Examining the Difference Between Automated Identification Systems in Comparison to Traditional Methods

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Introduction

Firearm examiners must typically state the quantity and quality of the features to reliably draw conclusions regarding the likelihood that two specimen, either a recovered projectile or cartridge casing, match for an identification to be made [3]. Identifications are made when unique surface contours or features are in sufficient agreement, which is based upon the relative height or depth, width, curvature, and spatial relationship of the individual striae on one surface are defined and consistent with the corresponding surface [1]. When examining fired bullets, , the lands and grooves on the rifling will inscribe striae at varying depths, widths, and curvatures based on General Rifling Characteristics (GRC) direction of rifling twist and number of lands and grooves [5]. It is the *width* of these Land and Groove Engraved Areas (LEA/GEA) that are commonly quantified when an analysis is performed.

Traditional analysis is performed using a comparison microscope with a micrometer where the widths of all LEAs and GEