets to known standards. A survey/answer sheet will be utilized to compare the results of the pattern matchers and line counters. The survey/answer sheet was adapted by the researcher with the permission of Dr. James Hamby (see Appendix D).

Purpose of the Study

To date, no studies have been conducted with multiple consecutively manufactured Glock Miami Gun Barrels. Few empirical studies (Moran, 2001; Nichols, 2003; Walsh & Weavers, 2002) examine the relationship between the traditional pattern matching, and consecutive matching lines. Scholarly inquiry needs to be conducted to determine if firearm and tool mark examiners who use pattern matching and consecutive matching lines will reach the same conclusion. Additionally, scholarly inquiry needs to be conducted to determine if the theory of consecutive matching lines will exclude positive identifications. The specific purposes of this experimental, comparative study will examine the following:

1. The relationship between firearm and tool mark examiners who utilize pattern matching and line counting when examining bullets.
2. The relationship between the results based upon the years of experience of the firearm and tool mark examiners who utilize pattern matching and line counting.
Significance of the Study

The study of the Miami Barrel is of significant interest, regionally, nationally and globally, especially in the law enforcement community (Chin & Sampson, 2007; Fadul & Nunez, 2006; Martinez, 2008). It is of most importance because of the past inability to identify the fired bullets to an individual Glock pistol that they were fired in. With increased firearm violence (FDLE, 2008a; FDLE, 2008b), it is imperative that law enforcement maintains the ability to identify ballistic evidence, report the conclusions and provide expert testimony in the legal arena.

The issue of identifying a bullet as having been fired in a particular firearm to the exclusion of all other firearms in the world comes into question, and is of the utmost significance to law enforcement, the judicial system and most importantly, the community. Additionally, the criteria needed to make an identification is interesting because there is no set number of matching striations that are needed when identifying two tool marks/bullets as having been produced by one tool/firearm.

This Miami Barrel is worthy of study due to the implications and impact that it will have on the field of forensic science, the law enforcement community, and the judicial system. If the theory of identification can be validated with the Miami Barrel, it will revolutionize law enforcement and the field of forensic science, as well as impact the judicial system.

Assumptions

This study will be built upon the following assumptions:

1. All firearms/tools produce a signature of identification (striation/impression) that is unique to that firearm/tool, and through examining the individual
striations/impressions; the signature can be positively identified to the firearm/tool that produced it.

2. Qualified firearm and tool mark examiners have the ability to examine questioned bullets that are fired through 10 consecutively manufactured Glock Miami Barrels and report their conclusions.

3. Firearm and tool mark examiners will use either the theory of pattern matching or line counting for their examinations and testing in this study.

4. Survey respondents will answer the survey instrument questions truthfully and conduct all examinations on their own.

**Delimitations**

This study will be limited to firearm and tool mark examiners working for a law enforcement agency (crime laboratory), or like agency in the United States. Participants must have completed a two year training program. Independent examiners who retired from a qualifying agency will also be eligible. Firearm and tool mark examiners who did not complete a two year training program will be excluded. Any Independent examiner who at one time did not work for a law enforcement agency (crime laboratory), or like agency, will be excluded. Independent examiners who did not retire from a qualifying agency will be excluded.

This study will examine the influence of the Glock Miami Barrel in relation to the firearm and tool mark examiner’s ability to identify fired bullets to the barrel in which they were fired through. Additionally, this study will explain the relationship between pattern matching and line counting. Data analysis will include the firearm and tool mark
examiner's scores, firearm and tool mark examiner's characteristics, as well as equipment utilized.

**Organization of the Study**

Chapter I provides an overview of the study. It includes an introduction to the forensic science discipline of firearm and tool mark identification, issues relating to the firearm and tool mark identification field, purpose of the study, definitions of the study variables, justification for the study, and the delimitations of the study as they apply to the Miami Barrel.

Chapter II provides a review of the literature and theoretical framework leading to propositions that will be tested by the research questions and hypotheses addressed in this study. The major gaps in the literature consist of the following: 1) a limited number of empirical studies have been conducted on the Glock Miami Gun Barrel; and 2) a limited number of empirical studies addressing the relationship of pattern matching and line counting. The theoretical framework presented in Chapter II emphasizes that each firearm/tool produces a signature of identification (striation/impression) that is unique to that firearm/tool, and through examining the individual striations/impressions; the signature can be positively identified to the firearm/tool that produced it.

Chapter III reflects the research methodology testing the hypothesized model, as well as the research questions and hypothesis. It consists of the research design, the target population, sampling, research instruments, procedure of data collection, ethical considerations, methods of data analysis, and the methodology evaluation.

Chapter IV contains the results for this research study. The examination of research questions, hypotheses testing, and other findings related to this study about the
Miami Barrel was conducted by the researcher. Participant performance (test assessment – experimental exercise) relating to skill (experience) and methods utilized (pattern matching, consecutive matching striations - line counting, and/or a combination of both), as well as their demographic characteristics relating to the Participant’s ability to perform the assessment were examined.

Chapter V discusses the general and main findings of this research study, as well as theoretical considerations. This chapter also presents the conclusion of this study, limitations of the study, recommendations for future research and other implications detected by the researcher.
CHAPTER II
REVIEW OF THE LITERATURE AND THEORETICAL FRAMEWORK

Review of the Literature

The overview and purpose of this literature review is to determine the capability of identifying a particular tool (firearm) to a specific tool mark (striated impression on a fired bullet). More specifically, the issue of being able to identify a bullet as having been fired in a particular firearm to the exclusion of all other firearms in the world comes into question. There is no set number of matching striations that are needed when identifying two tool marks as having been produced by one tool/firearm. A set number needs to be established (Miller, 2000; Miller & McLean, 1998). Tool mark identification is not objective; it appears to be subjective in nature. A major research problem exists because it is impossible to examine every tool/firearm manufactured in the world. What is sufficient agreement?

Additionally, can firearm and tool mark examiners properly identify bullets that were fired from consecutively manufactured gun barrels? Firearm and tool mark examiners base their identifications on individual matching striations, their length, width, spatial relationship, surface contour and the number of these lines that are present. These striations are a result of minute imperfections on a cutting tool that cuts the lands and grooves into a barrel of a firearm (Hatcher, 1935; Mathews, 1973).

The lands and grooves are what cause the bullet to spin when it takes flight. When a bullet travels through a gun barrel, the bullet is scored by the minute imperfections that resulted in the manufacturing process, and appear on the bullet as
striations (fine microscopic lines). For example, run a rake through sand and you will create lines such as those that would be on a bullet.

The problem area of identifying fired bullets that have been fired through polygonal rifled barrels is that the polygonal rifling has rounded shoulders, and is smoother than the conventional rifling which utilizes square shoulders. According to Kennington (1992), "difficulty with rifling determinations occurs when an evidence projectile has been fired in a weapon with a polygonal barrel" (p. 17). The polygonal rifling does not mark the bullets as well as the conventional rifling.

High Profile police involved shootings in the City of Miami led to the creation of the Miami Barrel. The Miami-Dade Police Department (MDPD) Crime Laboratory Bureau examined the evidence in these shootings and was unable to positively identify which officer's Glock pistol fired the fatal shots. MDPD's inability to identify the fired bullets to an individual Glock pistol prompted political pressure within the community, as well as within the police community. This resulted in an in-depth study of Glock's polygonal rifled barrels, which resulted in the manufacturing of the Miami Barrel.

The lands and grooves of the Miami Barrel are rounded, where as the barrels in the Brundage study (1998), were conventionally square. The question is, does the cutting tool used in the Miami Barrel change enough from barrel to barrel in order to allow examiners to distinguish between them, and if so, can Miller's (1998, 2000) criteria for identification be applied?

The purpose of this review is to critically analyze the theoretical and empirical literature on the effectiveness of identifying impressions made by consecutively
manufactured tools/firearms, the Miami barrel, and the criteria needed to establish an identification, as well as to identify areas of future scholarly inquiry.

An Historical Perspective

Firearms and the science of firearm and tool mark examinations are two different categories, and have two different meanings. They both have their own historical timeline. A firearm is “any weapon which a projectile is discharged by explosive means” (Mueller & Olson, 1968, p. 81). The science of firearm and tool mark examinations deal with identifying the discharged projectile (bullet) as having been fired through a particular weapon to the exclusion of all other weapons.

The first firearm can be traced back to 1326, and the term handgun evolved in 1388 (NRA, 1989). The manufacturing timeline in the United States can be traced to Springfield, Massachusetts. In 1795, the Springfield Armory was created (Bussard & Stanton, 2006). As time, education and technology advanced, so did firearms, evolving them to their current state. The military played a pivotal role in the development of firearms; however, they have had a minor role in the science of firearm and tool mark examinations. The interest in the science aspect evolved mainly from law enforcement issues.

The science of firearm and tool mark examinations has been well established since the 1930’s (Hatcher, Jury & Weller, 1977); however, the timeline for the science can be traced back to the Civil War. In 1862, it was determined that a projectile that killed General Stonewall Jackson was fired through a Confederate weapon (Saferstein, 1988). Other significant historical cases that shaped the science of firearm and tool mark examinations were the Brownsville, Texas Raid; Stielow; Sacco and Vanzetti; and the St.
Valentine’s Day massacre. Each case played a significant role, developing a sound foundation for the science of firearm and tool mark examinations.

The Brownsville, Texas Raid occurred due to racial tension, and 150 to 200 shots were fired in downtown Brownsville. A total of 39 fired casings were examined and 33 were determined to have been fired in four different weapons. Six fired casings were unclassified (Berg, 1965; Garrison, 1986; Hamby, 2001; Hamby & Thorpe, 1999; Hatcher et al., 1977).

In the Stielow case, Stielow was found guilty and sentenced to death for killing his employer and his housekeeper. Stielow was exonerated when a group of experts examined the firearms evidence and determined that the rifling on the bullets from the victim did not match the rifling on the test bullets fired through Stielow’s firearm (Berg, 1965; Hamby & Thorpe, 1999; Hatcher et al., 1977).

The Saco and Vanzetti case was significantly important because both the defense and prosecution provided expert witnesses who stated different conclusions reference the firearms evidence. This case involved an armed robbery in which two men were shot and killed. Based on the firearms evidence presented, Saco and Vanzetti were convicted and executed (Berg, 1965; Gunther & Gunther, 1935; Hatcher et al., 1977; Russell, 1986).

The St. Valentine’s Day massacre occurred on February 14, 1929 in Chicago, Illinois. Seven men were shot execution style, and the news of this shooting quickly spread coast to coast. Examination of the firearms evidence lead to the following conclusion that 70 fired casings were identified has having been fired through two weapons (Berg, 1965; Goddard, 1980; Hamby, 2001; Hamby & Thorpe, 1999; Hatcher et al., 1977).
Mathews (1973) reported that bullets that were fired through four consecutively manufactured barrels at the Springfield Arsenal were correctly identified to the correct weapon in 1926. Additionally, Calvin Goodard fired 500 rounds through a machine gun and he was able to identify the first bullet fired through the weapon to the 500th bullet (Mathews, 1973).

Firearm and tool mark examiners base their identifications on individual matching striations, their length, width, spatial relationship, surface contour, and the number of these lines that are present. These striations are a result of minute imperfections on a cutting tool that cuts the lands and grooves into a barrel of a firearm (Davis, 1958; Hatcher, 1935; Mathews, 1973).

The history of the Miami Barrel can be traced to 1994 (Carr & Fadul, 1997). It should be noted that there is no known record of military testing regarding the Miami Barrel.

**Theoretical Framework**

The theory of identification allows like items with the same origin to be identified. This theory allows firearm and tool mark examiners to conclude that a particular bullet was fired through a particular weapon to the exclusion of all other weapons. Within this theory, there are two theories that guide the science of firearm and tool mark identification: pattern matching and consecutive matching lines (CMS), which is known as line counting.

**Theory of Identification**

Thornton and Peterson (2002) define Identification as the act of identifying. For the purpose of this paper, Identification shall mean identifying two items as being
produced by a common origin. In firearm and tool mark examinations, an identification is the “agreement of a combination of individual characteristics and all discernable class characteristics where the extent of agreement exceeds that which can occur in comparison of tool marks made by different tools” (Moran, 2002, p. 229). Furthermore, it must be “consistent with agreement demonstrated by tool marks known to have been produced by the same tool” (Moran, 2002, p. 229).

In 1992, the Association of Firearm and Tool Mark Examiners published the theory of identification in their scientific journal. The theory of identification “as it pertains to the comparison of tool marks enables opinions of common origin to be made when the unique surface contours of two tool marks are in sufficient agreement” (AFTE, 1992, p. 337). Sufficient agreement is the “significant duplication of random tool marks as evidenced by the correspondence of a pattern or combination of patterns of surface contours. The statement that sufficient agreement exists between two tool marks means that the likelihood another tool could have made the mark is so remote as to be considered a practical impossibility” (AFTE, 1992, p. 337).

The principals described in the AFTE Theory of Identification have been well established since the 1930’s (Hatcher et al., 1977); however, the timeline for the Theory of Identification in firearms identification can be traced back to the Civil War (Saferstein, 1988). Significant cases that utilized the Theory of Identification are as follows: the Brownsville, Texas Raid (Berg, 1965; Garrison, 1986; Hamby, 2001; Hamby & Thorpe, 1999; Hatcher et al., 1977); Stielow (Berg, 1965; Hamby & Thorpe, 1999; Hatcher et al., 1977); Sacco and Vanzetti (Berg, 1965; Gunther & Gunther, 1935; Hatcher et al., 1977;

The Brownsville, Texas Raid occurred due to racial tension, and 150 to 200 shots were fired in downtown Brownsville. A total of 39 fired casings were examined and 33 were determined to have been fired in four different weapons. Six fired casings were unclassified (Berg, 1965; Garrison, 1986; Hamby, 2001; Hamby & Thorpe, 1999; Hatcher et al., 1977).

In the Stielow case, Stielow was found guilty and sentenced to death for killing his employer and his housekeeper. Stielow was exonerated when a group of experts examined the firearms evidence and determined that the rifling on the bullets from the victim did not match the rifling on the test bullets fired through Stielow’s firearm (Berg, 1965; Hamby & Thorpe, 1999; Hatcher et al., 1977).

The Saco and Vanzetti case was significantly important because both the defense and prosecution provided expert witnesses who stated different conclusions reference the firearms evidence. This case involved an armed robbery in which two men were shot and killed. Based on the firearms evidence presented, Saco and Vanzetti were convicted and executed (Berg, 1965; Gunther & Gunther, 1935; Hatcher et al., 1977; Russell, 1986).

The St. Valentine’s Day massacre occurred on February 14, 1929 in Chicago, Illinois. Seven men were shot execution style. This case was very important in its day due to the popularity of the gangster era. A total of 70 fired casings were identified has having been fired through two weapons (Berg, 1965; Goddard, 1980; Hamby, 2001; Hamby & Thorpe, 1999; Hatcher et al., 1977).
Mathews (1973) reported that bullets that were fired through four consecutively manufactured barrels at the Springfield Arsenal were correctly identified to the correct weapon in 1926. Additionally, Calvin Goodard fired 500 rounds through a machine gun and he was able to identify the first bullet fired through the weapon to the 500th bullet (Mathews, 1973).

The Theory of Identification is utilized in the forensic science discipline of firearm and tool mark examinations. This theory has been established through the utilization of scientific methods. Additionally, the Theory of Identification is supported by several empirical studies (Brundage, 1998; Hamby, 2001; Hamby & Brundage, 2007; Miller, 2000a).

**Pattern Matching**

The theory of pattern matching can be traced back to ancient times. As ordered society developed, rank and positions within the society became important, and man became concerned with identity. Symbols (patterns) were invented to achieve recognition of rank, and to identify one’s position within the society. Kings and queens wore crowns and carried scepters. Slaves and criminals were branded for identification. As society developed, symbols (patterns) were counterfeited, requiring a more personal and positive method of identification, setting the platform for the use of fingerprints and the theory of pattern matching as it pertains to forensic science.

Historians have generally accepted that the Chinese used thumb prints on clay seals for identification prior to “the third century B.C.” (Lee & Gaensslen, 1991, p.12). Additionally, it has been reported that the Chinese used fingerprints on contracts, deeds, and other legal documents dating back to the Tang Dynasty of the eighth century (FBI,
n.d.). In the 14th century, the Persian Government affixed fingerprints on official papers, and it was observed that no two persons bore the same fingerprints (Aufderheide, n.d.).

In 1891 Francis Galton concluded mathematically that the chances were “64,000,000,000 to 1,” that no two humans possessed the same fingerprint patterns (Menzel, 1983, p. 5). In 1896, Juan Vucetich developed a system to classify fingerprint patterns, and Argentina became the first country to base criminal identification on fingerprints (Aufderheide, n.d.; Bridges, 1942). Sir Edward Henry created a classifying system that recognized five basic line patterns, with sub-patterns, which was adopted by most of Europe by 1901; however, the United States continued to utilize the Bertillon Method (Hoover, 1937), which utilized photographs and body measurements.

The Will West / William West case in 1903 revolutionized the theory of pattern matching regarding fingerprints in the United States. Will West was sentenced to Leavenworth, Kansas. The Bertillon method was used on West and it was discovered that another prisoner, William West had the same measurements and facial features (Olson, 1983). Subsequently, the fingerprints of both men were taken and compared. The fingerprint patterns bore no resemblance and the West case clearly established that fingerprinting was a superior method of identification.

The West case resulted in the adoption of fingerprinting prisoners at the New York State Prison. In 1905, the United States Army began fingerprinting servicemen (FBI, n.d.). The Federal Bureau of Identification established their Identification Division in 1924 (FBI, 1979), setting the tone for the theory of pattern matching in Forensic
Science and the ability to be able to identify two items as being produce by a common origin.

In fingerprint identification, "there is no valid scientific basis for requiring a minimum number of ridge characteristics which must be present in two fingerprints in order to establish positive identification" (Olson, 1978, p. 27). Additionally, there is no set number of characteristics required in shoe impression evidence (Bodziak, 2000), and tire impression evidence (Nause, 2001).

The theory of pattern matching has been widely used by firearm and tool mark examiners since its inception, and has involved pattern recognition of microscopic lines and impressions. The method of pattern recognition is dependent upon the firearm and tool mark examiner's training and experience. Under this method, firearm and tool mark examiners base their identifications on individual matching striations, their length, width, spatial relationship, surface contour and the number of these lines that are present.

**Consecutive Matching Lines (CMS) Theory**

Biasotti (1959) introduced his seminal theory of consecutive matching lines based on his quantitative empirical study to determine whether or not he could establish a numerical count to be used to determine whether or not set number of matching striations could be established for identifying two bullets as having been produced by one firearm. The major proposition of this theory is that a numerical value can be used to make an identification.

Biasotti and Murdock (1984) introduced a seminal empirical review to support Biasotti's theory. They further explained that a conclusion reached by pattern recognition can not be quantitatively explained to anyone else. Miller and McLean
(1998) developed a schematic model depicting these direct and indirect relationships among concepts described by Biasotti, which continues to be examined today. This theory is scientifically significant addressing essential issues about a quantitative numerical value in the discipline of firearm and tool mark examinations.

Miller and McLean (1998) conducted an empirical study to test the CMS theory and determine whether or not a set number of matching striations could be established for identifying two tool marks as having been produced by one tool/firearm. They used a quasi experimental, quantitative design. Their literature review was thorough and current. Miller and McLean’s hypothesis was that tool mark identification can be objective in nature, because a set number of consecutive matching lines (striations) can be used as a guideline to identify or eliminate impressions and bullets as having been produced by a particular tool/firearm.

Miller and McLean’s (1998) target population was the forensic science community, more specifically, firearm and tool mark examiners. They used an abstract population for their research project. Miller and McLean test fired 100 .38 caliber Smith & Wesson revolvers. They retrieved the bullets for comparison and line counting. Each bullet had five lands and grooves. Their sampling technique was a simple random sample because every striation in their abstract population had an equal opportunity to be included.

Miller and McLean (1998) used a comparison microscope, and the Integrated Ballistic Identification System (IBIS) for collecting their data. They examined the striations in both two dimensional images, and three dimensional images. The IBIS was used for two dimensional images, and the comparison microscope for three dimensional
images. Miller and McLean counted the total number of striations, the number of matching striations, as well as the groups of consecutive matching striations. Miller and McLean used the bullets from 50 of the 100 Smith & Wesson revolvers for their examination of two dimensional images, and the bullets from the other 50 Smith & Wesson revolvers for their examination of three dimensional images. They compared both known matches and known non-matches.

The independent variable was examination and comparison of known non-matches. The total matching striations, as well as any consecutive matching striations were counted and totaled. The dependant variable measured the difference in the line count results of the total matching striations, as well as consecutive matching striations between the known non-matches, and the known matches.

Miller and McLean’s (1998) research design was experimental for both two dimensional images, and three dimensional images. In both the two dimensional images, and three dimensional images, they created two groups (known non-matches, and the known matches), which were as similar as possible. Both groups were comparable. Miller and McLean administered their program of line counting (total matching lines, consecutive matching lines). Miller and McLean then compared the results of the line counting between their two groups (known non-matches verse known matches).

In order to ensure reliability, Miller and McLean (1998) compared their results (line counts of total matching lines, and consecutive matching lines) between all their known matches. They then did the same for their known non-matches. Miller and McLean’s line counts for their known matches were similar, as were their counts for the known non-matches. The validity of this paper was dependent upon the accuracy of
Miller and McLean’s ability to line count. Their counts appear to be within an acceptable range, and are consistent with the previous study conducted by Biasotti (1959), and Biasotti and Murdock (1984).

Miller and McLean’s (1998) key results were that no arbitrary number could be placed on the number of total matching lines; however, they were able to distinguish criteria for consecutive matching lines in both two dimensional images, and three dimensional images. In the known non-match two dimensional images, “no groups greater than six consecutive striae were found” (1998, p. 24). In the known non-match three dimensional images “no groups over four were found” (1998, p. 27).

Miller and McLean’s (1998) results corroborated a quantitative standard for identification in both two dimensional images, and three dimensional images. A two dimensional image would require at a minimum, one group of eight consecutive matching lines, or two groups of five consecutive matching lines. A three dimensional image would require at a minimum, one group of six consecutive matching lines, or two groups of three consecutive matching lines.

The key limitations of this article were that not all firearms and tools could be tested. It would be impossible to conduct such a test. This research was conducted at the discretion of Miller and McLean’s ability to count lines, and/or what they considered to be a line. Miller and McLean (1998) have opened the door for future research on line counting, specifically consecutive matching lines. Additionally, different caliber bullets should be used, as well as striated tool marks produced from knives, screwdrivers, and so forth.
Miller (2000b) conducted a study to further validate the empirical study of Miller and McLean (1998) and this study was based on the criteria needed to make a positive identification of tool marks in the field of forensic science utilizing the CMS theory. Miller used a quasi experimental, quantitative design, and he did not list a literature review.

In Miller’s previous study (Miller & McLean, 1998), he was able to distinguish criteria for consecutive matching lines in both two dimensional images, and three dimensional images. Miller’s (2000b) results corroborated a quantitative standard for identification in both two dimensional images, and three dimensional images.

The theoretical framework of Miller’s (2000b) study was that a set number of consecutive matching lines could be used to make a positive Identification. Each tool produces an impression that is unique to that tool, and through examining the individual striations; counting the consecutive matching striations, the impression can be positively identified to the tool that produced it. The caliber of the bullets should not matter. Additionally, the conclusion reached by an examiner will be objective in nature due to the quantitative factor.

Miller’s (2000b) target population was the forensic science community, more specifically, firearm and tool mark examiners. He used an abstract population for his research project. Miller used test fired .25 auto caliber bullets, .380 auto caliber bullets, and 9mm caliber bullets. He used the bullets for comparison and line counting. Each bullet had six lands and grooves. Miller’s sampling technique was a simple random sample.
Miller (2000b) used a comparison microscope, and the Integrated Ballistic Identification System (IBIS) for collecting his data. He examined the striations in both two dimensional images, and three dimensional images. The IBIS was used for two dimensional images, and the comparison microscope for three dimensional images. Miller counted the total number of striations, the number of matching striations, as well as the groups of consecutive matching striations. Miller used 10 fired bullets from each of the following calibers: .25 auto, .380 auto, and 9mm, which consisted of 60 land comparisons for the examination of three dimensional images. Miller used the same fired bullets for his examination of two dimensional images. He compared both known matches and known non-matches for his data. He then compared his data to the data of his previous study (Miller & McLean, 1998).

The independent variable was the examination and comparison of known non-matches. The total matching striations, as well as any consecutive matching striations were counted and totaled. The dependant variable measured the difference in the line count results of the total matching striations, as well as consecutive matching striations between the known non-matches, and the known matches.

In order to ensure reliability, Miller (2000b) compared his results (line counts of total matching lines, and consecutive matching lines) between all his known matches. He then did the same for his known non-matches. Miller’s line counts for his known matches were similar, as were his counts for the known non-matches. The validity of this paper was dependent upon the accuracy of Miller’s ability to line count. His counts appear to be within an acceptable range, and are consistent with his previous study.
(Miller & McLean, 1998), and a previous study that was conducted by Biasotti and Murdock (1984).

Miller’s (2000b) key results were consistent with his 1998 study, in which no arbitrary number could be placed on the number of total matching lines; however, he was able to distinguish the same criteria for consecutive matching lines in both two dimensional images and three dimensional images as he did in his 1998 study. In the .25 auto caliber known non-match two dimensional images, as well as the known non-match three dimensional images Miller found “no consecutive groups over four were observed” (2000b, p. 119). With the .380 auto caliber known non-match two dimensional images, Miller found “no consecutive groups over four were observed” (2000b, p. 122). With the .380 auto caliber, and 9mm caliber known non-match three dimensional images, Miller did not observe any consecutiveness over three. Miller also concluded the same for the 9mm caliber known non-match two dimensional images. Miller’s theory of using consecutive matching lines can generalize for all tool marks.

Miller’s (2000b) results corroborated the results of his previous study, which is a quantitative standard for identification in both two dimensional images, and three dimensional images. A two dimensional image would require at a minimum, one group of eight consecutive matching lines, or two groups of five consecutive matching lines. A three dimensional image would require at a minimum, one group of six consecutive matching lines, or two groups of three consecutive matching lines.

The key limitations of this article were that not all firearms and tools could be tested. Miller (2000b) only examined three calibers in this study, in which he compared
to a previous study that included one additional caliber. This research was conducted at the discretion of Miller’s ability to count lines, and/or what he considered to be a line.

Miller has examined four calibers, .38 (Miller & McLean, 1998), .25 auto (2000b), .380 auto (2000b), and 9mm (2000b). He has opened the door regarding future research on line counting, specifically consecutive matching lines. There are many more calibers that need to be examined, as well as striated tool marks produced from knives, screwdrivers, and so forth. Miller’s study can be used as a guide for additional research.

Bunch (2000) critically analyzed the CMS theory. He raised the question of subjectivity in striation counting, and the fact that barrels can change over time. Additionally, current testing has been completed on a limited firearms population. According to Brunch, the CMS model is a probability model, and testing needs to be conducted on various calibers. He does conclude that CMS is objective, and that research should continue.

Miller (2001) conducted a study to further validate the CMS theory by applying it to the Brundage study. Miller used a quasi experimental, quantitative design, and he did not list a literature review. His target population was the forensic science community, more specifically, firearm and tool mark examiners. He used an abstract population for his research study. Miller used the known standards and questioned bullets from the Brundage study, which he used for comparison and line counting. Each bullet had six lands and grooves. Miller’s sampling technique was a simple random sample.

Miller (2001) used a comparison microscope, and the Integrated Ballistic Identification System (IBIS) to collect his data. He examined the striations in both two dimensional images, and three dimensional images. The IBIS was used for two
Miller counted the total number of striations, the number of matching striations, as well as the groups of consecutive matching striations.

The independent variable was examination and comparison of known non-matches. The total matching striations, as well as any consecutive matching striations were counted and totaled. The dependent variable measured the difference in the line count results of the total matching striations, as well as consecutive matching striations between the known non-matches, and the known matches. Miller (2001) did not state how he ensured reliability and validity.

Miller's (2001) key results corroborated the results of his previous study, which was a quantitative standard for identification in both two dimensional images, and three dimensional images. Miller concluded that using CMS, there would be no erroneous identifications; however, the possibility to exclude a positive identification exists.

Miller (2001) did not cite any limitations. We do not know what extraneous variables may have existed. Additionally, this research was conducted at the discretion of Miller's ability to count lines, and/or what he considered to be a line. Areas of future research could include additional participants from across the United States applying the CMS theory to the Brundage study and like studies.

Nichols (2003) performed a comparison between traditional pattern recognition and the theory of consecutive matching lines. Basically, Nichols theorized that the use of consecutive matching lines would allow a numerical quantitative value to be placed on the pattern observed by the examiner. Consecutive matching lines identifies "a numerical threshold that allows one to distinguish between what constitutes an identification from a
non-identification or inconclusive” (2003, p. 303). Biasotti and Murdock (2002) advocate that a high degree of statistical certainty exists when utilizing CMS. They believe that CMS provides a quantitative and objective criterion.

Miller (2004) theorized “that a conservative criteria for tool mark identification when using patterns of consecutive groups of striae defines a specific level between a known match and a known non-match” (2004, p.14). Miller uses the theory to support his examination conclusions by applying Biasotti’s theory of consecutive matching lines.

Howitt (2007) examined the probability of finding patterns of CMS on the surfaces of fired bullets. The probability assumes that the CMS patterns are produced from a random course of action. He presented that the probabilities for matching sequences can be utilized to quantify the probability for any identification, as well as non-identifications.

Neel (2007) completed a comprehensive statistical analysis to quantify the theory of CMS. He examined over 4,000 tool mark comparisons. He quantified the total matching striations, percent matching striations, and CMS. Neel determined that there was a substantial statistical difference between identifications and non-identifications, which supports the CMS theory.

Stone (2007) examined fired bullets that were fired in three hammer forged rifle barrels. The barrels were forged from the same mandrel. He determined that each barrel was unique to itself. Stone used both CMS and pattern matching; however comparative statistics between the two were not cited.

Howitt, Tulleners, Cebra and Chen (2008) examined the theoretical significance for calculating the probability of striations. They found that the probability of chance for
consecutive matching lines were similar to Biasotti’s (1959) study. Howitt et al. (2008) stated that CMS is “less rigorous case of congruent pattern matching” (p. 873).

**Empirical Literature**

**Instrumentation Studies**

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. He used a quasi experimental, quantitative design. Brundage’s literature review contained both historical and current studies that supported the hypothesis in the science of firearm and tool mark identification that each firearm produces a signature of identification (striations) that is unique to that firearm, and through examining the individual striations, the signature can be positively identified to the firearm that produced it. The assembly line manufacturing process of consecutively manufactured firearms will inadvertently change the signature of each firearm; promoting Brundage’s hypothesis that bullets fired through the consecutive manufactured barrels will be distinguishable for each barrel.

Hamby (2001) also conducted an empirical study to determine whether or not firearm and tool mark examiners could properly identify bullets that were fired from consecutively manufactured gun barrels. He used a quasi experimental, quantitative design. His literature review contained both historical and current studies supporting Brundage’s (1998) framework. Hamby’s (2001) literature review also supported the hypothesis in the science of firearm and tool mark identification that each firearm produces a signature of identification (striations) that is unique to that firearm.
Furthermore, through examining the individual striations; the signature can be positively identified to the firearm that produced it.

Brundage’s (1998) target population was the forensic science community, more specifically, firearm and tool mark examiners. He used an abstract population for his research study. Brundage obtained 10 consecutively manufactured 9mm Ruger firearm barrels from the Storm Ruger Company. An independent assembler was utilized to make each test set, which included at least one question bullet from each barrel plus five additional bullets, all randomly selected. The test sets were sent to 30 firearm and tool mark examiners. Brundage’s sampling technique was a simple random sample because every firearm examiner in his abstract population had an equal opportunity to be included.

Hamby’s (2001) target population was also the forensic science community, and was specifically focused towards firearm and tool mark examiners. He used an abstract population for his research study. Hamby obtained the 10 consecutively manufactured 9mm firearm barrels that were utilized in the Brundage study. Hamby used three assistants to make each test set, which included at least one question bullet from each barrel plus five additional bullets, all randomly selected. The test sets, including Brundage’s numbers, were sent to 204 firearm and tool mark examiners. Hamby’s sampling technique was a simple random sample because every firearm examiner in his abstract population had an equal opportunity to be included.

Brundage’s (1998) method of data collection involved each examiner (participant) receiving two test fired bullets (known standards) from each of the 10 consecutive manufactured barrels. The examiners also received a total of 15 bullets (question bullets)
with instructions to determine which barrels fired the questioned bullets. Each examiner received an answer sheet to mark their results on. Each examiner used a comparison microscope for their examinations. Each answer sheet was either mailed back or faxed to the researcher.

Hamby’s (2001) method of data collection involved each examiner receiving two test fired bullets (known standards) from each of the 10 consecutive manufactured barrels. They also received a total of 15 bullets (question bullets) with instructions to determine which barrels fired the questioned bullets. Each examiner received an answer sheet to mark their results on. Each examiner used a comparison microscope for their examinations. Each answer sheet was either mailed back or faxed to the researcher.

The independent variable in Brundage’s (1998) study was the examination and comparison of the questioned bullets to the known standards, which were fired in the 10 consecutive manufactured Ruger barrels. The dependant variable measured whether or not the questioned bullets could be distinguished between consecutively manufactured gun barrels.

The independent variable in Hamby’s (2001) study was patterned after the Brundage (1998) study, which was the examination and comparison of the questioned bullets to the known standards, which were fired in the 10 consecutive manufactured Ruger barrels. Hamby’s (2001) dependant variable measured whether or not the questioned bullets could be distinguished between consecutively manufactured gun barrels.

In order to ensure reliability, Brundage (1998) labeled everything with a number and used containers to keep the questioned bullets separated into groups, and he used an
independent assembler. Brundage administered a pretest to five examiners prior to releasing his thirty tests. The validity of his study was dependent upon the accuracy of the assembly of the tests.

Hamby (2001) labeled everything with a number and used containers to keep the questioned bullets separated into groups in order to ensure reliability. Hamby conducted a 10% random sampling of his tests to validate that it was possible to correctly identify the questioned bullets prior to distribution. The validity of his study was dependent upon the accuracy of the assembly of the tests.

The key results from the Brundage (1998) study were that each of the 30 examiners returned their answer sheet, and that there were no wrong answers. The examiners were able to distinguish the questioned bullets from multiple consecutively manufactured gun barrels. The data collected demonstrates that consecutively manufactured gun barrels differ from each other, producing different signatures. The data also allows for the generalization that firearm and tool mark examiners, on a national level, can identify bullets as having been fired through a particular barrel to the exclusion of all others.

The key results from the Hamby (2001) study were that Hamby reported that a total of 201 examiners returned their answer sheets, and that there were no wrong answers. The examiners were able to distinguish the questioned bullets from multiple consecutively manufactured gun barrels. The data collected demonstrates that consecutively manufactured gun barrels differ from each other, producing different signatures. The data also allows for the generalization that firearm and tool mark
examiners, on a national level, can identify bullets as having been fired through a particular barrel to the exclusion of all others.

The key limitations of the Brundage (1998) study were that not all firearm barrels could be tested. It would probably be impossible to conduct such a test. All of the firearm and tool mark examiners in the world were not able to participate. Additionally, Brundage had to assume that the participants followed AFTE procedures and reached their conclusions independently. The environment of the 30 participants was not controllable, nor do we know the study conditions. The researcher was not able to identify or control extraneous variables at the other laboratories. Brundage (1998) generated the following areas of future study: additional testing utilizing other calibers, criterion for identification, and error rates.

Hamby’s (2001) key limitations were similar to Brundage’ (1998) limitations, which indicated that it would have been practically impossible to conduct such a test. Additionally, all of the firearm and tool mark examiners in the world were not able to participate. The environment of the participants was not controllable. The researcher was not able to identify or control extraneous variables at the other laboratories. Hamby (2001) generated the following areas of future study: additional testing utilizing other barrels, criterion for identification, and error rates.

Hamby and Brundage (2007) have continued the quest of the Brundage study. To date, they have had a total of 438 participants from 17 countries. There are 47 states in the United States represented. The error rate for their study is .001. According to Nichols (2007), “error rates have been studied and can provide consumers of the disciple
with a useful guide as to the frequency with which misidentifications are reported in the community using appropriate methodologies and controls" (2007, Abstract, ¶ 1).

Hamby (2008) reported that his worldwide 10 consecutively manufactured Ruger barrel research project had a total of 441 participants from 18 countries, which gained three participants and one country since last reported by Hamby and Brundage (2007). These numbers are significant because they demonstrate the reliability and validity in the science of firearm and tool mark identification. This study (Hamby, 2008) also demonstrated the general acceptance of the science through peer review and testability and error rate.

**Related Studies**

Miller (2000a) conducted an empirical study to determine whether or not a firearm and tool mark examiner could properly identify bullets that were fired from consecutively manufactured gun barrels. He used a quasi experimental, quantitative design. Miller’s literature review contained both historical and current studies supporting Brundage’s (1998) framework. Miller’s (2000a) literature review supported the hypothesis in the science of firearm and tool mark identification that each firearm produces a signature of identification (striations) that is unique to that firearm. Furthermore, through examining the individual striations; the signature can be positively identified to the firearm that produced it. Miller’s target population was the forensic science community, more specifically, firearm and tool mark examiners. He used an abstract population for his research study. Miller obtained two consecutively manufactured .44 caliber firearm barrels. Miller created known standards (test fired bullets), and the question bullets.
Bachrach (2002) conducted an empirical study to determine whether or not a 3D-based computer system could properly identify bullets that were fired from consecutively manufactured gun barrels. He used a quasi experimental, quantitative design. Bachrach’s target population was the forensic science community, more specifically, firearm and tool mark examiners. He used an abstract population for his research study. Bachrach obtained three consecutively manufactured 9mm caliber Beretta firearm barrels. Bachrach created known standards (test fired bullets), and question bullets.

Roberge and Beauchamp (2006) also conducted an empirical study to determine whether or not a 3D-based computer system could properly identify bullets that were fired from consecutively manufactured gun barrels. They used a quasi experimental, quantitative design. Roberge and Beauchamp’s target population was the forensic science community, more specifically, firearm and tool mark examiners. They used an abstract population for their research study.

The independent variable in Miller’s (2000a) study was the examination and comparison of the questioned bullets to the known standards, which were fired in the two consecutively manufactured barrels. The dependant variable measured whether or not the questioned bullets could be distinguished between the two consecutively manufactured gun barrels. In order to ensure reliability, Miller labeled everything with a number. The validity of his study was dependent upon the accuracy of the assembly of the standard and questioned bullets.

The independent variable in Bachrach’s (2002) study was the examination and comparison of the questioned bullets to the known standards, which were fired in the three consecutively manufactured barrels. The dependant variable measured whether or
not the questioned bullets could be distinguished between the three consecutively manufactured gun barrels. The validity of his study was dependent upon the accuracy of the assembly of the standard and questioned bullets.

Roberge and Beauchamp’s (2006) obtained known standards (test fired bullets) and questioned bullets that were fired in 10 consecutively manufactured 9mm caliber Hi-Point firearm barrels. The independent variable in their study was the examination and comparison of the questioned bullets to the known standards, which were fired in 10 consecutively manufactured barrels. The dependant variable measured whether or not the questioned bullets could be distinguished between the 10 consecutively manufactured gun barrels. The validity of his study was dependent upon the accuracy of the assembly of the standard and questioned bullets.

Miller (2000a) preformed all of the examinations himself and he 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 demonstrating that consecutively manufactured gun barrels differ from each other, producing different signatures, which supported Brundage’s (1998) framework.

Bachrach (2002) preformed all of the computer entries himself and he found that the 3D-based computer system could properly identify bullets that were fired from consecutively manufactured gun barrels. The key limitation of Bachrach’s study was the computer’s limited database. Bachrach generated the following areas of future study: additional testing utilizing other calibers, and larger databases.
Roberge and Beauchamp (2006) also preformed all of the computer entries themselves and they found that the 3D-based computer system properly identified the bullets that were fired from the consecutively manufactured 9mm Hi-Point firearm barrels. They did not list any limitations; however, the size of the computer’s database is believed to be a factor. Roberge and Beauchamp generated the following areas of future study: additional testing utilizing other calibers, and larger databases.

The key limitations of Miller’s (2000a) study were that he only used two barrels. Miller was the only firearm and tool mark examiner who participated in his study. Additionally, we do not know what Miller’s environment was, nor did he state whether or not he was able to control extraneous variables. Miller generated the following areas of future study: additional testing utilizing other calibers, criterion for identification, and error rates.

**Polygonal Rifled Barrels.** Haag (1977) conducted a study to determine whether or not a firearm and tool mark examiner could properly identify bullets that were fired from a Heckler and Koch polygonal gun barrel. He used a quasi experimental, quantitative design. Freeman (1978) followed up on Haag’s (1977) study and conducted a research study to determine whether or not a firearm and tool mark examiner could properly identify bullets that were fired from consecutively manufactured polygonal gun barrels. Freeman (1978) used a quasi experimental, quantitative design.

Hall (1983) conducted a research study to determine whether or not a firearm and tool mark examiner could properly identify bullets that were fired from consecutively manufactured polygonal rifled gun barrels. He used a quasi experimental, quantitative
design. Hall's literature review was limited; however, it supported Freeman's (1978) study and the hypothesis of science of firearm and tool mark identification.

Hocherman, Giverts and Shosani (2003) conducted a research study to determine whether or not a firearm and tool mark examiner could properly identify the manufacture of the firearms in which polygonal rifled bullets were fired in. They used a quasi experimental, quantitative design. Their literature review was limited, and brief.

Freeman's (1978) literature review was brief; however, it contained historical studies supporting the hypothesis in the science of firearm and tool mark identification that each firearm produces a signature of identification (striations) that is unique to that firearm. Furthermore, through examining the individual striations, the signature can be positively identified to the firearm that produced it, and that bullets fired through the consecutive manufactured barrels will be distinguishable for each barrel.

Haag (1977) obtained one Hecklor and Koch P9S pistol from the manufacturer for his study. He fired five bullets through the Hecklor and Koch P9S pistol. Each bullet was from a different manufacturer. Haag indexed the bullets and cartridges prior to test firing in order to assist with orientation for microscopic examinations.

Freeman's (1978) target population was the forensic science community, more specifically, firearm and tool mark examiners. He used an abstract population for his research study. Freeman obtained three consecutively manufactured 9mm caliber Heckler and Koch polygonal rifled firearm barrels. Freeman created known standards (test fired bullets), and the question bullets.

Hall's (1983) target population was also the forensic science community and was specifically focused towards firearm and tool mark examiners. He used an abstract
population for his research study. Hall obtained four consecutively manufactured polygonal rifled Shilen rifle barrels. Hall created known standards (test fired bullets), and the question bullets.

Hocherman’s et al. (2003) target population was the firearm and tool mark examiners in the forensic science community. They used an abstract population for their research study. They obtained three types of polygonal rifled pistols, of which they determined fit two profiles. They created known standards (test fired bullets), and the question bullets using different Glock, and Hecklor and Koch (H&K) pistols.

The independent variable in Freeman’s (1978) study was the examination and comparison of the questioned bullets to the known standards, which were fired in the three consecutively manufactured Heckler and Koch polygonal rifled firearm barrels. The dependant variable measured whether or not the questioned bullets could be distinguished between the three consecutively manufactured gun barrels. In order to ensure reliability, Freeman labeled everything. The validity of his study was dependent upon the accuracy of the assembly of the standard and questioned bullets.

The independent variable in Hall’s (1983) study was the examination and comparison of the questioned bullets to the known standards, which were fired in four consecutively manufactured polygonal rifled Shilen rifle barrels. The dependant variable measured whether or not the questioned bullets could be distinguished between the four consecutively manufactured gun barrels. Hall did not state how he ensured validity or reliability.

The independent variable in Hocherman’s et al study (2003) was the examination and comparison of the questioned bullets to the known standards, which were fired in the
aforementioned pistols. The dependant variable measured whether or not the questioned bullets could be distinguished between the two profiles of Glock and H&K pistols. The authors did not state how they ensured validity or reliability.

Haag (1977) reported that the barrel of the Heckler and Koch P9S pistol was hammer forged, which is “a process that involves no cutting as the steel is compressed around the form” (p. 46). Haag reported that there were some matching striations amongst some of the bullets; however, “others revealed no positive comparison” (p. 47).

Like Miller (2000a) and Haag (1977), Freeman (1978) performed all of the examinations himself and he was able to correctly distinguish the questioned bullets from the consecutively manufactured Heckler and Koch polygonal rifled firearm barrels demonstrating that consecutively manufactured gun barrels differ from each other, producing different signatures.

Hall (1983) also performed all of the examinations himself and he was able to correctly distinguish the questioned bullets from the consecutively manufactured polygonal rifled Shilen rifle barrels demonstrating that consecutively manufactured gun barrels differ from each other, producing different signatures. Like Miller (2000a), Hall (1983) noted that a subclass characteristic was present; however, it would not create a false identification.

The key limitation reported by Freeman (1978) was that one of the Heckler and Koch polygonal rifled firearm barrels used in his study did not mark as well as the other two. Freeman generated the following areas of future study: additional testing utilizing polygonal rifled barrels, and a criterion for identification.
The key limitations reported by Hall (1983) were that his study was limited to the four consecutively manufactured polygonal rifled Shilen rifle barrels. Hall generated the following areas of future study: additional testing utilizing polygonal rifled barrels, and a criterion for identification.

Six examiners were used in the Hocherman et al. (2003) study, and they had a 65% success rate in determining the manufacture. The authors did not list any limitations; however limitations present include training on rifling characteristics, as well as additional specimens. They suggested the following areas of future study: additional testing utilizing polygonal rifled barrels, and the examination of subclass characteristics within the polygonal family.

Giverts, Springer, and Argaman (2004) presented a technical note citing the inability of the Integrated Ballistics Identification System, which is a computerized database, to search and match unknown fired polygonal bullets. They cited the study of Hocherman et al. (2003), and indicated that the Integrated Ballistics Identification System needs to change its acquisition process. This technical information was brief, and needs to be explored further.

The New York Police Department (NYPD) (1996) conducted a research study comparing bullets that were fired through polygonal barrels and conventionally rifled barrels. The main purpose of the study was to determine the bullets suitability for microscopic comparisons. NYPD fired 10 cartridges through 20 polygonal barrels and 20 conventionally rifled barrels. NYPD concluded that the ability to identify bullets that were fired through polygonal barrels would be unlikely. They also found that
conventionally rifled barrels produced better microscopic marks for identification than polygonal barrels.

**The Miami Barrel.** Carr and Fadul (1997) conducted a study to determine whether or not a firearm and tool mark examiner could readily identify bullets that were fired from 22 different pistols. Additionally, five Glock barrels marked with the electronic spark reduction method, which started the revolution of the Miami Barrel, were used. They used a quasi experimental, quantitative design. Carr and Fadul's target population was the forensic science community, more specifically, firearm and tool mark examiners. They used an abstract population for their study. They obtained 22 different pistols, and five Glock barrels marked with the electronic spark reduction. Carr and Fadul created known standards (test fired bullets), and the question bullets.

Fadul and Nunez (2003) conducted a study on the Miami Barrel to determine whether or not Glock Inc, improved its ability to reproduce identifiable striations that could be readily identifiable. They used a quasi experimental, quantitative design. Their target population was the forensic science community, more specifically, firearm and tool mark examiners. Fadul and Nunez used 22 Miami Barrels manufactured by Glock in their study. They created known standards (test fired bullets), and the question bullets.

Fadul and Nunez (2006) conducted a follow-up study on the Miami Barrel to determine whether or not Glock Inc, improved its barrel’s ability to reproduce identifiable striations that could be readily identifiable. They used three Miami Barrels manufactured by Glock, which incorporated a new version of the single cutter used in the Fadul and Nunez 2003 study. Glock called the cutter the Enhanced Bullet Identification System; however, the barrel is still named the Miami Barrel. Fadul and Nunez created
known standards (test fired bullets), and the question bullets with the three new Miami Barrels.

Chin and Sampson (2007) followed up the Fadul and Nunez 2006 study on the Miami Barrel to determine whether or not Glock Inc’s Enhanced Bullet Identification System (EBIS) reproduced identifiable striations that would allow unknown samples to be identified to known standards. The researchers used four Miami Barrels manufactured by Glock, which incorporated the EBIS.

Martinez (2008) conducted a study to test the durability of the Miami Barrel to determine whether or not Glock Inc’s EBIS reproduced identifiable striations that would allow unknown samples 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 at a minimum fired through the barrel, and no more than 10,000 maximum.

The independent variable in the Carr and Fadul (1997) study was the examination and comparison of the questioned bullets to the known standards, which were fired in the weapons used for this study. The dependant variable measured whether or not the questioned bullets could readily identified to the known standards. The authors did not state how they ensured validity or reliability.

The independent variable in the Fadul and Nunez study (2003) was the examination and comparison of the questioned bullets to the known standards, which were fired through the 22 Miami Barrels. The dependant variable measured whether or not the questioned bullets could be readily identified to the known standards. The authors did not state how they ensured validity or reliability.
The independent variable in the Fadul and Nunez's (2006) study was the examination and comparison of the questioned bullets to the known standards, which were fired through the new Miami Barrels. The dependent variable measured whether or not the questioned bullets could be readily identified to the known standards. The authors did not state how they ensured validity or reliability.

Chin and Sampson (2007) created known standards (test fired bullets), and the question bullets with the four Miami Barrels. The independent variable in their study was the examination and comparison of the questioned bullets to the known standards, which were fired through the Miami Barrels. The dependent variable measured whether or not the questioned bullets could be identified to the known standards. The authors utilized a blind study to ensure validity and reliability.

The independent variable in the Martinez (2008) study was the examination and comparison of the questioned bullets to the known standards, which were fired through the Glock EBIS Barrels. The dependent variable measured whether or not the questioned bullets could be identified to the known standards. Martinez utilized a blind study to ensure validity and reliability.

Three firearm and tool mark examiners participated in the Carr and Fadul (1997) study. This study found that all of the weapons except Glock and H&K 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.

Nine firearm and tool mark examiners participated in the Fadul and Nunez (2003) study. This study found that Glock used a single cutter that was pulled through their
polygonal rifled barrel, which created a subclass characteristic. All nine examiners concluded that the new Miami barrel was not readily identifiable. The key limitations of Fadul and Nunez’s study were that they did not cite extraneous variables. They generated future study in the Miami Barrel.

The key limitations of Carr and Fadul’s (1997) study were that they only had three firearm and tool mark examiners participate in their study, and no extraneous variables were cited. They generated the following areas of future study: the Miami Barrel, Electronic spark reduction method, and the capability of identifying bullets to the originating Glock pistol.

Fadul and Nunez (2006) concluded that that the new Miami barrel was readily identifiable. They did not list the number of participants. Their key limitation was that they were only able to examine three barrels and they expressed a concern of the subclass characteristics. They suggested future study in the Miami Barrel; specifically with consecutively rifled polygonal barrels utilizing the Enhanced Bullet Identification System.

Chin and Sampson (2007) concluded that that the questioned bullets and known standards (test fired bullets) were correctly identified. They did not list the number of participants. Their key limitation was that they were only able to examine four barrels. They expressed the same concern that Fadul and Nunez (2006) expressed about the subclass characteristics. This study (Chin & Sampson 2007) suggested that there is a need for future study with consecutively rifled polygonal barrels utilizing the Enhanced Bullet Identification System.
The Martinez (2008) study reported that 29% of the participants with 5 to 10 years of experience reported via survey testing that there were not enough individual characteristics present to conclude an identification, and/or elimination. Additionally, 14% of the participants 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.

Haag (2003; 2006a) introduced a method that utilized a grinding compound to individualize polygonal barrels. He found that placing a couple drops of a rubbing compound on the nose of a bullet that was fired in the weapon created reproducible, identifiable striations. The key limitation of this method was that the manufacturer considered this method to be an alteration to the weapon; therefore, invalidating the factory warranty, and/or contract (A. Valdes, personal communication, June 2, 2003).

Other Consecutively Manufactured Gun Parts

Slides, Breech Bolts and Ejectors

Coody (2003) conducted a study to determine whether or not a firearm and tool mark examiner could properly identify fired casings that were fired from consecutively manufactured firearm slides. She used a quasi experimental, quantitative design. Coody’s literature review contained brief historical and current studies supporting previous studies conducted by Brundage (1998), and Miller (2000), as well as the hypothesis in the science of firearm and tool mark identification that each firearm produces a signature of identification that is unique to that firearm. Furthermore, through examining the individual striations, the signature can be positively identified to the firearm that produced it. Coody’s (2003) target population was the forensic science
community, more specifically, firearm and tool mark examiners. She used an abstract population for her research study. Coody obtained 10 consecutively manufactured Ruger P-89 slides, which were designated for the 9mm caliber. Coody created known standards (test fired casings), and the question casings.

Coffman (2003) conducted a study to determine whether or not a firearm and tool mark examiner could properly distinguish tool marks on casings by identifying them to the breech bolts that produced them. He used a quasi experimental, quantitative design. Coffman failed to include a literature review. Coffman’s target population was also the forensic science community, and focused towards firearm and tool mark examiners. He used an abstract population for his research study. Coffman obtained 10 manufactured Remington Model 870 production run breech bolts. Coffman created known standards (test fired casings), and questioned casings.

Finklestein, Kaofman and Siso (2005) conducted an experiment to determine what caused the tool mark (tornado shaped) at the mouth of a cartridge casing that was fired in a Glock pistol. They used a quasi experimental, quantitative design, and they did not provide a literature review. Finklestein and colleague’s (2005) target population was the firearm and tool mark examiners in the forensic science community. They used an abstract population for their research project. They used 19 different models of Glock pistols, of which 17 models were 9mm caliber, one was a .40 caliber, and the last one was a .45 caliber. It was impossible for them to examine and test fire every Glock pistol in the world. They also test fired four other pistols of different manufacturers. The researcher’s sampling technique was a simple random sample because every cartridge
casing in their abstract population had an equal opportunity to receive the ejection port mark.

The independent variable in Coody’s (2003) study was the examination and comparison of the questioned casings to the known standards, which were fired in the 10 consecutively manufactured Ruger P-89 slides. The dependant variable measured whether or not the questioned casings could be distinguished between the consecutively manufactured Ruger slides. In order to ensure reliability, Coody labeled her questioned casings and known standards with letters and numbers. The validity of his study was dependent upon the accuracy of the assembly of the standard and questioned casings.

The independent variable in Coffman’s (2003) study was the examination and comparison of the questioned casings to the known standards, which were fired by the 10 Remington Model 870 production run breech bolts. The dependant variable measured whether or not the questioned casings could be distinguished between the manufactured Remington breech bolts. Coffman used random label assignment to ensure reliability. The validity of his study was dependent upon the accuracy of the assembly of the standard and questioned casings.

The data collection in the Finklestein et al. (2005) study was obtained by the two experimenters and one participant. The data was recorded by the experimenters, based on their observation. Each fired cartridge casing was physically and microscopically examined. The independent variable in this research paper was the use of two different magazines, as well as hand loading without using the magazines. The dependant variable in this paper measured whether or not the two different magazine fed cartridge casings, as well as the loaded magazines ended up with the ejection port marks.
Coody (2003) performed all of the examinations herself and she concluded that it is possible to properly identify fired casings that were fired from consecutively manufactured Ruger P-89 firearm slides, which substantiated the earlier work of Brundage (1998) and Miller (2000a). Coffman (2003) also performed all of the examinations himself and he concluded that it is possible to properly identify fired casings that were fired by Remington Model 870 production run breech bolts, substantiating the science of firearm and tool mark examinations.

In order to ensure reliability, Finklestein et al. (2005) test fired 10 rounds consisting of the same two manufacturers through each weapon. They then test fired an additional eight rounds of multiple manufacturers through each weapon. Finklestein et al. also used two different magazines and a hand loading approach with one weapon. The validity of this study was the consistent appearance of the ejection port mark (tornado shaped tool mark) on each cartridge casing that was fired through the Glock pistols. Additionally, an open case file containing fired cartridge casings from suspect Glock pistols were examined and compared with the current casings.

Finklestein et al. (2005) reported that every cartridge casing fired in a Glock pistol had an ejection port mark (tornado shaped tool mark) on its body towards the mouth of the casing. These marks were caused by the ejection port. Due to the location, the null hypothesis of the chamber causing the mark was rejected. The additional null hypothesis of the mark being produced by the magazine was also rejected. The cartridge casings that were fired from two different magazines, plus the hand-fed cartridge casings all had the ejection port mark (tornado shaped tool mark), and they were positively identified to one source. The tool mark was produced as a result of the cartridge casing being ejected from
the pistol. The cartridge casing hits against the left inner side of the ejection port as it is being ejected from the firearm. Finklestein et al. also found that other pistols may produce a similar mark; however, they do not produce it each time like the Glock pistols did. This experiment (Finklestein et al., 2005) supports the other listed studies because these tool marks are unique to themselves and they can be identified to other cartridge casings fired from the same gun. They were also distinguished from cartridge casings fired from different guns.

Coody (2003) did not cite any limitations; however, she did not state the criteria that she used for her identifications. Additionally, Coody was the only firearm and tool mark examiner who participated in her study, and we do not know what extraneous variables may have existed. Coody generated the following areas of future study: additional testing utilizing other consecutively manufactured slides, and a criterion for identification.

Coffman (2003) did not cite any limitations. Coffman also did not state the criteria that he used for his identifications. Additionally, Coffman was the only firearm and tool mark examiner who participated in his study, and we do not know what extraneous variables may have existed. Coffman generated the following areas of future study: additional testing utilizing other caliber breech bolts, and a criterion for identification.

Key limitations of the Finklestein et al., (2005) experiment were that the authors rubbed a white powder on the ejection port to locate the source. They could have taken pieces of lead and pushed them against the left inner side of the ejection port creating standards that were known to have been produced by the ejection port. Areas of future
research could include pushing lead across the ejection port in order to identify the
ejection port as the source. Additionally, more weapons should be examined for this
study.

Consecutively Manufactured Tools

Knives

Seminal studies (Bonte, 1975; Galan, 1986; Kockel, 1980; May, 1930; Rao &
Hart, 1983; Tuira, 1982; Tuira, 1989; Watson, 1978) guided the framework for research
involving knife impressions. May (1930) conducted over 100 tests involving knives and
there impressions. Watson (1978) tested two consecutively manufactured knives and
determined that they both contained an individual signature that was identifiable. Tuira
(1982, 1989) validated Watson’s (1978) study using two different consecutively
manufactured knives. Tuira (1982, 1989) used tires to make his impressions, where as
Watson’s (1978) utilized wire similar to telephone wire.

According to Bonte (1975), the grinding process applied during manufacturing
individualizes the knife’s signature. Kockel (1980) discussed defects as individual
characteristics. Rao and Hart (1983) made an identification in actual case work. The
Rao and Hart identification involved a stabbing victim, in which Hart identified the
suspect knife as having produced the tool mark that was made in the victim’s rib
cartilage. Galan (1986) identified the knife that made a knife wound made in bone,
which was also a criminal case.

Thompson and Wyant (2003) conducted an empirical study to determine whether
or not firearm and tool mark examiners could properly identify knife impressions that
were made by 10 consecutively manufactured knives. Their study paralleled Brundage’s
study of 10 consecutively manufactured barrels. Thompson and Wyant used a quasi experimental, quantitative design. Thompson and Wyant’s literature review contained cited peer review journal articles with no explanation.

Clow (2005) conducted an empirical study to determine whether or not firearm and tool mark examiners could properly identify consecutively manufactured knives to stab wounds in cartilage. He used a quasi experimental, quantitative design. His literature review contained both historical and current studies supporting the hypothesis in the science of firearm and tool mark identification that each knife produces a signature of identification (striations) that is unique to that individual knife and through examining the individual striations, the signature can be positively identified to the knife that produced it.

Clow (2005) presented that the assembly line manufacturing process of consecutively manufactured knives will inadvertently change the signature of each knife; promoting his hypothesis that consecutively manufactured knives can make identifiable impressions that can be distinguished from each other. Additionally, cartilage is an acceptable medium capable of reproducing a knife impression for identification.

Thompson and Wyant’s (2003) target population was the forensic science community, more specifically, firearm and tool mark examiners. They used an abstract population for their research study. Thompson and Wyant obtained 10 consecutively manufactured knives to make impressions for their study. The test sets were deployed to 140 firearm and tool mark examiners. Thompson and Wyant’s sampling technique was a simple random sample because every firearm examiner in their abstract population had an equal opportunity to be included.
Clow's (2005) target population was the firearm and tool mark examiners in the forensic science community. He used an abstract population for his research project. Clow obtained the 10 consecutively manufactured knives that were used in the Knife Identification Project, which was dubbed KIP (Thompson & Wyant, 2003). Clow's sampling technique was a simple random sample because every knife in his abstract population had an equal opportunity to produce striations in cartilage.

Thompson & Wyant's (2003) method of data collection involved each examiner receiving one set of test impressions for each knife (known standards), and 10 questioned impressions. Each examiner received an answer sheet to mark their results on. According to the researchers, each examiner used a comparison microscope for their examinations. The independent variable in Thompson and Wyant's study was the examination and comparison of the questioned impressions to the known standards, which were made by 10 consecutively manufactured knives. The dependant variable measured whether or not the questioned impressions could be distinguished between consecutively manufactured knives.

Clow (2005) used a comparison microscope, and personal observation for his method of data collection. He examined the striations in both his test mark impressions, and the cartilages. The independent variable in this research study was examination and comparison of the questioned tool marks to the known standards, which were made by the 10 consecutive manufactured knives. The dependant variable in this study measured whether or not the questioned tool marks could be distinguished between consecutively manufactured knives.
Thompson and Wyant (2003) labeled everything with numbers and letters in order to ensure reliability. They administered a pretest to eight examiners prior to releasing their 140 test sets. The validity of their study was dependent upon the accuracy of the assembly of the tests. In order to ensure reliability, Crow (2005) used a jig to keep all stab impressions (standards and questions) the same angle and depth. Additionally, he also labeled everything with a number. The validity of this study was maintained by using blind testing. Clow created a blind test in which he administered to five firearm and tool mark examiners.

The key results of the Thompson and Wyant (2003) study were that they reported that 103 out of 140 examiners from around the world returned their answer sheets. Thompson and Wyant calculated an error rate of 0.8%. The data collected demonstrates that consecutively manufactured knives differ from each other, producing different impressions. The data also allows for the generalization that firearm and tool mark examiners, on a national level, can identify impressions as having been made by a particular knife to the exclusion of all others.

Clow (2005) reported that each of his participants was able to identify the impressions to the knives that produced them and they were able to distinguish them from the remaining consecutively manufactured knives. The data collected demonstrated that consecutively manufactured knives differ from each other, producing different signatures. The data also suggested that firearm and tool mark examiners, on a national level, could identify stabbing impressions as having been made by a particular knife to the exclusion of all others. Another key result was that cartilage was an acceptable medium for obtaining tool marks. The impressions that were made in the cartilage were identified to
the knives that produced them. Thirdly, the rate of speed of the stabbing motion did not matter.

The key limitations of the Thompson and Wyant (2003) study were that not all knives and test mediums were tested. A total of 37 firearm and tool mark examiners did not return their answerer sheets. Additionally, Thompson and Wyant had to assume that the participants followed proper AFTE procedures and reached their conclusions independently. The environment of the participants was not controllable, nor do we know their conditions. The researchers were not able to identify or control extraneous variables at the other laboratories. Thompson and Wyant generated the following areas of future study: additional testing utilizing other mediums, criterion for identification, and error rates.

The key limitation of the Clow (2005) study was that Clow used cartilage from a pig. It could be argued that there is no validation studies that prove that human cartilage would be an acceptable medium for the reproduction of tool marks. Additionally, the number of participants was minute. Areas of future research could include additional participants from across the United States. Other tools that could be used in a stabbing motion such as ice picks, scissors, and screwdrivers could be utilized.

**Chisels**

Tulleners, Stoney and Hamiel (1999) conducted an empirical study to compare the patterns of striations produced by consecutively manufactured chisels, as well as randomly chosen chisels. They used a quasi experimental, quantitative design. Tulleners et al. used an abstract population for their research project. They obtained six consecutively manufactured chisels and four random manufactured chisels.
Eckerman (2002) conducted an empirical study to determine whether or not firearm and tool mark examiners could properly identify tool mark impressions to consecutively manufactured chisels. She used a quasi experimental, quantitative design. Eckerman’s literature review contained an in-depth review, which supports the hypothesis in the science of firearm and tool mark identification. Eckerman’s (2002) target population was the forensic science community, more specifically, firearm and tool mark examiners. She used an abstract population for her research project. Eckerman obtained four sets of three consecutively manufactured chisels. Her sampling technique was a simple random sample because every chisel in her abstract population had an equal opportunity to produce identifiable impressions.

Tulleners et al. (1999) used six student interns, and personal observation for their method of data collection. The independent variable in this research paper was examination and comparison of the impressions, which were made by the six consecutively manufactured chisels, as well as the four randomly selected chisels. The dependant variable measured the number of consecutive matching striations.

Eckerman (2002) used a comparison microscope, and personal observation for her method of data collection. She examined the striations in all impressions. The independent variable in this research paper was examination and comparison of the impressions, which were made by the four sets of three consecutively manufactured chisels. The dependant variable measured whether or not the impressions and chisels could be distinguished between each other. Eckerman did not state how she ensured reliability or validity; however, she did number her chisels.
Tulleners et al. (1999) reported that they found a clear distinction between known identifications and known non-identifications. They also reported that the chisels themselves were individualized to the marks that they produced, creating an objective measureable threshold. Eckerman (2002) reported that she was able to distinguish each chisel from one and other. She also reported finding subclass characteristics. The data collected demonstrated that consecutively manufactured chisels differ from each other, producing different signatures. The data also suggested that the results can be generalized for all chisels. Eckerman did not cite any limitations; however, she did not state the criteria that she used for her comparisons. Additionally, Eckerman was the only firearm and tool mark examiner who participated in her study, and we do not know what extraneous variables may have existed. Eckerman wishes to expand her research in the future to include grinding belts.
Discussion of the Literature

Summary and Interpretations

High Profile police involved shootings in the City of Miami lead to the creation of the Miami Barrel. These series of high profile police involved shootings enraged the community, and attracted mass media attention (Epstein, 1993; Epstein, 1994a; Epstein, 1994b; Epstein, 1994c). The Miami-Dade Police Department (MDPD) Crime Laboratory Bureau examined the evidence in these shootings and was unable to positively identify which officer’s Glock pistol fired the fatal shots.

MDPD’s inability to identify the fired bullets to an individual Glock pistol prompted political pressure within the community, as well as within the police circle. This resulted in an in-depth study of Glock’s polygonal rifled barrels, which resulted in the manufacturing of the Miami Barrel.

The issue is the capability of identifying a particular tool (firearm) to a specific tool mark (striated impression on a fired bullet). More specifically, the issue of being able to identify a bullet as having been fired in a particular firearm to the exclusion of all other firearms in the world comes into question. There is no set number of matching striations that are needed when identifying two tool marks as having been produced by one tool/firearm. A set number needs to be established (Miller, 2000b; Miller & McLean, 1998). Tool mark identification is not objective; it appears to be subjective in nature. A major research problem exists because it is impossible to examine every tool/firearm manufactured in the world. What is sufficient agreement?

Additionally, can firearm and tool mark examiners properly identify bullets that were fired from consecutively manufactured gun barrels? Firearm and tool mark
examiners base their identifications on individual matching striations, their length, width, spatial relationship, surface contour and the number of these lines that are present. These striations are a result of minute imperfections on a cutting tool that cuts the lands and grooves into a barrel of a firearm.

The lands and grooves are what cause the bullet to spin when it takes flight. When a bullet travels through a gun barrel, the bullet is scored by the minute imperfections that resulted in the manufacturing process, and appear on the bullet as striations (fine microscopic lines). For example, run a rake through sand and you will create lines such as those that would be on a bullet. The lands and grooves of the Miami Barrel are rounded, where as the barrels in the Brundage study (1998), were conventionally square. The question is, does the cutting tool used in the Miami Barrel change enough from barrel to barrel in order to allow examiners to distinguish between them, and if so, can Miller’s (1998, 2000b) criteria for identification be applied?

**Theoretical Literature**

*Pattern Matching.* The theory of pattern matching has been accepted as the traditional method for concluding an identification in the forensic science community and the forensic science disciplines of fingerprint identification, shoe impression evidence and tire impression evidence, as well as the discipline of the science of firearm and tool mark examinations.

The traditional method of pattern recognition has been deployed since its inception in each of the aforementioned forensic science disciplines. Cases such as Will and William West, Brownsville Texas Raid, Steilow, Saco and Vanzetti, as well as the St.
Valentine’s Day massacre set the corner stone for the pattern matching theory in today’s science.

The main issue with the pattern matching theory is that it is subjective in nature and dependent upon the training and experience of the examiner. There is no set number of individual characteristics required to conclude an identification when utilizing the theory of pattern matching. An identification is based upon the overall pattern and the individual characteristics that are present.

Opponents of the pattern matching theory claim that conclusions can not be quantitatively explained; however, Galton concluded mathematically that the chances were “64,000,000,000 to 1” that two humans possessed the same fingerprint patterns (Menzel, 1983, p.5).

The Association of Firearm and Tool Mark Examiners, which is the professional organization for the forensic science discipline of firearm and tool mark examinations, supports the pattern matching theory. The association maintains that pattern matching “enables opinions of common origin to be made when the unique surface contours of two tool marks are in sufficient agreement” (AFTE, 1992, p. 337).

Sufficient agreement is the “significant duplication of random tool marks as evidenced by the correspondence of a pattern or combination of patterns of surface contours. The statement that sufficient agreement exists between two tool marks means that the likelihood another tool could have made the mark is so remote as to be considered a practical impossibility” (AFTE, 1992, p. 337). Therefore, the theory of pattern matching has been generally accepted in the legal arena.
Consecutive matching lines (CMS). The theory of consecutive matching lines was introduced by seminal empirical studies (Biasotti, 1959; Biasotti & Murdock, 1984). They determined that a set number of consecutive matching lines could be used to make an identification. The work of Biasotti and Murdock suggested that a quantitative number could be used by a firearm and tool mark examiner to explain a conclusion that was reached through pattern recognition. The theory of consecutive matching lines could change the conclusions reached by firearm and tool mark examiners from a subjective opinion to an objective opinion. The major limitation of their work was the variance in the total number of matching lines.

A schematic model depicting these direct and indirect (known matches and known non-matches) relationships among concepts described by Biasotti was developed (Miller, 2000b; Miller, 2004 & Miller & McLean, 1998). The continued empirical study of this theory was scientifically significant in addressing essential issues about a quantitative numerical value in the discipline of firearm and tool mark examinations. Miller and McLean (1998) were able to distinguish criteria for consecutive matching lines in both two dimensional images, and three dimensional images, adding credence to the theory of consecutive matching lines. Their counts appear to be within an acceptable range, and are consistent with a previous study that was conducted by Biasotti (1959), and Biasotti and Murdock (1984). Miller and McLean should have used the test-retest reliability, which could have been easily administered by having another qualified examiner count all the lines.

My overall impression of Miller and McLean’s study is very positive. Their paper was well constructed, and thought out. I have mixed emotions about Miller and
McLean’s point of view. I agree that you need to have a qualified firearm and tool mark examiner to interpret the results of the identifications. I do not agree on basing tool mark identifications solely on the amount of consecutive matching lines, or dismissing tool mark identifications solely on the absence of consecutive matching lines.

Miller’s (2000b) study further validated the theory of consecutive matching lines. His results corroborated a quantitative standard for identification in both two dimensional images, and three dimensional images. Miller was unable to place an arbitrary number on the number of total matching lines. My reaction to this study is as follows: based on Miller’s study, and employing his criteria of consecutive matching lines, no bad/wrong identifications would be made. However, one may fail to make an identification, resulting in a false elimination.

Miller (2001) applied the theory of consecutive matching lines to the Brundage (1998) study. Miller’s results supported his study (2000b). He concluded that there would be no erroneous identifications applying the theory; however, the possibility to exclude a positive identification exists. Both studies (Miller, 2000b; & Miller 2001) suggest a major limitation, which is the exclusion of a positive identification. I do not agree with basing firearm and tool mark identifications solely on the amount of consecutive matching lines, or dismissing tool mark identifications solely on the absence of consecutive matching lines, because it may lead you to dismiss a positive identification.

Nichols (2003) does not believe that it is possible to exclude a positive identification using the theory of consecutive matching lines. He stated that if the impressions did not meet the criteria of the theory, then it would not be an identification,
and therefore, if it is not an identification by the standard, then you are not excluding an identification. Consecutive matching lines identifies “a numerical threshold that allows one to distinguish between what constitutes an identification from a non-identification or inconclusive” (p. 303). I disagree with Nichols, because I have seen numerous identifications in which did not meet the criteria of the theory of consecutive matching lines.

Neel (2007) completed a comprehensive statistical analysis which supports the CMS theory. He quantified the striations and documented a substantial statistical difference between identifications and non-identifications, which further supports the CMS theory. Neel’s statistical analysis was very positive for the CMS theory and it strengthened the CMS cause; however, the lack of CMS could result in an inability to make an identification.

Most examiners utilize pattern matching (Mancini, 2008; SWGGUN, 2007). They base their identifications on individual matching striations, their width, length, special relationship, surface contour and the number of these lines that are present. They do not count lines, it is more of a mental observation. It is subjective and is based on the training and experience of the examiner. Line counting is a phenomenon that originated on the West Coast. It may have some merit, and it definitely brings an objective approach to the table. The theory of consecutive matching lines may be a viable method for identifying tool mark impressions in an objective manner. The theory may also prove to be a viable means to document an identification with a numerical number.
Empirical Literature

The hypothesis in 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 examining the individual striations/impressions, the signature can be positively identified to the firearm/tool that produced it.

Consecutively manufactured barrels. Several empirical studies were conducted to determine whether or not firearm and tool mark examiners could properly identify bullets that were fired from consecutively manufactured gun barrels (Bachrach, 2002; Brundage, 1998; Freeman, 1978; Hall, 1983; Hamby, 2001; Hamby & Brundage, 2007; Miller, 2000a; Roberge & Beauchamp, 2006). All studies used a quasi experimental, quantitative design. Their studies supported and validated the hypothesis.

Freeman (1978), Hall (1983), and Miller’s (2000a) studies were conducted by themselves. Freeman and Hall used polygonal rifled barrels, while Miller and Brundage (1998) used conventionally rifled barrels. Freeman correctly distinguished the questioned bullets from the consecutively manufactured Heckler and Koch polygonal rifled firearm barrels. Hall correctly distinguished the questioned bullets from the consecutively manufactured polygonal rifled Shilen rifle barrels. Both Freeman and Hall demonstrated that consecutively manufactured gun barrels differ from each other, producing different signatures. There was a major gap with the study of polygonal rifled barrels.

The original Brundage (1998) study, followed by Hamby (2001), and Hamby and Brundage (2007) were the most in-depth, utilizing a total of 438 participants (firearm and tool mark examiners). All of 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, supporting the hypothesis.

The Brundage (1998), Hamby (2001), and Hamby and Brundage (2007) studies were excellent studies for the forensic discipline of firearm and tool mark examinations. These studies demonstrated an excellent error rate for the identification field. The random nature in which these tests were constructed eliminated any bias. I share their point of view that examiners can properly identify fired bullets to the correct barrel, even if they were consecutively manufactured. My overall impression of their papers was that they were excellent. There studies support the science of firearm and tool mark identification. It adds proven validity to the field.

**Other consecutively manufactured gun parts.** Additional studies, conducted on other consecutively manufactured gun parts supported the hypothesis of firearm and tool mark identification. Coody (2003), Coffman (2003), and Finklestein, Kaofman and Siso (2005) all used a quasi experimental, quantitative design. Coody studied slides, Coffman studied breech bolts, and Finklestein, Kaofman and Siso studied ejection port marks.

Coody (2003) determined that it was possible to properly identify fired casings that were fired from consecutively manufactured firearm slides, which substantiated the hypothesis. Coffman (2003) determined that it was possible to properly identify fired casings that were fired by production run breech bolts, which further substantiated the hypothesis.

Finklestein, Kaofman and Siso (2005) determined that every cartridge casing fired in a Glock pistol in their study had an ejection port mark (tornado shaped tool mark), and
that they were caused by, and identified to the ejection port. I agree with Finklestein et al., and their results. They presented a valid and valuable study for the forensic community; however, they should have been innovative. For example, they should have taken pieces of lead and pushed them against the left inner side of the ejection port creating standards that were known to have been produced by the ejection port. The authors rubbed a white powder on the ejection port to locate the source.

**Consecutively Manufactured Tools.** Tulleners et al. (1999) and Eckerman (2002) conducted empirical studies utilizing consecutively manufactured chisels. Both studies utilized a quasi experimental, quantitative design. Tulleners et al. (1999) reported that the chisels themselves were individualized to the marks that they produced. Eckerman (2002) was able to distinguish each chisel from one another. Both Tulleners et al. (1999) and Eckerman's (2002) data collection demonstrated that consecutively manufactured chisels differ from each other, producing different signatures, supporting the hypothesis.

Seminal studies (Bonte, 1975; Galan, 1986; Kockel, 1980; May, 1930; Rao & Hart, 1983; Tuira, 1982; Tuira, 1989; and Watson, 1978) guided the framework for research involving knife impressions. Rao and Hart (1983), and Galan (1986) made positive identifications in actual criminal cases.

Thompson and Wyant (2003) conducted an empirical study to determine whether or not firearm and tool mark examiners could properly identify knife impressions that were made by 10 consecutively manufactured knives using a quasi-experimental, quantitative design. A total of 103 examiners from around the world reported results. Thompson and Wyant calculated an error rate of 0.8%. The data collected demonstrated that consecutively manufactured knives differ from each other, producing different
impressions, which supported the hypothesis. This study paralleled Brundage’s 1998 study of 10 consecutively manufactured barrels.

Clow (2005) used a quasi-experimental, quantitative design to determine whether or not firearm and tool mark examiners could properly identify 10 consecutively manufactured knives to stab wounds in cartilage. Clow used the same knives as the Thompson and Wyant (2003) study. Clow reported that five the examiners were able to identify the impressions to the knives that produced them and they were able to distinguish them from the remaining consecutively manufactured knives. The data collected demonstrated that consecutively manufactured knives differ from each other, producing different signatures, which supported the hypothesis.

**The Miami Barrel.** Carr and Fadul (1997), Fadul and Nunez (2003), and Fadul and Nunez (2006), conducted an in-depth empirical study with Glock’s polygonal rifled barrel and the Miami Barrel. Early research (Carr & Fadul, 1997; Fadul & Nunez, 2003), demonstrated that Glock’s polygonal rifled barrel and the Miami Barrel were not readily identifiable.

Fadul and Nunez (2006) conducted a follow-up study on the Miami Barrel and determined that Glock Inc improved its barrel’s ability to reproduce identifiable striations. They found the new barrels readily identifiable. Their key limitation was that they were only able to examine three barrels and they expressed a concern of the subclass characteristics. The data in this study supported the hypothesis; however, future study of the Miami Barrel; specifically with consecutively rifled polygonal barrels utilizing the Enhanced Bullet Identification System is needed.
Chin and Sampson (2007) conducted a study on the Miami Barrel to validate the Fadul and Nunez 2006 study. They utilized a blind study to ensure validity and reliability. Chin and Sampson concluded that that the questioned bullets and known standards (test fired bullets) were correctly identified, which validated the Fadul and Nunez 2006 study. Their key limitation was that they were only able to examine four barrels, which were not consecutively manufactured. They also expressed the same concern that Fadul and Nunez (2006) expressed about the subclass characteristics. The data in this study supported the hypothesis; however, this study suggested that there is a need for future study with consecutively rifled polygonal Miami barrels utilizing the Enhanced Bullet Identification System.

Martinez (2008) conducted a study to test the durability of the Miami Barrel to determine whether or not Glock Inc's Enhanced Bullet Identification System (EBIS) reproduced identifiable striations that would allow unknown samples to be identified to known standards. She reported that 29% of the participants with 5 to 10 years of experience reported via survey testing that there were not enough individual characteristics present to conclude an identification, and/or elimination. A total of 14% of the participants 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.

The Martinez (2008) study contradicts the research of Fadul and Nunez (2006), as well as the research of Chin and Sampson (2007). This researcher believes that Martinez (2008) results may be due to the following three factors: lack of examiner awareness with EBIS; the actual test itself; and/or the instructions provided by Martinez. The data
in this study supports the need for future study with consecutively rifled polygonal Miami barrels utilizing the Enhanced Bullet Identification System.

**Conclusion**

The theory of pattern matching has been accepted as the traditional method for concluding an identification in the forensic science community and the forensic science discipline of the science of firearm and tool mark examinations. The traditional method of pattern recognition has been deployed since its inception; however, it has been subjective in nature and dependent upon the training and experience of the examiner.

The hypothesis in firearm and tool mark identification is based on the premise that each firearm/tool produces a signature of identification (striation/impression) that is unique to that firearm/tool, and through examining the individual striations/impressions; the signature can be positively identified to the firearm/tool that produced it (Brundage, 1998).

Firearm and tool mark examiners base their identifications on individual matching striations, their width, length, spatial relationship, surface contour and the number of these lines that are present. They do not count lines; it is more of a mental observation. It is subjective and is based on the training and experience of the examiner.

Several empirical studies (Brundage, 1998; Clow, 2005; Coffman, 2003; Cody, 2003; Hamby, 2001; Hamby & Brundage, 2007; Miller, 2000a; Thompson & Wyant, 2003) have clearly documented and validated the theory and hypothesis of the forensic science discipline of firearm and tool mark identification. The major limitation of all of these studies was that the conclusions were reached based on the examiner’s training and experience. The results were based on a subjective opinion.
The theory of consecutive matching lines was introduced by seminal and empirical studies (Biasotti, 1959; Biasotti & Murdock, 1984; Miller, 2000b; Miller, 2004; Miller & McLean, 1998). They determined that a set number of consecutive matching lines could be used to make an identification, and that a quantitative number would make conclusions an objective opinion. Miller (2000b) concluded that there would be no erroneous identifications applying the theory; however, the possibility to exclude a positive identification exists.

Extensive research was conducted on Glock’s polygonal rifled barrel and the Miami Barrel. Fadul and Nunez (2006) determined that Glock Inc improved its barrel’s ability to reproduce identifiable striations. They found the new Miami Barrels readily identifiable. Chin and Sampson (2007) validated their study. These studies indicated that future research needs to be conducted on the Miami Barrel; specifically with consecutively rifled polygonal barrels utilizing the Enhanced Bullet Identification System.

The use of firearm violence is a global issue which affects every city, state, and nation. The threat that a criminal may go free or undetected threatens our environment. Firearm and tool mark examiners have the responsibility to examine firearms and related ballistic evidence. There conclusions help convict the guilty and exonerate the innocent.

The existing empirical and theoretical literature supported the hypothesis in firearm and tool mark identification, in which each firearm/tool produces a signature of identification (striation/impression) that is unique to that firearm/tool, and through examining the individual striations/impressions; the signature can be positively identified to the firearm/tool that produced it. This literature review has brought together some of
the existing theories and research to better understand the theoretical issues surrounding the hypothesis of firearm and tool mark identification.

The result of this analysis provides new knowledge on the issue in terms of providing a clearer, more complete understanding of the criteria of identification and indicates some areas in which additional scholarly study is needed. The Miami Barrel and the criteria for identification are researchable topics and the strategies recommended for study provide a framework for research. This concludes the critical analysis of the present literature on consecutively manufactured barrels, other gun parts, tools, and consecutive matching lines.
CHAPTER III
RESEARCH METHODOLOGY

Chapter III presents a description of the methodology that was utilized in this study of the relationship between the performance of pattern matchers and line counters, as well as the level of their experience. The research questions and hypotheses evolved from the gaps in the literature, as well as the need to examine the influence of pattern matching and line counting associated with bullets fired through Glock Miami Gun Barrels. This chapter begins with a discussion of the research design and continues with the study’s population and sampling plan, instrumentation, data collection procedures and ethical aspects, data analysis methods, and evaluation of this study’s research methods.

Research Design

This study utilized an experimental research design (Christensen, 2004; Creswell, 2005), and was conducted in a crime laboratory setting. Participants examined and compared questioned bullets to the known standards, which were be fired through ten consecutively manufactured Glock Miami Gun Barrels in order to determine whether or not consecutively manufactured Glock Miami Gun Barrels differ from each other, producing different signatures.

Quantitative data (Creswell, 2005) was analyzed to determine if the examiners who utilized pattern matching and line counting could correctly distinguish questioned bullets from multiple consecutively manufactured Glock Miami Gun Barrels. Additionally, the years of experience of the examiners was analyzed. This data demonstrated the following: whether or not consecutively manufactured Glock Miami Gun Barrels differ from each other, producing different signatures; whether pattern
matching or line counting is more accurate; and whether years of experience impacts perceived accuracy. Survey/answer sheets were utilized to collect the quantitative data (see Appendix A). Analysis of Variance (ANOVA) tests were utilized to examine the data (Garson, 2007).

Further Analysis based upon the recommendations for the future study resulting from the review of the literature and theoretical framework guided this study. Research questions and hypotheses were generated in this study about relationships between pattern matchers, line counters and the relationships between their levels of experience. The outcome in this section is presented with the intention that the findings will be able to answer the research questions.

**Research Questions**

Q1. Will firearm and tool mark examiners who use pattern matching reach different conclusions than those who use consecutive matching striations (line counting) when examining bullets fired through consecutively manufactured Glock Miami Gun Barrels?

Q2. Will firearm and tool mark examiners with less than 10 years of experience reach different conclusions than those with greater than 10 years of experience when examining bullets fired through consecutively manufactured Glock Miami Gun Barrels?

**Research Hypotheses**

H1. Pattern matchers will be more accurate than line counters when examining bullets fired through consecutively manufactured Glock Miami Gun Barrels.
H2. The experience level of firearm and tool mark examiners will affect results when examining bullets fired through consecutively manufactured Glock Miami Gun Barrels.

There are three dependent variables that were examined in this study. The first dependent variable is accuracy, which measured whether or not the questioned bullets could be distinguished between the consecutively manufactured Glock Miami Gun Barrels. The second dependent variable is variation, which measured the difference of the results between the pattern matchers and line counters (consecutive matching striations “CMS” theorist). The third dependent variable is skill, which measured the years of experience in conjunction with the results between the pattern matchers and line counters (CMS theorist).

There is one independent variable in this study, which is assessment. Assessment is defined as the examination and comparison of the questioned bullets to the known standards, which will be fired in ten consecutively manufactured Glock Miami Gun Barrels. The intervening variable is the number of lines counted, and possibly the amount of training, and experience of the examiners (participants). Extraneous variables were controlled by utilizing a laboratory setting, and through sampling.

Using an experimental design, two research questions were explored in this study. For research question one, “will firearm and tool mark examiners who use pattern matching reach different conclusions than those who use consecutive matching striations (line counting) when examining bullets fired through consecutively manufactured Glock Miami Gun Barrels,” the dependent variable was measured by the Consecutively Rifled
For research question two, "will firearm and tool mark examiners with less than 10 years of experience reach different conclusions than those with greater than 10 years of experience when examining bullets fired through consecutively manufactured Glock Miami Gun Barrels," the dependent variable was measured by the Consecutively Rifled Glock Miami Barrel Test Set Instrument Survey by a 1 to 15 point system (1 point for each correct answer, with a maximum point value of 15).

Two hypotheses were tested in this research study. For the first hypotheses, "pattern matchers will be more accurate than line counters when examining bullets fired through consecutively manufactured Glock Miami Gun Barrels," the independent variable was the examination and comparison of the questioned bullets to the known standards utilizing their accepted theory. The dependent variable measured the theories based on the participant’s results.

The second hypotheses, "the experience level of firearm and tool mark examiners will affect results when examining bullets fired through consecutively manufactured Glock Miami Gun Barrels," the independent variable is the examination and comparison of the questioned bullets to the known standards. The dependent variable is the participant’s ability, measured by their results.
Population and Sampling Plan

Target Population

In this study, the target population will represent the forensic science community, more specifically, firearm and tool mark examiners who are working for a law enforcement agency (crime laboratory), or like agency in the United States. The researcher will utilize the membership list for the Association of Firearm and Tool Mark Examiners (AFTE). Every firearms examiner in the United States who is a member of AFTE had an equal opportunity to be included. Each examiner was contacted by the primary investigator via email inviting them to participate in this study, which included completing demographic questions and participation in an experimental test. The researcher planned on contacting every fourth person on the membership list after the initial email until there were 100 participants. The sample size exceeded the recommended number based on the formula of $n > 50 + 8m$ (Green, 1991).

The test utilized in this study was similar to the work that the participants perform on a routine daily basis. This researcher is a member of AFTE, and one of the privileges of membership is access to the membership list. The use of randomization of the AFTE members strengthened the results of this study and should eliminate extraneous variables as well as control any rival hypotheses.

Eligibility-Inclusion Criteria

Participants must be firearm and tool mark examiners working for a law enforcement agency (crime laboratory), or like agency in the United States. Participants must have completed a two year training program. Independent examiners who retired from a qualifying agency were also be eligible to participate in this study.
Accessible Population

Accessibility was limited to firearm and tool mark examiners for whom the researcher was able to obtain email addresses by querying the membership list for the Association of Firearm and Tool Mark Examiners (AFTE).

Sampling Plan and Setting

The plan for this study involved an abstract population. Every firearm and tool mark examiner in the United States who is a member of AFTE was invited to participate in this research. The accessible population included approximately 400 firearm and tool mark examiners in the United States. The number of participants was derived from identifying firearm and tool mark examiners working in each crime laboratory in the United States. The researcher was able to quickly identify eligible firearm and tool mark examiners by utilizing the AFTE membership list. The AFTE identified participants that meet this researcher's inclusion criteria.

Setting

To ensure confidentiality, the researcher invited firearm and tool mark examiners to participate via email. The survey and test (see Appendix A) was conducted by each participant in privacy, in a crime laboratory setting, which strengthened the study's validity (Gall & Borg, 1996).

Instrumentation

This study included a questionnaire that included the participant's demographics, as well as an answer sheet for an experimental exercise. The survey took less than ten minutes to complete based on personal experience with this instrument. The
experimental exercise took approximately four to eight hours to complete based on personal experience.

The instrument was originally utilized by Brundage (1998), and redesigned by Hamby (2001). Over 400 firearm and tool mark examiners have used this instrument (Hamby & Brundage, 2007). This researcher adapted the statement to include the number of years of experience for each firearm and tool mark examiner. Additionally, the researcher added a category for pattern matching and line counting.

**Procedures**

**Ethical Considerations**

The data collection method for this research study was collected by utilizing an answer sheet that could be faxed, or mailed in a self stamped and addressed envelope to the researcher. Ethical considerations included keeping all of the participant’s names unknown, especially linking a name to results if they were incorrect (wrong identification).

**Data Collection Methods**

The primary investigator performed the following:

1. Obtained permission to use the instrument in this study (see approval, Appendix B).

2. Obtained Institutional Review Board approval for the study from Lynn University. The following required form: IRB Form 1 – *Application and Research Protocol for Review of Research Involving Human Subjects in a New Project IRB was submitted to Lynn University Institutional Review Board. Data collection was not initiated until IRB approval was obtained.
3. Request for waiver of signature was requested by the researcher to prevent the lack of participation. Police personnel do not like to sign their names and this could hinder the recruitment of the participants. A consent form will be provided to the participants. The participants will provide their consent to participate by completing and returning the questionnaire/answer sheet.

4. Sent email to the AFTE membership upon IRB approval. Due to lack of response, every fourth person on the AFTE membership list was contacted via phone until there were 100 participants. Participation was voluntary.

5. Obtained ten Glock Miami Gun Barrels and label them 1 through 10.

6. Obtained Federal 9mm cartridges (ammunition/bullets).

7. Obtained a 9mm Glock pistol for the test firing.

8. Utilized a vertical water tank for the test firing and retrieval of the bullets.

9. Placed each barrel one at a time in the Glock pistol.

10. Loaded Glock pistol with five cartridges.

11. Fired the weapon into the vertical water tank.

12. Fired five bullets through each barrel to create one test set. (This was repeated 100 times per barrel, 500 bullets per barrel in total).

13. Used properly labeled containers (pre-labeled by the researcher) to keep each group of five bullets separated.

14. Labeled two of the five bullets with the number of the barrel in which they were fired in (1 through 10) to create the test fired bullets (known standards). They were placed in a coin envelope (pre-labeled by the researcher).
15. Labeled remaining three bullets with an alpha character designated by the researcher to represent the questioned bullets (different alpha characters were assigned to each barrel).

16. Selected randomly one questioned bullet from each barrel from the container and placed it in a coin envelope (pre-labeled by the researcher).

17. Selected an additional five questioned bullets to complete the test set of 15 questioned bullets. They were each placed in a coin envelope (pre-labeled by the researcher).

18. Created 120 test sets and placed each test set in a medium manila envelope.

19. Mailed test sets to respondents. Each respondent received one test packet through the mail which included the following:
   - One questionnaire/answer sheet
   - 15 questioned bullets
   - 10 sets of test fired bullets (known standards) that were fired through 10 consecutively manufactured Glock Miami Gun Barrels.

20. 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 answer sheet.
   - The instructions directed the participants to mail back the answer sheet in a self stamped and addressed envelope, or to fax it.
21. Conducted the data collection process for eight weeks.

22. Started research one week after IRB approval. The completion date was four months after the start date.

23. Submitted IRB Report of Termination of Project to Lynn University within four weeks of the conclusion of the data collection.

24. Coded and copied data into SPSS (version 16).

25. Performed data analyses as described in the data analysis section using SPSS.

26. Stored data on a password-protected computer.

27. Keep all facsimiles and test data at the researcher’s laboratory office in a locked file cabinet.

28. Retain data for five years. After five years, the data will be destroyed.

Data Coding

Each participant was assigned a number from 1 to end. Each variable (Barrel 1 through 10) was designated as B1 through B10, and received a numerical code related to the number of bullets that were fired through each barrel (max = 6). Alpha was coded as correct or incorrect. The pattern matcher’s code was 1, and the line counters was 2. The job title was coded 1 through 5. Type of lighting was coded 1 or 2. Years experience was coded based on >10 (code 1) and <10 (code 2) years of experience. Examination of other evidence was coded 1 for “yes” and 2 for “no.” The type of other evidence was coded 1 through 5. Professional or Forensic organizations was coded 1 for “yes” and 2 for “no.” The type of other organization was coded 1 through 5. FBI Specialized Technique School was coded 1 for “yes” and 2 for “no.” The number of years of training was coded 1 for >2 years, 2 for 2 years, or 3 for <2 years. The type of training was coded
into 2 groups, 1 for structured and 2 for unstructured. CMS trained was coded 1 for "yes" and 2 for "no." Have you ever encountered the Miami Barrel or EBIS Barrel was coded 1 for "yes" and 2 for "no" (see Appendix A).

**Descriptive Analysis**

Descriptive Analysis was used to discuss/explain about the participants. Descriptive analysis included job title, years of training, years of experience, CMS training, Miami Barrel or Enhanced Bullet Identification System (EBIS) Barrel experience, as well as the type of microscope and lighting used.

**Data Analysis Methods**

Once the data was collected, simple descriptive scores from pattern matchers and line counters were used to analyze all variables. Next, correlation statistics was performed with Statistical Program for Social Sciences (SPSS) for multiple regression analyses to answer the two research questions.

**Objective of Research Question 1 and the Means to Answer**

Will firearm and tool mark examiners who use pattern matching reach different conclusions than those who use consecutive matching striations (line counting) when examining bullets fired through consecutively manufactured Glock Miami Gun Barrels? The objective was to determine if firearm and tool mark examiners can properly identify questioned bullets to the Glock Miami Gun Barrel in which they were fired in. This question was answered by comparing the results of the line counters to the pattern matchers utilizing ANOVA tests. ANOVA will analyze the differences between the independent variable (assessment) and two dependent variables (accuracy and variance).
Objective of Research Question 2 and the Means to Answer

Will firearm and tool mark examiners with less than 10 years of experience reach different conclusions than those with greater than 10 years of experience when examining bullets fired through consecutively manufactured Glock Miami Gun Barrels? The objective was to determine if years of experience matters when identifying questioned bullets to the Glock Miami Gun Barrel in which they were fired in. This was answered by examining the test results of barrel 1 through barrel 10 in correlation with the years of experience (<10, >10) utilizing ANOVA tests. ANOVA analyzed the differences between the independent variable (assessment) and dependent variable (skill).

Methodology to test Hypothesis 1

Pattern matchers will be more accurate than line counters when examining bullets fired through consecutively manufactured Glock Miami Gun Barrels. The methodology included a comparison between the results of pattern matchers and line counters utilizing ANOVA tests. ANOVA analyzed the differences between the independent variable (assessment) and two dependent variables (accuracy and variance).

Methodology to test Hypothesis 2

The experience level of firearm and tool mark examiners will affect their results when examining bullets fired through consecutively manufactured Glock Miami Gun Barrels. The methodology included a comparison between the results of pattern matchers and line counters based on experience utilizing ANOVA tests. ANOVA analyzed the differences between the independent variable (assessment) and dependent variable (skill).
Evaluation of Research Methods

Internal Validity Strengths

- The internal validity of the quantitative data was valid due to the procedures set forth to assemble the tests.
- All the test materials was assembled in a crime laboratory setting.
- All questioned bullets and known standards were labeled with a number or letter.
- Containers were used to keep the questioned bullets separated into groups.
- The researcher microscopically examine every 10th test set to ensure that the bullets were comparable and identifiable.
- The instrument has been used and documented in previous studies.
- The participants were use to the format.

Internal Validity Weaknesses

- The validity of this study was dependent upon the accuracy of the assembly of the tests. The internal validity should be fine due to the utilization of a laboratory setting.
- Communication between participants could threaten the internal validity.
- The questioned bullets and known standards could have failed to mark.

External Validity Strengths

- The external validity strength of this research project is that all testing was conducted in a crime laboratory setting.
- Participants utilized a comparison microscope.
- The participants are trained firearm and tool mark examiners.
- The training and experience of the participants strengthen the external validity.
• The researcher exceeded the required sample size.

• The use of randomization of the AFTE members strengthened the results of this study and eliminated extraneous variables as well as controlled any rival hypotheses.

**External Validity Weaknesses**

• The researcher had to assume that the participants are following appropriate AFTE procedures.

• The researcher 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 participant could start the test, stop it, and resume at a later date.

• The external validity is acceptable due to the utilization of a laboratory setting, as well as controlled sampling.

Chapter III described the research methods that were used to answer the research questions and test the hypotheses about the relationship between the accuracy, variance and skill of firearm and tool mark examiners. The examiners utilized pattern matching and line counting to examine bullets fired through multiple consecutively manufactured Glock Miami Gun Barrels.
CHAPTER IV

RESULTS

In Chapter IV, the examination of research questions, hypotheses testing, and other findings related to this study about the Miami Barrel was conducted by the researcher. Participant performance (test assessment – experimental exercise) relating to skill (experience) and methods utilized (pattern matching, consecutive matching striations - line counting, and/or a combination of both), as well as their demographic characteristics relating to the Participant’s ability to perform the assessment were examined.

Previous research indicated that the method of pattern matching was subjective and dependent upon the firearm and tool mark examiner’s training and experience (Howitt, Tulleners, Cebra, & Chen, 2008). Under this method, firearm and tool mark examiners base their identifications on individual matching striations, their length, width, spatial relationship, surface contour and the number of these lines that are present.

The theory of consecutive matching lines - line counting (CMS) was introduced to the firearm and tool mark profession in an attempt to quantify examiner conclusions and to make the results objective. The work of Biasotti (1959), and Biasotti and Murdock (1984) suggested that a quantitative number could be used by a firearm and tool mark examiner to explain a conclusion that was reached through pattern recognition.

The experience of the firearm and tool mark examiners was reported as a factor in the Martinez (2008) study, which tested the durability of the Miami Barrel to determine whether or not Glock Inc’s Enhanced Bullet Identification System (EBIS) reproduced identifiable striations that would allow unknown samples to be identified to known
standards. She reported that 29% of the participants with 5 to 10 years of experience reported via survey testing that there were not enough individual characteristics present to conclude an identification, and/or elimination. A total of 14% of the participants with 5 to 10 years of experience reported identifications and the ability to eliminate.

For this research study regarding participant performance relating to skill and methods utilized, a mass email was sent out to the membership of the Association of Firearm and Tool Mark Examiners. A total of 208 examiners representing 130 crime laboratories in 41 states including the District of Columbia responded that they wanted to participate. After four months of data collection, 182 participants completed the Consecutively Rifled Glock Miami Barrel Test Set Survey/Instrument. There were 24 participants that did not respond and were removed from the study due to follow-up. A total 32 of the 182 participants did not meet the training requirement for this study. This resulted in a data-producing sample of 150 participants.

The firearm and tool mark examiners that responded to the Consecutively Rifled Glock Miami Barrel Test Set Survey/Instrument represented 82% of the total states in the United States that conduct firearm and tool mark examinations. This researcher coded all usable questionnaires for data analysis through the Statistical Package for Social Sciences (SPSS) version 16 computer software. The researcher performed frequency distributions, and no missing data or coding errors were detected.

The instrument utilized for this study allowed the participants to record their answer by circling the appropriate alpha designator of the unknown bullets on the same line as the known test fired bullet sets designated by a numerical number 1 – 10 (Brundage, 1998; Hamby, 2001; Hamby & Brundage, 2007, 2009). This experimental
exercise of the instrument was designed to measure skill. The alpha letters were coded as
1 = correct, 2 = incorrect. A total score of 15 for each of the alpha letters used was
possible. A score of 15 for each alpha indicates a score of 100%.

In addition to the use of bullet test, several demographic items were captured
within a personal structural factors survey. These were listed as years experience, years
training, type of training, brand of microscope, type of lighting, do you examine other
types of evidence, do you belong to a professional or forensic organization, have you ever
attended the FBI Specialized Techniques School, CMS trained, did you use pattern
matching or CMS for this test, have you ever encountered the Miami or EBIS Barrel in
your case work, and how many times for each participant. Gender was coded by name
association.

In the study, Cronbach’s alpha was utilized to measure internal consistency
reliability. In order to illustrate the validity of the experimental exercise, Cronbach
Alpha Coefficients were calculated on grouped scores and the individual components of
the experimental exercise. The researcher utilized Cronbach’s Alpha to measure of
internal consistency which indicates whether individual test scores of the experimental
exercise vary with the total score. Cronbach’s Alpha is a measure of coefficient of
reliability (Gall, Borg & Gall, 2009). The results of the Cronbach Alpha coefficients are
depicted in Table 1, which indicated that the results of the experimental exercise were
within the acceptable range.
TABLE 1

Cronbach Alpha Reliability Coefficients for the Exercise: Cronbach Alpha (α)

<table>
<thead>
<tr>
<th>Exercise Components</th>
<th>Coefficient Alphas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experience</td>
<td>.89</td>
</tr>
<tr>
<td>Training</td>
<td>.88</td>
</tr>
<tr>
<td>Microscope</td>
<td>.86</td>
</tr>
<tr>
<td>Lighting</td>
<td>.82</td>
</tr>
<tr>
<td>Other Evidence</td>
<td>.85</td>
</tr>
<tr>
<td>Professional Organization</td>
<td>.87</td>
</tr>
<tr>
<td>FBI School</td>
<td>.82</td>
</tr>
<tr>
<td>CMS Trained</td>
<td>.76</td>
</tr>
<tr>
<td>Method</td>
<td>.88</td>
</tr>
</tbody>
</table>

Demographics

The demographic variables depicted in Table 2 were coded as follows. The participants were coded based on their years of experience, 1 = <10 years of experience and 2 = > 10 years of experience. Additionally, the total number of years was recorded on a sliding scale. The number of years of training was coded as 1 = >2 years, 2 = < 2 years. The type of training will be coded into 2 groups, 1 = structured and 2 = unstructured. The brand of microscope was coded as follows: 1 = Leica, 2 = Leeds, 3 = other. The type of lighting was coded as 1 = fluorescent, 2 = fiber optics, 3 = other. Examination of other evidence was coded 1 for “yes” and 2 for “no.” Professional or Forensic organizations were coded 1 for “yes” and 2 for “no.” FBI Specialized Technique School was coded 1 for “yes” and 2 for “no.” CMS trained was coded 1 for “yes” and 2 for “no.” The method used was coded as 1 = pattern matching, 2 = CMS, 3 = combination of both. Have you ever encountered the Miami Barrel or EBIS Barrel will be coded 1 for “yes” and 2 for “no” The number of times that the EBIS Barrel was encountered was coded as follows: 1 = zero, 2 = < 5, 3 = 5 – 10, 4 = > 10.
### Table 2

**Profile of Firearm and Tool Mark Examiners (Participants)**

<table>
<thead>
<tr>
<th>Demographic Variables</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>n=150</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Experience</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 10 Years</td>
<td>75</td>
<td>50%</td>
</tr>
<tr>
<td>&gt; 10 Years</td>
<td>75</td>
<td>50%</td>
</tr>
<tr>
<td>Training Type</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Structured</td>
<td>149</td>
<td>99.3%</td>
</tr>
<tr>
<td>Other</td>
<td>1</td>
<td>.7%</td>
</tr>
<tr>
<td>Microscope</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leica</td>
<td>98</td>
<td>65.3%</td>
</tr>
<tr>
<td>Leeds</td>
<td>33</td>
<td>22%</td>
</tr>
<tr>
<td>Other</td>
<td>19</td>
<td>12.7%</td>
</tr>
<tr>
<td>Lighting</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Florescent</td>
<td>101</td>
<td>67.3%</td>
</tr>
<tr>
<td>Fiber Optic</td>
<td>16</td>
<td>10.7%</td>
</tr>
<tr>
<td>Other</td>
<td>33</td>
<td>22%</td>
</tr>
<tr>
<td>Evidence</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>106</td>
<td>70.7%</td>
</tr>
<tr>
<td>No</td>
<td>44</td>
<td>29.3%</td>
</tr>
<tr>
<td>Organization</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>142</td>
<td>94.7%</td>
</tr>
<tr>
<td>No</td>
<td>8</td>
<td>5.3%</td>
</tr>
<tr>
<td>FBI School</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>36</td>
<td>24%</td>
</tr>
<tr>
<td>No</td>
<td>114</td>
<td>76%</td>
</tr>
<tr>
<td>CMS Trained</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>37</td>
<td>24.7%</td>
</tr>
<tr>
<td>No</td>
<td>113</td>
<td>75.3%</td>
</tr>
<tr>
<td>Method</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PM</td>
<td>140</td>
<td>93.3%</td>
</tr>
<tr>
<td>CMS</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>Both</td>
<td>10</td>
<td>6.7%</td>
</tr>
<tr>
<td>EBIS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>6</td>
<td>4%</td>
</tr>
<tr>
<td>No</td>
<td>144</td>
<td>96%</td>
</tr>
<tr>
<td>Zero</td>
<td>144</td>
<td>96%</td>
</tr>
<tr>
<td>5 or &lt;</td>
<td>1</td>
<td>.7%</td>
</tr>
<tr>
<td>6 – 10</td>
<td>2</td>
<td>1.3</td>
</tr>
<tr>
<td>&gt; 10</td>
<td>3</td>
<td>2%</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>100</td>
<td>66.7%</td>
</tr>
<tr>
<td>Female</td>
<td>36</td>
<td>24%</td>
</tr>
<tr>
<td>Unknown</td>
<td>14</td>
<td>9.3%</td>
</tr>
</tbody>
</table>
The demographic years of experience variable is depicted in Figure 1. The experience of the participants propelled from just out of training (2.7%) to 46 years (.7%). The largest percent of the participants (6.7%) had two years of experience. A total of 75 participants had < 10 years of experience, and 75 participants had 10 or > 10 years of experience. The largest percent of the participants > 10 years of experience was 12 years of experience, which equaled 5.3%. Ten years of experience was also 5.3%.

**Figure 1:** Participant Years of Experience
Instrument Parameters

Each participant received a total of 10 pairs of known test fired bullets labeled Barrel 1 through Barrel 10 and 15 questioned unknown fired bullets labeled with an alpha character. The participants examined and compared the 15 questioned unknown fired bullets to the 10 pairs of known test fired bullets, which were labeled Barrel 1 through Barrel 10, and determined which barrel fired the 15 questioned unknown fired bullets. The 15 questioned unknown fired bullets were labeled with the following alpha characters: A, B, C, F, H, I, K, L, M, P, Q, R, U, X, and Y. Table 3 depicts the frequency and the percentage of the examination/comparison of each questioned unknown fired bullet. There were a total of 2250 questioned unknown fired bullets examined, which resulted in 2241 correct answers and 9 incorrect answers. The error rate was 0.4% based of the formula of Thompson and Wyant (2003), Figure 2.
Table 3

Examination/Comparison of Questioned Unknown Fired Bullets

<table>
<thead>
<tr>
<th>Questioned Unknown Fired Bullets</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>A Correct</td>
<td>148</td>
<td>98.7%</td>
</tr>
<tr>
<td>Incorrect</td>
<td>2</td>
<td>1.3%</td>
</tr>
<tr>
<td>B Correct</td>
<td>149</td>
<td>99.3%</td>
</tr>
<tr>
<td>Incorrect</td>
<td>1</td>
<td>0.7%</td>
</tr>
<tr>
<td>C Correct</td>
<td>150</td>
<td>100%</td>
</tr>
<tr>
<td>D Correct</td>
<td>150</td>
<td>100%</td>
</tr>
<tr>
<td>E Correct</td>
<td>149</td>
<td>99.3%</td>
</tr>
<tr>
<td>Incorrect</td>
<td>1</td>
<td>0.7%</td>
</tr>
<tr>
<td>F Correct</td>
<td>150</td>
<td>100%</td>
</tr>
<tr>
<td>G Correct</td>
<td>150</td>
<td>100%</td>
</tr>
<tr>
<td>H Correct</td>
<td>149</td>
<td>99.3%</td>
</tr>
<tr>
<td>Incorrect</td>
<td>1</td>
<td>0.7%</td>
</tr>
<tr>
<td>I Correct</td>
<td>150</td>
<td>100%</td>
</tr>
<tr>
<td>J Correct</td>
<td>150</td>
<td>100%</td>
</tr>
<tr>
<td>K Correct</td>
<td>149</td>
<td>99.3%</td>
</tr>
<tr>
<td>Incorrect</td>
<td>1</td>
<td>0.7%</td>
</tr>
<tr>
<td>L Correct</td>
<td>150</td>
<td>100%</td>
</tr>
<tr>
<td>M Correct</td>
<td>150</td>
<td>100%</td>
</tr>
<tr>
<td>N Correct</td>
<td>150</td>
<td>100%</td>
</tr>
<tr>
<td>O Correct</td>
<td>150</td>
<td>100%</td>
</tr>
<tr>
<td>P Correct</td>
<td>150</td>
<td>100%</td>
</tr>
<tr>
<td>Q Correct</td>
<td>150</td>
<td>100%</td>
</tr>
<tr>
<td>R Correct</td>
<td>149</td>
<td>99.3%</td>
</tr>
<tr>
<td>Incorrect</td>
<td>1</td>
<td>0.7%</td>
</tr>
<tr>
<td>U Correct</td>
<td>149</td>
<td>99.3%</td>
</tr>
<tr>
<td>Incorrect</td>
<td>1</td>
<td>0.7%</td>
</tr>
<tr>
<td>X Correct</td>
<td>149</td>
<td>99.3%</td>
</tr>
<tr>
<td>Incorrect</td>
<td>1</td>
<td>0.7%</td>
</tr>
<tr>
<td>Y Correct</td>
<td>149</td>
<td>99.3%</td>
</tr>
<tr>
<td>Incorrect</td>
<td>1</td>
<td>0.7%</td>
</tr>
</tbody>
</table>

\[
9 \quad 2250 \ (150 \text{ participants} \times 15 \text{ Unknowns}) \times 100 = 0.4\%
\]

Figure 2: Miami/EBIS Barrel Error Rate
Table 4 illustrates the frequency and percentage of the total number of correct answers based on a sliding scale of 1 – 15, with one point for every correct answer. A total of 145 participants, 96.7% scored the maximum 15 points, 100% the experimental exercise. Only five participants, 3.3% did not achieve 100%. Three participants misidentified one questioned unknown fired bullet, one participant misidentified two bullets and 1 participant misidentified 4.

Table 4

<table>
<thead>
<tr>
<th>Total Score</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>1</td>
<td>.7%</td>
</tr>
<tr>
<td>13</td>
<td>1</td>
<td>.7%</td>
</tr>
<tr>
<td>14</td>
<td>3</td>
<td>2%</td>
</tr>
<tr>
<td>15</td>
<td>145</td>
<td>96.7%</td>
</tr>
<tr>
<td>Total</td>
<td>150</td>
<td>100%</td>
</tr>
</tbody>
</table>

Participant characteristics (experience, training type, microscope, lighting, evidence, professional organization, FBI school, CMS trained, method, EBIS, EBIS exposure, years experience, and gender) positively influence the examination, comparison and identification of bullets fired through consecutively manufactured Glock Miami (EBIS) Gun Barrels.

An ANOVA with fixed factors was run including variables EXPERIENCE (<10, >10), TRAINING TYPE, MICROSCOPE, LIGHTING, EVIDENCE, ORGANIZATION (professional membership), FBI SCHOOL, CMS TRAINED, METHOD, EBIS, EBIS TIMES (Exposure), YEARS EXPERIENCE (by year), and GENDER. The dependent variable was the total experimental exercise score. With an alpha level of .05, the results indicated a significant difference was found with the affect of ORGANIZATION, in
which there was an F score of 9.73 (p < .01). Table 5 summarizes the significant findings of 13 variables and TOTAL experimental exercise scores. Based on the fixed factors, there were no intervening variables that affected this study. Furthermore, no confounding variables were found, and the results indicate that no external variables affected this study.

Table 5

**Factorial ANOVA of Thirteen Variables: Total Experimental Exercise Scores**

<table>
<thead>
<tr>
<th>Dependent Variable: Source Type</th>
<th>III Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corrected Model</td>
<td>6.102*</td>
<td>58</td>
<td>.105</td>
<td>.585</td>
<td>.985</td>
</tr>
<tr>
<td>Intercept</td>
<td>398.225</td>
<td>1</td>
<td>398.225</td>
<td>2215.318</td>
<td>.000</td>
</tr>
<tr>
<td>Experience (&lt;10, &gt;10)</td>
<td>.000</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Training Type</td>
<td>.060</td>
<td>1</td>
<td>.060</td>
<td>.335</td>
<td>.564</td>
</tr>
<tr>
<td>Microscope</td>
<td>.327</td>
<td>2</td>
<td>.163</td>
<td>.909</td>
<td>.407</td>
</tr>
<tr>
<td>Lighting</td>
<td>.125</td>
<td>2</td>
<td>.063</td>
<td>.348</td>
<td>.707</td>
</tr>
<tr>
<td>Evidence</td>
<td>2.773E-5</td>
<td>1</td>
<td>2.773E-5</td>
<td>.000</td>
<td>.990</td>
</tr>
<tr>
<td>Organization</td>
<td>1.750</td>
<td>1</td>
<td>1.750</td>
<td>9.738*</td>
<td>.002</td>
</tr>
<tr>
<td>FBI School</td>
<td>.119</td>
<td>1</td>
<td>.119</td>
<td>.664</td>
<td>.417</td>
</tr>
<tr>
<td>CMS Trained</td>
<td>.070</td>
<td>1</td>
<td>.070</td>
<td>.390</td>
<td>.534</td>
</tr>
<tr>
<td>Method</td>
<td>.000</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>EBIS</td>
<td>.000</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>EBIS Times</td>
<td>.020</td>
<td>2</td>
<td>.010</td>
<td>.056</td>
<td>.946</td>
</tr>
<tr>
<td>Experience (actual)</td>
<td>3.342</td>
<td>42</td>
<td>.080</td>
<td>.443</td>
<td>.998</td>
</tr>
<tr>
<td>Gender</td>
<td>.343</td>
<td>2</td>
<td>.172</td>
<td>.955</td>
<td>.389</td>
</tr>
<tr>
<td>Error</td>
<td>16.358</td>
<td>91</td>
<td>.180</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td>33503.000</td>
<td>150</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corrected Total</td>
<td>22.460</td>
<td>149</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a. R Squared = .272 (Adjusted R Squared = -.193)
Main Analysis

The ANOVA (Analysis of Variance) was selected for this study due to the design of this inquiry. ANOVA has the ability to perform analysis on dependent and independent variables while examining the interactions and contrasts among the variables (Field, 2005). The one-way ANOVA provided the most effective measure for the means of this research study’s population (Huck, 2004).

Pattern Matching Verses CMS

The first research question is: "Will firearm and tool mark examiners who use pattern matching reach different conclusions than those who use consecutive matching striations (line counting) when examining bullets fired through consecutively manufactured Glock Miami Gun Barrels?" The researcher chose the one-way ANOVA due to its ability to analyze as a univariate test, allowing single inferential findings (Huck, 2004). Based on the number of variables in this study, this approach led to a reduced chance of performing a type 1 error (Gall, Borg & Gall, 2009). No post-hoc testing was warranted because there were no between group differences (Houck, 2004).

The dependent variables (accuracy and method) were compared against the independent variable (assessment – experimental exercise). No participants utilized CMS independently for the experimental exercise, which was unexpected by this researcher. The participants utilized pattern matching, and/or a combination of pattern matching and CMS. Analyses of the data revealed no significant difference between Pattern Matching with a variance score equal to .16 (p > .05) as compared to Both which had a variance equal to .00. These scores were indicative of the Minimum and Maximum scores. The
researcher found that 24% of the participants were trained in CMS; however, only 6.7% (n = 10) of the participants chose to utilize both methods for the experimental exercise.

One-way ANOVA was performed to examine the differences in the methods (PM = Pattern matching, Both = PM and CMS) used by the participants scores of their experimental exercise. As found in Table 6, comparisons revealed no significant difference between the PM (Variance score = .16) as compared to Both (Variance score = .00), which is indicative of the Minimum and Maximum.

Table 6

Method of Participants versus Examination/Comparison Results

<table>
<thead>
<tr>
<th>Method</th>
<th>n</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>Variance</th>
<th>Standard Error</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>PM</td>
<td>140</td>
<td>14.9</td>
<td>.401</td>
<td>.16</td>
<td>.033</td>
<td>11</td>
<td>15</td>
</tr>
<tr>
<td>Both</td>
<td>10</td>
<td>15</td>
<td>.000</td>
<td>.000</td>
<td>.000</td>
<td>15</td>
<td>15</td>
</tr>
</tbody>
</table>

The Levene Statistic Test of Homogeneity of Variances was utilized to examine the homogeneity of variance for the methods utilized by the participants in correlation with the results of the experimental exercise. As found in Table 7, p > .05.

Table 7

Homogeneity of Variances for Method of Participants versus Examination/Comparison Results

<table>
<thead>
<tr>
<th>Levene Statistic</th>
<th>df1</th>
<th>df2</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.048</td>
<td>1</td>
<td>148</td>
<td>.308</td>
</tr>
</tbody>
</table>

The researcher performed an ANOVA to determine the differences in the methods (PM = Pattern matching, Both = PM and CMS) used by the participants scores of their
experimental exercise. As found in Table 8, ANOVA comparisons of Between Groups and Within Groups showed no significant differences ($F = .25, p > .05$).

Table 8

**ANOVA – Method of Participants versus Examination/Comparison Results**

<table>
<thead>
<tr>
<th></th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>.039</td>
<td>1</td>
<td>.039</td>
<td>.255</td>
<td>.615</td>
</tr>
<tr>
<td>Within Groups</td>
<td>22.421</td>
<td>148</td>
<td>.151</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

One-way ANOVA was performed to examine the differences in the scores of the experimental exercise between the participants who were CMS trained and those who were not CMS trained (Yes = *CMS trained*, No = *non-CMS trained*). As found in Table 9, comparisons revealed no significant differences between the CMS trained participants ($M = 14.9$, Variance = .03) and the non-CMS trained participants ($M = 14.9$ Variance = .19). The Minimum score reflects that at least one non-CMS trained participant ($n = 1$) had at least 4 errors on the experimental exercise.

Table 9

**CMS Trained/Non-Trained versus Examination/Comparison Results**

<table>
<thead>
<tr>
<th>CMS Trained</th>
<th>n</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>Variance</th>
<th>Standard Error</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>37</td>
<td>14.9</td>
<td>.164</td>
<td>.03</td>
<td>.027</td>
<td>14</td>
<td>15</td>
</tr>
<tr>
<td>No</td>
<td>113</td>
<td>14.9</td>
<td>.437</td>
<td>.19</td>
<td>.041</td>
<td>11</td>
<td>15</td>
</tr>
</tbody>
</table>

The Levene Statistic Test of Homogeneity of Variances was utilized to examine the participants who were CMS trained, non-CMS trained in correlation with the results of the experimental exercise. As found in Table 10, $p > .05$.
The researcher performed an ANOVA to determine the differences in the scores of the experimental exercise between the participants who were CMS trained and those who were not CMS trained (Yes = CMS trained, No = non-CMS trained). As found in Table 11, ANOVA comparisons of Between Groups and Within Groups showed no significant differences (F = .35, p > .05).

Table 11

ANOVA – CMS Trained/Non-Trained versus Examination/Comparison Results

<table>
<thead>
<tr>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>.053</td>
<td>1</td>
<td>.053</td>
<td>.353</td>
</tr>
<tr>
<td>Within Groups</td>
<td>22.407</td>
<td>148</td>
<td>.151</td>
<td></td>
</tr>
</tbody>
</table>

Examination/Comparison Based on Experience

The second research question is: “Will firearm and tool mark examiners with less than 10 years of experience reach different conclusions than those with greater than 10 years of experience when examining bullets fired through consecutively manufactured Glock Miami Gun Barrels?” The dependent variable skill was compared against the independent variable assessment (experimental exercise) using the one-way ANOVA, which yielded results of a significant value. The results of this one-way ANOVA found that for < 10 years of experience, (Variance = .25, SE = .06), and >10 years of experience (Variance = .05, SE = .03), p < .05.
One-way ANOVA was performed to examine the differences based on experience of the participants, < 10 \( (n = 75) \), >10 \( (n = 75) \) and their skill based upon the scores of the experimental exercise. As found in Table 12, ANOVA comparisons showed some differences between the participants with < 10 years of experience (Variance = .25, SE = .06) and those participants with >10 years of experience (Variance = .05, SE = .03). The Minimum score reflects that at least one participant \( (n = 1) \) with < 10 years of experience had at least 4 errors on the experimental exercise.

Table 12

*Experience Correlated with Skill*

<table>
<thead>
<tr>
<th>Years of Experience</th>
<th>n</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>Variance</th>
<th>Standard Error</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;10</td>
<td>75</td>
<td>14.9</td>
<td>.497</td>
<td>.25</td>
<td>.057</td>
<td>11</td>
<td>15</td>
</tr>
<tr>
<td>&gt;10</td>
<td>75</td>
<td>14.9</td>
<td>.230</td>
<td>.05</td>
<td>.026</td>
<td>13</td>
<td>15</td>
</tr>
</tbody>
</table>

The Levene Statistic Test of Homogeneity of Variances was utilized to examine the homogeneity of variance for the participants experience in correlation with the results of the experimental exercise. As found in Table 13, \( p < .05 \).

Table 13

*Homogeneity of Variances for Experience Correlated with Skill*

<table>
<thead>
<tr>
<th>Levene Statistic</th>
<th>df1</th>
<th>df2</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.328</td>
<td>1</td>
<td>148</td>
<td>.039</td>
</tr>
</tbody>
</table>

The researcher performed an ANOVA to determine the differences based on experience of the participants, < 10 \( (n = 75) \), >10 \( (n = 75) \) and their skill based upon the scores of the experimental exercise. As found in Table 14, ANOVA comparisons of Between Groups and Within Groups showed no significant differences \( (F = 1.1, p > .05) \).
Table 14

ANOVA – Experience Correlated with Skill

<table>
<thead>
<tr>
<th>Ex/Skill</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between</td>
<td>.167</td>
<td>1</td>
<td>.167</td>
<td>1.106</td>
<td>.295</td>
</tr>
<tr>
<td>Within</td>
<td>22.293</td>
<td>148</td>
<td>.151</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

One-way ANOVA was performed to examine the differences between the gender (M = Male, F = Female, U = Unknown) of the participants and their skill based upon the scores of the experimental exercise. As found in Table 15, ANOVA comparisons showed significant differences between the participants skill level. All female participants ($n = 36$) scored 100% on the experimental exercise. The Minimum score reflects that at least one male participant ($n = 1$, Variance = .22, SE = .05) had at least 4 errors on the experimental exercise.

Table 15

Gender Correlated with Skill

<table>
<thead>
<tr>
<th>Gender</th>
<th>n</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>Variance</th>
<th>Standard Error</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>100</td>
<td>14.9</td>
<td>.473</td>
<td>.22</td>
<td>.047</td>
<td>11</td>
<td>15</td>
</tr>
<tr>
<td>F</td>
<td>36</td>
<td>15</td>
<td>.000</td>
<td>.000</td>
<td>.000</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>U</td>
<td>14</td>
<td>15</td>
<td>.000</td>
<td>.000</td>
<td>.000</td>
<td>15</td>
<td>15</td>
</tr>
</tbody>
</table>

The Levene Statistic Test of Homogeneity of Variances was utilized to examine the homogeneity of variance for the gender of the participants in correlation with the results of the experimental exercise. As found in Table 16, $p < .05$. 

111
The researcher performed an ANOVA to determine the differences between the gender of the participants and their skill based upon the scores of the experimental exercise. As found in Table 17, ANOVA comparisons of Between Groups and Within Groups showed significant differences (F = .89, p > .05).

Table 17

**ANOVA – Gender Correlated with Skill**

<table>
<thead>
<tr>
<th>Gender Skill</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>.270</td>
<td>2</td>
<td>.135</td>
<td>.894</td>
<td>.411</td>
</tr>
<tr>
<td>Within Groups</td>
<td>22.190</td>
<td>147</td>
<td>.151</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Summary**

**Research Question One**

The first question asked if there would be a difference in the conclusion reached by firearm and tool mark examiners based on the method (Pattern Matching or CMS) used when examining bullets fired through consecutively manufactured Glock Miami Gun Barrels. The dependent variables (accuracy and method) were compared against the independent variable (assessment – experimental exercise). The data collection revealed that none of the participants utilized CMS independently for the experimental exercise. The participants utilized pattern matching (93.3%), and/or a combination of pattern
matching and CMS (6.7%). No post-hoc testing was warranted because there were no
to between group differences (Houck, 2004)

The data also revealed that no errors were made in the experimental exercise by
the participants who utilized both methods. A total of nine errors were made by 5
participants (3.3%) who utilized pattern matching. The standard deviation for pattern
matching was .40, and .00 for both methods (p > .05), which was not significant. A
comparison of these scores suggests that utilizing a combination of both methods may
improve performance.

Research Question Two

The second research question asked if firearm and tool mark examiners with less
than 10 years of experience will reach different conclusions than those with greater than
10 years of experience when examining bullets fired through consecutively manufactured
Glock Miami Gun Barrels. The dependent variable skill was compared against the
independent variable assessment (experimental exercise). Comparisons of the
experimental exercise scores revealed a difference in skill between the participants with <
10 years of experience (Variance = .25, SE = .06) and those participants with >10 years
of experience (Variance = .05, SE = .03), p < .05, which is a significant finding.

Additional analysis of the data revealed that 5.3% of the participants with <10
years of experience made errors on the experimental exercise, compared to 1.3% of the
participants with > 10 years of experience. These findings indicate that firearm and tool
mark examiners with > 10 years of experience are less likely to commit an error when
examining bullets fired through a Glock Miami/EBIS Gun Barrel.
Other Factors

Although gender was not a perceived topic, and/or variable for this research study, gender was discovered to play an important role in the experimental exercise. This researcher found a significant difference in the scores of the experimental exercise base on gender, \((p < .05)\). This difference may be due to the gender sample size, even though it did not show up in the Factorial ANOVA. The researcher discovered that all female participants accurately identified all of the unknown questioned bullets to the Glock Miami/EBIS Gun Barrels in which they were fired through, 100% of the time. The male participants accounted for the 9 errors that occurred in the experimental exercise.

The researcher discovered that the category of Professional Organization was a significant finding based on the Factorial ANOVA \((p < .01)\). Professional organizations such as the Association of Firearm and Tool Mark Examiners (AFTE) play an essential role in the forensic science community (Heard, 1997). Even though professional organization was not a perceived topic, its role should be dually noted.

The findings of this research study supports the theory in firearm and tool mark identification, that each firearm/tool produces a signature of identification (striation/impression) that is unique to that firearm/tool, and through examining the individual striations/impressions; the signature can be positively identified to the firearm/tool that produced it. There were a total of 2250 questioned unknown fired bullets examined by the participants, which resulted in 2241 correct answers and 9 incorrect answers.
Hypothesis One

The first hypothesis, "pattern matchers will be more accurate than line counters (CMS) when examining bullets fired through consecutively manufactured Glock Miami Gun Barrels" was found to be null (p > .05). No participants utilized CMS independently for the experimental exercise, which was unexpected by this researcher. The participants utilized pattern matching, and/or a combination of pattern matching and CMS. Analyses of the data revealed no significant difference. The results of this research study, as well as the past studies indicate that there is evidence to support the theory of pattern matching, as well as a combination of both pattern matching and CMS. This study suggests that the use of both methods may result in more accurate results.

Hypothesis Two

The second hypothesis states: "the experience level of firearm and tool mark examiners will affect their results when examining bullets fired through consecutively manufactured Glock Miami Gun Barrels." The findings of this research study support this hypothesis. Based on this study, the experience level of firearm and tool mark examiner will affect the firearm and tool mark examiners examination/comparison conclusions when examining bullets fired through consecutively manufactured Glock Miami Gun Barrels. The analysis of the data revealed that 5.3% of the participants with <10 Years of experience made errors on the experimental exercise, compared to 1.3% of the participants with > 10 years of experience (p < .05).
CHAPTER V
SUMMARY OF FINDINGS

The purpose of this study was to explore the potential measurable differences between the relationship of traditional pattern matching, and consecutive matching striations (CMS) achieved through a experimental exercise involving consecutively manufactured Glock Miami/EBIS Gun Barrels. To date, no studies have been conducted that utilized multiple consecutively manufactured Glock Miami/EBIS Gun Barrels. Few empirical studies (Moran, 2001; Nichols, 2003; Walsh & Weavers, 2002) examined the relationship between traditional pattern matching and CMS. The existing body of research found within the literature suggested two things. The first research segment questioned whether the identification technique utilized could have a measurable effect on the identification of fired bullets (Miller & McLean, 1998; Moran, 2001; Nichols, 2003; Walsh & Weavers, 2002). The second research segment proposed that the experience of the firearm and tool mark examiner can have a positive effect on the examination of bullets fired through Glock Miami/EBIS Gun Barrels (Martinez, 2008).

This particular study explored the measurable differences between the relationship of traditional pattern matching, consecutive matching lines and/or a combination of both techniques through an experimental exercise involving bullets that were fired through consecutively manufactured Glock Miami/EBIS Gun Barrels. In addition to the aforementioned testing, the years of experience in relationship to the results of the experimental exercise was explored using two different groups determined strictly by the participant’s years of experience.
The researcher adapted the Consecutively Rifled P85 Barrel Test Set Survey/Answer Sheet as the Instrument to measure the performance of the pattern matchers and line counters, as well as the participant’s skill level based on their experience. This instrument was introduced by Brundage (1998), and redesigned by Hamby (2001). Over 500 firearm and tool mark examiners have used this instrument (Hamby, Brundage, & Thorpe 2009). This instrument allows the participants to participate in an experimental exercise as well as record their results/findings. In addition to the experimental exercise, the instrument introduced a demographic survey to measure other factors which could have an influence on the outcomes of the experimental exercise. The ultimate goal of this study was to ascertain if pattern matching was a superior technique than line counting when examining bullets that were fired through Glock Miami/EBIS Gun Barrels. Furthermore, this investigative research explored the variables included in the demographic survey, and the corresponding scores impacted by skill.

**Review**

According to initial studies (Brundage, 1998; Hamby, 2001; Hamby, Brundage, & Thorpe 2009), the scientific foundation in 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 examining the individual striations/impressions; the signature can be positively identified to the firearm/tool that produced it. Firearm and tool mark examiners utilize pattern matching, line counting and/or a combination of both to conclude an identification.
The theory of pattern matching has been widely used by firearm and tool mark examiners since its inception, and has involved pattern recognition of microscopic lines and impressions. The method of pattern recognition is dependent upon the firearm and tool mark examiner’s training and experience. Under this method, firearm and tool mark examiners base their identifications on individual matching striations, their length, width, spatial relationship, surface contour and the number of these lines that are present.

The theory consecutive matching striations (CMS) allow firearm and tool mark examiners to base their identifications on a set number of consecutive matching lines. Bunch (2000) critically analyzed this theory. He raised the question of subjectivity in striation counting, and the fact that barrels can change over time. According to Brunch, line counting is a probability model, and that it is objective. Nichols (2003) theorized that the use of consecutive matching lines would allow a numerical quantitative value to be placed on the pattern observed by the examiner. Biasotti and Murdock (2002) advocated that a high degree of statistical certainty existed when utilizing line counting. Miller (2001) theorized that using line counting, there would be no erroneous identifications; however, the possibility to exclude a positive identification exists.

Utilizing the adapted Consecutively Rifled P85 Barrel Test Set Survey/Answer Sheet, as well as the Glock Miami/EBIS Gun Barrels in this study allowed the researcher to test and measure the differences between the theory of pattern matching, and the theory of CMS, as well as the utilization of both pattern matching and CMS. This instrument allowed this researcher to measure the performance of the pattern matcher’s and line counter’s skill level based on their experience. Additionally, the researcher was able to account for the participants who were trained in CMS.
The impact of years of experience, gender, type of training, brand of microscope, type of lighting, examination of other evidence, professional organization, FBI School, and experience with the Miami/EBIS Barrel were included within the demographic survey, to measure other factors which could have influenced the outcomes of the experimental exercise. This section was utilized by the researcher, as previous investigations implied that demographic differences, mainly experience of the participants might offer varying results with the experimental exercise (Martinez, 2008).

The researcher initially hypothesized that pattern matchers would perform significantly better than line counters (CMS theorist) when examining bullets fired through consecutively manufactured Glock Miami/EBIS Gun Barrels \( (\alpha = .05) \). The researcher also hypothesized that firearm and tool mark examiners with >10 years of experience would perform better than firearm and tool mark examiners with <10 years of experience. \( (\alpha = .05) \).

**General Findings**

Based upon a comparison of the experimental exercise test scores, the researcher discovered that there was a variance in the participant’s scores on the *Consecutively Rifled Glock Miami Barrel Test Set Survey/Instrument* depending upon gender \( (p < .05) \). The researcher found that all female participants accurately identified all of the unknown questioned bullets to the Glock Miami/EBIS Gun Barrels in which they were fired through, 100% of the time. The male participants accounted for the 9 errors that occurred in the experimental exercise.

In a comparison of the experimental exercise test scores by microscope and lighting type, the participants who utilized the Leeds comparison microscope scored
higher overall than the remaining participants. The Leeds users accurately identified all of the unknown questioned bullets to the Glock Miami/EBIS Gun Barrels in which they were fired through, 100% of the time. Participants that utilized the Leica comparison microscope and the brand listed as other accounted for the 9 errors that occurred in the experimental exercise (p > .05).

The experimental exercise test scores revealed no variance in the participant’s skill of those who previously attended the Federal Bureau of Investigation’s (FBI) Specialized Firearms Technique School compared to those who did not have the training (p > .05). The researcher found that the participants who attended the FBI Specialized Firearms Technique School accounted for one of the nine errors. The participants who did not attend the FBI Specialized Firearms Technique School accounted for the remaining eight errors in the experimental exercise. This indicated that the FBI Specialized Firearms Technique School could be an integral component of the training for firearm and tool mark examiners.

The researcher also discovered that there was no variance in the participant’s scores on experimental exercise based upon their experience with the Glock Miami/EBIS Gun Barrel (p > .05). The researcher discovered that all participants who had previous experience with the gun barrels accurately identified all of the unknown questioned bullets to the gun barrels in which they were fired through, 100% of the time. The participants who did not have experience with the Glock Miami/EBIS Gun Barrels accounted for the 9 errors that occurred in the experimental exercise.
Main Findings

The *Consecutively Rifled Glock Miami Barrel Test Set Survey/Instrument* revealed that none of the participants utilized line counting (CMS) independently for the experimental exercise, which was unexpected by this researcher. The participants utilized pattern matching, and/or a combination of pattern matching and CMS. The researcher found that all participants who utilized a combination of pattern matching and CMS accurately identified all of the unknown questioned bullets to the gun barrels in which they were fired through, 100% of the time. The participants who solely utilized pattern matching accounted for the 9 errors that occurred in the experimental exercise, indicating that the utilization of both methods may improve performance and lead to more accurate results.

Based upon a comparison of the experimental exercise test scores, the researcher discovered that there was a variance in the participant’s scores on the *Consecutively Rifled Glock Miami Barrel Test Set Survey/Instrument* depending upon experience (p < .05). The researcher found that participants with less than ten years of experience made more errors than those with ten or more years of experience when examining unknown questioned bullets to the Glock Miami/EBIS Gun Barrels in which they were fired through. Additional analysis of the data revealed that 5.3% of the participants with <10 years of experience made errors on the experimental exercise, compared to 1.3% of the participants with > 10 years of experience. These findings indicate that firearm and tool mark examiners with > 10 years of experience are less likely to commit an error when examining bullets fired through a Glock Miami/EBIS Gun Barrel.
The most noteworthy conclusion discovered by this researcher for the forensic discipline of firearm and tool mark examinations was the error rate for the examination of unknown questioned bullets to the Glock Miami/EBIS Gun Barrels. The error rate of the participants was established by this researcher to be 0.4%, which is significant for the forensic community. There were a total of 2250 questioned unknown fired bullets examined, which resulted in 2241 correct answers and 9 incorrect answers. A total of five participants were responsible for the errors (n = 150).

The factorial survey items of training type, microscope, lighting, evidence, organization, FBI School, CMS trained, EBIS, EBIS times and gender were compared against the scores of the experimental exercise. Gender and organization were the only variables amongst this group that had an observable effect on the scores of the experimental exercise (p < .05). The researcher found that all female participants accurately identified all of the unknown questioned bullets to the Glock Miami/EBIS Gun Barrels in which they were fired through, 100% of the time. The male participants accounted for the 9 errors that occurred in the experimental exercise.

The researcher discovered that the category of Professional Organization was a significant finding based on the Factorial ANOVA (p < .01). Professional organizations promote professionalism and ensure that their membership meets certain standards. Professional organizations such as the Association of Firearm and Tool Mark Examiners (AFTE), the International Association for Identification (IAI), and the American Academy of Forensic Sciences (AAFS) apply to the participants of this study and play an essential role in the forensic science community (Heard, 1997). Even though professional organization was not a perceived topic, its role should be dually noted.
Theoretical Considerations

The theory in 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 examining the individual striations/impressions; the signature can be positively identified to the firearm/tool that produced it (Brundage, 1998; Hamby, 2001; Hamby, Brundage, & Thorpe 2009). Firearm and tool mark examiners base their identifications on individual matching striations, their length, width, spatial relationship, surface contour and the number of these lines that are present. These striations are a result of minute imperfections on a cutting tool that cuts the lands and grooves into a barrel of a firearm (FBI, 1941; Hatcher, 1935; Mathews, 1973).

The theory of pattern matching has been widely used by firearm and tool mark examiners since its inception, and has involved pattern recognition of microscopic lines and impressions. According to Howitt, Tulleners, Cebra and Chen (2008), the method of pattern recognition is dependent upon the firearm and tool mark examiner’s training and experience. Under this method, firearm and tool mark examiners base their identifications on individual matching striations, their length, width, spatial relationship, surface contour and the number of these lines that are present.

The theory of consecutive matching striations - line counting (CMS) was introduced to the firearm and tool mark profession in an attempt to quantify firearm and tool mark examiner conclusions and to make the results objective. The work of Biasotti (1959) and Biasotti and Murdock (1984) suggested that a quantitative number could be used by a firearm and tool mark examiner to explain conclusions. The theory of CMS
changed the conclusions reached by firearm and tool mark examiners from a subjective opinion to an objective opinion.

A schematic model depicting direct and indirect (known matches and known non-matches) relationships among concepts described by Biasotti was developed (Miller, 2000b; Miller, 2004; Miller & McLean, 1998). The continued empirical study of this theory was scientifically significant in addressing essential issues about a quantitative numerical value in the discipline of firearm and tool mark examinations. Miller and McLean (1998) distinguished criteria for CMS in both two dimensional images, and three dimensional images, adding credence to the theory of CMS.

The experience of the firearm and tool mark examiners was reported as a factor in the Martinez (2008) study, which tested the durability of the Miami/EBIS Barrel to determine whether or not Glock Inc’s Enhanced Bullet Identification System (EBIS) reproduced identifiable striations that would allow unknown samples to be identified to known standards. Martinez reported that 14% of the participants with 5 to 10 years of experience reported identifications and the ability to eliminate. A total of 29% of the participants with 5 to 10 years of experience reported that there were not enough individual characteristics present to conclude an identification, and/or elimination.

In this study, the researcher found that after providing the participants with the experimental exercise, no measurable gains were observed between pattern matchers and CMS theorist. This portion of the research investigation revealed that experience is an important factor when examining bullets fired through Glock Miami/EBIS Gun Barrels.
This data supported past findings regarding the use of pattern matching and indicated that the utilization of both methods may improve performance and lead to more accurate results.

**Conclusions**

This research study provided pertinent information relative to the Forensic Science community and the forensic science discipline of firearm and tool mark examinations. This research study was the first investigation to utilize multiple consecutively manufactured Glock Miami/EBIS Gun Barrels. There is evidence that firearm and tool mark examiners can accurately identify bullets that were fired through Glock Miami/EBIS Gun Barrels; however, there is no clear conclusion as to which method (pattern matching or CMS) is superior. The results indicate that the utilization of both methods may improve performance and lead to more accurate results. Additionally, the utilization of both methods will provide a quantitative number, making the conclusion objective.

The results of this research study, as well as the past studies indicate that there is evidence to support the theory of pattern matching, as well as a combination of both pattern matching and CMS. The scientific foundation in 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 examining the individual striations/impressions; the signature can be positively identified to the firearm/tool that produced it (Brundage, 1998; Hamby, 2001; Hamby, Brundage, & Thorpe 2009). There were a total of 2250 questioned unknown fired bullets examined by the participants in this study, which resulted in 2241 correct answers and 9 incorrect
answers. These findings demonstrate repeatability and uniqueness of striations left on fired evidence.

This research study supports the results of the Martinez (2008) study, indicating that the experience of the firearm and tool mark examiner is an important factor when examining bullets fired through Glock Miami/EBIS Gun Barrels. The results of the data revealed that 5.3% of the participants with <10 years of experience made errors on the experimental exercise, compared to 1.3% of the participants with > 10 years of experience. These findings indicate that firearm and tool mark examiners with > 10 years of experience are less likely to commit an error when examining bullets fired through a Glock Miami/EBIS Gun Barrel.

The researcher also discovered that Gender had an observable effect on the scores of the experimental exercise. The researcher found that all female participants accurately identified all of the unknown questioned bullets to the Glock Miami/EBIS Gun Barrels in which they were fired through, 100% of the time. The male participants accounted for the 9 errors that occurred in the experimental exercise.

The most significant finding discovered by this researcher was the error rate for the examination of unknown questioned bullets to the Glock Miami/EBIS Gun Barrels. The error rate of the participants was established by this researcher to be 0.4%, which is significant for the forensic community. There were a total of 2250 questioned unknown fired bullets examined, which resulted in 2241 correct answers and 9 incorrect answers. A total of five participants were responsible for the errors.
Limitations

There are several limitations to this study. First, the researcher assumed that the participants followed appropriate Association of Firearm and tool Mark Examiners (AFTE) procedures. Each participant administered the experimental exercise at their own crime laboratory via mail, and this research had no observable control. The researcher also had to assume that each participant independently completed the experimental exercise on their own with no outside assistance.

The researcher had no control of the equipment that participant’s utilized for the experimental exercise. As stated above, each participant was administered the experimental exercise at their own crime laboratory via mail, and this researcher had no control of the equipment that the participants utilized for the experimental exercise. The researcher had to assume that the equipment utilized was appropriate, properly maintained and in a functional condition.

Due to the nature of the participants, the researcher had no control over the training and skill level, as well as the experience of the participants. Firearm and tool mark examiners generally undergo a two year training program. This program could vary amongst law enforcement agencies. Additionally, the skill level of each person could vary depending upon the training and amount of examinations performed on a routine basis. Additional limitations included the number of participants who utilized CMS, as well as the number of female participants. Also, this study did not include culture or ethnicity within the demographic survey.

The instrument for the experimental exercise, as well as the experimental exercise was individually administered utilizing the United States Postal Service according to the
email response of the participants and all eligible firearm and tool mark examiners were invited to participate. This research study utilized all the eligible participants that volunteered, and the lack of pure line counters (CMS theorist) could not be anticipated. The experimental exercise instrument functioned as a competent measure of technique and skill in this study; however, it has never been used previously in this type of research design.

While the researcher personally mailed the experimental exercise to one participant per crime laboratory, that participant in turn maintained control of the exercise. The researcher had no observable control. Some crime laboratories had more than one participant partake in the experimental exercise, of which, the same exercise was utilized. Also, the participants could have started the experimental exercise, stopped it, and resumed at a later date. Additionally, the participants were required to have two years of structured training; however, they were trained by several different trainers, from multiple crime laboratories and the quality and skill of the training officers was not collected.

The researcher discovered that the category of Professional Organization was a significant finding based on the Factorial ANOVA ($p < .01$). Professional organizations such as the Association of Firearm and Tool Mark Examiners (AFTE), the International Association for Identification (IAI), and the American Academy of Forensic Sciences (AAFS) apply to the participants of this study and play an essential role in the forensic science community (Heard, 1997). Professional organizations promote professionalism and ensure that their membership meets certain standards; however, this researcher had
no control over the standards set by the professional organization. Additionally, the researcher was unable to tell which organizations may have impacted the study.

Although gender was not a perceived topic, and/or variable for this research study, gender was discovered to play an important role in the experimental exercise. This researcher found a significant difference in the scores of the experimental exercise base on gender, \((p < .05)\). This difference may be due to the gender sample size, even though it did not show up in the Factorial ANOVA.

The researcher discovered that the experience of the participants was a limitation to this study even though the two groups analyzed \(< 10\) years of experience \((n= 75)\) and \(> 10\) years of experience \((n= 75)\) had a sufficient number of participants \((\text{Green, 1991})\). The researcher discovered that the participants of each group were clustered together. This clustering prevented post-hoc testing of the between groups \((\text{Houck, 2004})\).

The issue of accreditation was not addressed in this research study. The researcher does not know if the participants were trained, and/or employed by an accredited crime laboratory. The main objective of accreditation is to improve quality within a laboratory through the development and maintenance of standards \((\text{ASCLD/LAB, 2007})\). This researcher had no control of the development and maintenance of standards utilized by the participant's laboratories.

Additionally, the researcher did not examine the function of individual certification in firearm and tool mark examination/identification in this research study and has no way of determining if any of the participants are certified. The National Academy of Sciences (NAS) Report \((\text{2009})\) indicates that certification should be made mandatory.
Recommendations for Future Research

Future research is needed in the forensic science community in the area of multiple consecutively manufactured Glock Miami/EBIS Gun Barrels. Considerable research has been conducted on multiple consecutively manufactured gun barrels (Brundage (1998); Hamby, 2001; Hamby, Brundage, & Thorpe 2009); however, this research study was the first to examine multiple consecutively manufactured Glock Miami/EBIS Gun Barrels. Participants from 130 crime laboratories in 41 states participated in this study, and additional participants from the remaining crime laboratories and states should be sought out.

This research study was also the first to compare the theory of pattern matching and CMS utilizing an experimental exercise. Research should continue examining the two theories, as well as the utilization of combining both methods. Nichols (2003) theorized that the use of consecutive matching lines would allow a numerical quantitative value to be placed on the pattern observed by the examiner. Biasotti and Murdock (2002) advocated that a high degree of statistical certainty existed when utilizing line counting. Miller (2001) theorized that using line counting, there would be no erroneous identifications; however, the possibility to exclude a positive identification exists. This research study suggests that continued study is necessary.

Other research should include the aforementioned methods utilizing other calibers of firearms. Both fired bullets and casings should be examined. Additionally, more tools and tool mark impressions should be examined with the method in mind. The research should analyze the repeatability and uniqueness of striations/impressions. The Knife Identification Project was an excellent study (Thompson & Wyant, 2003); however, it
should be expanded to include the investigation of the method utilized to conclude an identification.

Ability and accuracy related to gender should also be explored, based on the findings of this study. This researcher discovered that there was a variance in the participant's scores on the *Consecutively Rifled Glock Miami Barrel Test Set Survey/Instrument* depending upon gender. The researcher found that all female participants accurately identified all of the unknown questioned bullets to the Glock Miami/EBIS Gun Barrels in which they were fired through, 100% of the time, whereas the errors were committed by the male participants. The correlation of culture and ethnicity should also be examined.

The researcher discovered that the category of Professional Organization was a significant finding based on the Factorial ANOVA (p < .01). Professional organizations promote professionalism and ensure that their membership meets certain standards. Professional organizations such as the Association of Firearm and Tool Mark Examiners (AFTE), the International Association for Identification (IAI), and the American Academy of Forensic Sciences (AAFS) apply to the participants of this study and play an essential role in the forensic science community (Heard, 1997). Even though professional organization was not a perceived topic, its role should be dually noted and its role investigated. Future practice needs to be examined more in-depth by future researchers.

Future research needs to explore the experience level of firearm and tool mark examiners as well as examine the clustering phenomenon that was detected in this study. This researcher analyzed two groups of participants in this research study, firearm and
tool mark examiners with < 10 years of experience (n= 75) and firearm and tool mark examiners with > 10 years of experience (n= 75). The phenomenon of the clustering between the two groups needs to be further researched.

Although gender was not a perceived topic, and/or variable for this research study, gender was discovered to play an important role in the experimental exercise. This researcher found a significant difference in the scores of the experimental exercise base on gender, (p < .05). This difference may be due to the gender sample size, even though it did not show up in the Factorial ANOVA, which suggests that additional research is needed in this area. The researcher discovered that all female participants accurately identified all of the unknown questioned bullets to the Glock Miami/EBIS Gun Barrels in which they were fired through, 100% of the time. The male participants accounted for the 9 errors that occurred in the experimental exercise. These factors suggest that additional research between genders should be explored.

The topic of accreditation should be explored to determine the affect accreditation has on the examination and comparison of firearm and tool mark evidence. The main objective of accreditation is to improve quality within a laboratory through the development and maintenance of standards (ASCLD/LAB, 2007). The National Academy of Sciences (NAS) Report (2009) indicates that accreditation should be made mandatory for all crime laboratories. This area should be further investigated.

Future research should examine whether individual certification affects the outcome of the examination and comparison of firearm and tool mark evidence. Certification promotes professionalism and offers further proof of demonstrated professional levels of knowledge. Certification demonstrates proof of skill, as well as
ability in the area of the forensic science discipline of firearm and tool mark examinations. Certification needs to be included as a measurement, as well as an exploration into its relationship and affiliation with professional organizations, and correlated with the outcome of firearm and tool mark examinations.

The National Academy of Sciences Report (2009) questioned the repeatability and uniqueness of striations/impressions left on fired evidence as well as the validity and error rate in firearms identification. Past studies (Biasotti & Murdock, 1984; Biasotti & Murdock, 2002; Brundage (1998); Hamby, 2001; Hamby, Brundage, & Thorpe 2009; Miller, 2000b; Miller, 2004; Miller & McLean, 1998) contradict the NAS Report; however, research in this area should continue.

Future research will only improve the scientific foundation of forensic firearm and tool mark identification through the evaluation testing and study, to determine the uniqueness of striations/impressions. Furthermore, it will allow the error rates for identifications of same gun evidence to be calculated from the additional data. This empirical data is needed to strengthen the foundation of firearms identification in the legal arena, and will address some of the National Academy of Sciences’ concerns with the ability to quantify the significance of an identification. Only fundamental research will improve the understanding of the accuracy, reliability and validity of the forensic science discipline of firearm and tool mark identification.

Other Implications

During the initial process of this research study, the researcher made a distinction between the theory of pattern matching and the theory of consecutive matching striations (CMS) based on personal experience. This researcher was trained in CMS; however,
utilized pattern matching for practical application and based identifications on individual matching striations, their width, length, spatial relationship, surface contour and the number of these lines that were present. Several empirical studies (Brundage, 1998; Clow, 2005; Coffman, 2003; Cody, 2003; Hamby, 2001; Hamby & Brundage, 2007; Miller, 2000a; Thompson & Wyant, 2003) have clearly documented and validated the theory of pattern matching.

The theory of CMS has gained support through seminal and empirical studies (Biasotti, 1959; Biasotti & Murdock, 1984; Miller, 2000b; Miller, 2004; Miller & McLean, 1998). These studies determined that a set number of consecutive matching lines could be used to make an identification, and that a quantitative number would make conclusions an objective opinion. Miller (2000b) concluded that there would be no erroneous identifications applying the theory; however, the possibility to exclude a positive identification exists.

Few empirical studies (Moran, 2001; Nichols, 2003; Walsh & Weavers, 2002) examined the relationship between traditional pattern matching and CMS. Based on this study, the majority of firearm and tool mark examiners continue to rely on pattern matching when conducting ballistic examinations. This results of this research study indicated that the utilization of both methods (Pattern matching and CMS) combined may improve performance and lead to more accurate results.

The findings of this research study supports the theory in firearm and tool mark identification, that each firearm/tool produces a signature of identification (striation/impression) that is unique to that firearm/tool, and through examining the individual striations/impressions; the signature can be positively identified to the
firearm/tool that produced it. There were a total of 2250 questioned unknown fired bullets examined by the participants, which resulted in 2241 correct answers and 9 incorrect answers.

Finally, this research study, although not intended to, addressed the questions that were raised by the National Academy of Sciences Report (2009). 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 error rate for the examination of unknown questioned bullets to the Glock Miami/EBIS Gun Barrels was established by this researcher to be 0.4%. There were a total of 2250 questioned unknown fired bullets examined, which resulted in 2241 correct answers and 9 incorrect answers, which addresses the repeatability and uniqueness of striations/impressions.
REFERENCES


*Evidence submission manual* (1997). Fort Lauderdale, FL: Broward County Sheriff’s Office.


http://faculty.chass.ncsu.edu/garson/PA765/anova.htm


MacInnis, L. (2007). *U.S. most armed country with 90 guns per 100 people*. Retrieved October 13, 2008 from ProQuest:

http://www.reuters.com/article/topNews/idUSL2834893820070828


Valdes, A. Sergeant, Miami Police Department, personal communication, June 2, 2003.


BIBLIOGRAPHY


(Original work published 1934).


Appendix A:

Survey Instrument
Answer Sheet: Consecutively Rifled Glock Miami Barrel Test Set

<table>
<thead>
<tr>
<th>Name:</th>
<th>Job Title:</th>
<th>Date:</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Years Experience:</th>
<th>Years Training:</th>
<th>Type of Training:</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Brand &amp; Model of Microscope:</th>
<th>Type of Lighting:</th>
</tr>
</thead>
</table>

Do you examine other types of evidence: Yes No If Yes, what other types?

<table>
<thead>
<tr>
<th>Do you belong to a professional or forensic organization(s)?</th>
<th>Yes No Please list:</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Have you attended the FBI Specialized Techniques School?</th>
<th>Yes No</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Did you use Pattern Matching or CMS for this test?</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Have you ever encountered the Miami or EBIS Barrel in your case work?</th>
<th>Yes No</th>
</tr>
</thead>
</table>

Please microscopically compare the known test shots from each of the 10 barrels with the 15 questioned bullets submitted. Indicate your conclusion(s) by circling the appropriate 'alpha' designator on the same line as the known test shots indicated. Note: There are at least one or more bullets associated with each of the 10 known bullet sets. All 15 questioned bullets were fired from the 10 barrels represented by these test shots. 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 base, you may elect to confirm the 'identifier' on the base and rescribe it on the nose of the bullet.

### Knowns


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

Permission for Instrument
You have my permission to adapt my questionnaire for your project.

Jim

James E. Harnby, Ph.D.
Laboratory Director
International Forensic Science Laboratory & Training Centre
2365 Executive Drive
Indianapolis, IN 46241

In a message dated 5/14/2006 8:53:57 P.M. Eastern Daylight Time, you wrote:

Hi Jim,

I am working on my Ph.D. and I will be conducting research utilizing 10 Glock Miami Barrels. May I have permission to adopt your questionnaire / answer sheet that you used for the Consecutively Rifled PB6 Barrel Test Set? I will cite the source.

Thank you,

Tom
Appendix C:

IRB Approval
PrINCIPAL INVESTIGATOR: Thomas G. Farah Jr.
Project Title: The Viscous Barrel: An Innovation in Forensic Firearms Identification

IRB Project Numbers: 2039-001 Request for Expedited Review of Application and Research Protocol for a New Project

IRB Action by the IRB Chair or Another Member or Members Designed by the Chair:

Expeditied Review of Application and Research Protocol and Request for Expedited Review (FORM 1): Approved X Approved; w/provision(s).

COMMENTS:
Consent Required: No , X Not Applicable ___ Written ___ Signed .
Consent forms must bear the research protocol expiration date of 02/10/2010.
Application to Continue/Review is due:
1) For an Expedited IRB Review, one month prior to the due date for renewal X
2) Other.

Name of IRB Chair: Farideh Farazmand

Signature of IRB Chair

Date: 02/18/09

Date: 02/18/09

Institutional Review Board for the Protection of Human Subjects
Lynn University
3601 N. Military Trail, Boca Raton, Florida 33431
Appendix D:

Voluntary Consent Form
Lynn University

THIS DOCUMENT SHALL ONLY BE USED TO PROVIDE AUTHORIZATION FOR VOLUNTARY CONSENT

PROJECT TITLE: The Miami Barrel: An Innovation in Forensic Crime Detection
Project IRB Number: Lynn University 760, N. Military Trail, Boca Raton, Florida 33431
2009-003

I, Thomas Fadul, am a doctoral student at Lynn University. I am writing Global Leadership, with a specialization in (choose one) leadership. One of my degree requirements is to conduct a research study.

DIRECTIONS FOR THE PARTICIPANT:

You are being asked to participate in my research study. Please read this carefully. This form provides you with information about the study. The Principal Investigator (Thomas Fadul) will answer all of your questions. Ask questions about anything you don't understand before deciding whether or not to participate. You are free to ask questions at any time before, during, or after your participation in this study. Your participation is entirely voluntary, and you can refuse to participate without penalty or loss of benefits to which you are otherwise entitled. You acknowledge that you are at least 18 years of age, and that you do not have medical problems or language or educational barriers that preclude understanding of expectations contained in this authorization for voluntary consent.

PURPOSE OF THIS RESEARCH STUDY: The study is about a 10 gun Glock Miami Barrel Test. Approximately 300 firearm and tool mark examiners are invited to participate in this study. You participants are selected from the FBI Membership List.

The results will include whether or not firearms and tool mark examiners can properly identify questioned bullets to known standards that were fired in Glock Miami Barrels. Additionally, this study will examine the results of pattern matches (as a group) to line comparisons (as a group).

PROCEDURES:

You will receive 15 questioned bullets that were fired through 10 consecutively manufactured Glock Miami Barrels. You will also receive 10 sets of semi-identified bullets (known standards) that were fired through the Glock Miami Barrels. You are asked to compare the questioned bullets to the known standards. You are asked to place your answers on the answer sheet that you will receive. You will also be asked to complete the questions that are on the answer sheet. Once you complete the task, you may mail back the answer sheet in the enclosed preaddressed, stamped envelope, or fax it. The fax number is (508) 771-3479.

POSSIBLE RISKS OR DISCOMFORT: This study involves minimal risk. In addition, participation in this study requires a minimal amount of your time and effort.

POSSIBLE BENEFITS: You may receive no direct benefit to you in participating in this research. But knowledge may be gained which may help the science, which will appear, but the hypothesis in Firearms and tool mark identification (each bullet/bullet produces an impression that is unique to lead/bullet, and through examining the individual signatures, the impression can be compared to the lead/bullet that produced it) is true for the Glock Miami Barrel.

Submitted for Review: 27 November 2009

Lynn University

159
FINANCIAL CONSIDERATIONS: There is no financial compensation for your participation in this research. There are no costs to you as a result of your participation in this study.

CONFIDENTIALITY

Every effort will be made to maintain confidentiality. Your identity in this study will be treated as confidential. Only the researcher Thomas Padal will know who you are. Numerical numbers will be assigned to all records to protect your identity in your participation.

The results of this study may be published in a dissertation, scientific journals, or presented at professional meetings. In addition, your individual privacy will be maintained in all publications or presentations resulting from this study.

All data gathered during this study, which were previously described, will be kept strictly confidential by the researcher. Data will be stored in locked files and destroyed at the end of the research. All information will be held in strict confidence and will not be disclosed unless required by law or regulation.

RIGHT TO WITHDRAW: You are free to choose whether or not to participate in this study. There will be no penalty or loss of benefits to which you are otherwise entitled if you choose not to participate.

CONTACTS FOR QUESTIONS/ACCESS TO CONSENT FORM: Any further questions you have about this study or your participation in it, whether now or at any time in the future, will be answered by Thomas Padal (Principal Investigator) who may be reached at: and Dr. Vendell, faculty advisor who may be reached at: . For any questions regarding your rights as a research subject, you may contact Chair of the University Institutional Review Board for the Protection of Human Subjects, as well.

If any problems arise as a result of your participation in this study, please call the Principal Investigator (Thomas Padal) and the faculty advisor (Dr. Vendell) immediately. Please make a copy of this consent form for your record.

AUTHORIZATION FOR VOLUNTARY CONSENT:

I have read and understand this consent form. I have been given the opportunity to ask questions, and all my questions have been answered to my satisfaction. I have been advised that any future questions that may arise will be answered. I understand that all aspects of this project will be carried out in the strictest of confidence and in a manner in which my rights as a human subject are respected. I have been informed of the risks and benefits. I have been informed in advance as to what my rights will be and what procedures will be followed.

I voluntarily choose to participate. I know that I can withdraw consent to participate at any time without penalty or prejudice. I understand that by signing this form I have not waived any of my legal rights. I further understand that nothing in this consent form is intended to replace any applicable Federal, state, or local laws, and I understand that I will receive a copy of this form.

I acknowledge that completing and returning the answer sheet will signify my consent to participate in this study.

INVESTIGATOR’S AFFIDAVIT:

I hereby certify that a written explanation of the nature of the above project has been provided to the person participating in this project. A copy of the written explanation may be obtained from the investigator. All persons of the project participating in this study for the above project were of the age and that the legal rights of the children or other participants were not violated by the conduct of the research. Therefore, I hereby certify that to the best of my knowledge the person participating in this project understood clearly the nature, demands, benefits, and risks involved in his/her participation.

Signature of Investigator

Date of IRB Approval

160
Appendix E:

Definition of Terms
Definition of Terms

AFTE is the acronym for The Association for Firearm and Tool Mark Examiners (AFTE Glossary, cover, 2001).

The barrel is defined as the “part of a firearm through which a projectile or shot charge travels under the impetus of powder gasses, compressed air, or other like means” (AFTE Glossary, 2001, p. 9).

Bore is defined as “the interior of a firearm”, whereas caliber is defined as “the diameter of the bore of a rifled firearm” (Saferstein, 2001, p. 422).

A bullet is defined as “a non-spherical projectile for use in a rifled barrel” (AFTE Glossary, 2001, p.24). Bullet engraving is defined as “the rifling impression on a fired bullet” (AFTE Glossary, 2001, p. 24).

A cartridge is defined as “a single unit of ammunition consisting of the case, primer, and propellant with one or more projectile(s). Also applies to a shot shell” (AFTE Glossary, 2001, p. 35).

A cartridge case or casing is defined as the container for all the other components which comprise a cartridge (AFTE Glossary, 2001, p. 35).

The chamber is defined as “the rear part of the barrel bore that has been formed to accept a specific cartridge” (AFTE Glossary, 2001, p. 43).

Class characteristics are defined as “properties of evidence that can only be associated with a group and never with a single source” (Saferstein, 2001, p. 65).

Comparison is defined as “the process of ascertaining whether two or more objects have a common origin” (Saferstein, 2001, p. 63).
Comparison microscope is defined as “two compound microscopes combined into one unit” (Saferstein, 2001, p. 168).

Consecutive matching striations (CMS) is defined as “a numerical threshold that allows one to distinguish between what constitutes an identification from a non-identification or inconclusive” (Nichols, 2003, p. 303).

The Broward County Sheriffs Office (1997) defines the Crime Laboratory as an entity that provides experts in the forensic field to interpret, compare, and identify physical evidence.

Criteria for Identification for the purpose of this paper will mean the requirement needed to reach the conclusion of an identification.

Cut rifling is defined as rifling with square shoulders. A cutter is “adjusted to make a cut of approximately .0005 inch depth and is then pulled through each groove in the barrel” (AFTE Glossary, 2001, p. 109). The cutter is then adjusted to cut deeper and is pulled through each groove. This method is repeated until the manufacture reaches the preferred depth.

An Ejector is defined as “the mechanism in a firearm that throws the cartridge or fired case from the firearm” (Saferstein, 2001, p. 429).

Ejection port is defined as “the opening in the receiver or slide of a self-loading or automatic weapon through which the fired cartridge case is ejected” (Heard, 1997, p. 241). Ejection port marks are defined as “indented or striated marks at one or more locations on a cartridge case as a result of striking one or more areas on the ejection port during egress” (Haag, 2006b, p. 311).
An extractor is a “mechanism for withdrawing the cartridge or cartridge case from the chamber” (AFTE Glossary, 2001, p. 55). An extractor mark is “tool marks produced upon a cartridge or cartridge case from contact with the extractor” (AFTE Glossary, 2001, p.54). “The extractor mark is “usually found on or just ahead of the rim” (AFTE Glossary, 2001, p.54).

Evidence is defined by Merriam-Webster (2008) as “something that furnishes proof” (¶ 1), such as testimony. Furthermore, dictionary.com (2007) defined evidence as something that is useful in helping one reach a conclusion, such as “material objects admissible as testimony in a court of law” (¶ 1).

Exclusion is defined by Merriam-Webster (2008) as “the act or an instance of excluding” (¶ 1). For the purpose of this paper, it will also mean to eliminate.

A firearm is defined as “an assembly of a barrel and action from which a projectile(s) is propelled by products of combustion” (AFTE Glossary, 2001, p. 58). Mueller and Olson (1968) define a firearm as “any weapon which a projectile is discharged by explosive means” (p. 81).

Firearms Identification is defined as “a discipline of forensic science which has as its primary concern to determine if a bullet, cartridge case or other ammunition component was fired by a particular firearm” (AFTE Glossary, 2001, p. 58).

Forensic science is defined as “the study and practice of the application of science to the purposes of the law” (Tuthill, 1994, p. 8).

Glock is the last name of Gaston Glock who was an engineer that formed his own company, Glock Inc., and the manufacture of the Glock Pistol (Kasler, 1992).
Hammer forging is defined as a rifling method in which a mandrel “is pulled through the bore whilst the barrel is hammered or squeezed on to it” (Heard, 1997, p. 124).

A jig is defined as “a device that holds a work piece in place and guides the cutting tool during a machining process” (Walker, 2004, p. 143).

Identifiable striae are “striations in the evidence mark which can be identified with reproduced striations in the test marks” (AFTE Glossary, 2001, p. 72).

Identification is defined by Thornton and Peterson (2002) as the act of identifying. For the purpose of this paper, Identification shall mean identifying two items as being produced by a common origin.

Individual characteristics are defined as “properties of evidence that can be attributed to a common source with an extremely high degree of certainty” (Saferstein, 2001, p. 65). Heard (1997) defined individual characteristics as “random imperfections produced during manufacture or caused by accidental damage, rusting, etc. which are unique to that object and distinguish it from all others” (p. 132).

The land and groove impression is defined as “the negative impressions on the bearing surface of a bullet caused by the rifling in the barrel from which it was fired” (AFTE Glossary, 2001, p. 75). The land is the raised portion, where as the groove is the cut portion.

Mandril is defined as “an extremely hard steel plug tapered at both ends containing an exact negative of the rifling profile required” (Heard, p. 121).
Miami Barrel is defined as a Glock polygonal rifled barrel that contains modifications which resulted due to the Miami-Dade Police Department’s inability to identify fired bullets to the shooting office’s weapon (Carr & Fadul, 1997).

Microscope marks are “striae or patterns of minute lines or grooves in an object. In firearm and tool mark identification these marks are characteristic of the object which produced them and are the basis for identification” (AFTE Glossary, 2001, p. 86).

“The result of Not Readily Identifiable means that tests of the same brand fired in the same pistol (barrel) could not be positively identified or that the identification generally could only be made on a small or select area of the bullet. The term further describes the signature of a fired bullet that is typically received in this laboratory as evidence and because of the general lack of detail or repeatable markings that identifications are difficult or sometimes impossible. It should be noted that all of the test bullets examined are not damaged or expanded, and therefore, they have the potential of receiving maximum transfer of barrel signature for that brand and type of ammunition” (Carr & Fadul, 1997, p. 233).

Objective is defined by Merriam-Webster (2008) as “dealing with facts or conditions as perceived without distortion of personal feelings, prejudices or interpretations” (¶ 3).

A pistol is defined as “a handgun in which the chamber is part of the barrel” (AFTE Glossary, 2001, p. 96).

Physical Evidence is defined as “any and all objects that can establish that a crime has been committed or can provide a link between a crime and its victim or a crime and its perpetrator” (Saferstein, 2001, p. 33).
**Police Department** is defined by Wikipedia.org (2007) as an organization that is charged with responsibility of enforcing the law, and preserving order.

**Polygonal rifling** is defined as “lands and grooves having a rounded profile instead of the traditional rectangular profile” (AFTE Glossary, 2001, p. 110).

A *projectile* is defined as “an object propelled by the force of rapidly burning gases or other means” (AFTE Glossary, 2001, p. 102).

“The result of **Readily Identifiable** means that several areas of the bullet can be positively identified to other bullets of the same brand fired from that pistol (barrel). It further describes the signature of a fired bullet that is typically received in this laboratory as evidence and because of the quality of the signature; we expect to identify it with the comparison microscope” (Carr & Fadul, 1997, p. 233).

**Rifling** is defined as “the spiral grooves in a barrel which impart spin or rotation to the bullet to stabilize it in flight” (Nonte, 1973, p. 214).

**Rim** is defined as the “flange at the base which is larger than the diameter of the body of the cartridge case” (Heard, 1997). The rim allows the extractor to remove the cartridge case from the firearm.

**Striated tool marks** are “produced when a tool is placed against another object and with pressure applied; the tool is moved across the object producing a striated mark” (AFTE Glossary, 2001, p. 126).

**Striations** are “contour variations, generally microscopic, on the surface of an object caused by a combination of force and motion where the motion is approximately parallel to the plane being marked. These marks can contain class and/or individual characteristics” (AFTE Glossary, 2001, p. 126).
Subclass characteristics is defined as “discernable surface features of an object which are more restrictive than class characteristics in that they are: produced incidental to manufacture, are significant in that they relate to a smaller group source (a subset of the class to which they belong), and can arise from a source which changes over time” (AFTE Glossary, 2001, p. 127).

Subjective is defined by Merriam-Webster (2008) as a judgment that is “modified, or affected by personal views, experience, or background” (¶ 4).

Sufficient agreement is the “significant duplication of random tool marks as evidenced by the correspondence of a pattern or combination of patterns of surface contours. The statement that sufficient agreement exists between two tool marks means that the likelihood another tool could have made the mark is so remote as to be considered a practical impossibility” (AFTE Glossary, 2001, p. 129).

The theory of identification “as it pertains to the comparison of tool marks enables opinions of common origin to be made when the unique surface contours of two tool marks are in “sufficient agreement” (AFTE Glossary, 2001, p. 129).

A tool is defined as “an object used to gain mechanical advantage. Also thought of as the harder of two objects which when brought into contact with each other, results in the softer one being marked” (AFTE Glossary, 2001, p. 144).

Tool mark identification is “a discipline of forensic science which has as its primary concern to determine if a tool mark was produced by a particular tool” (AFTE Glossary, 2001, p.144).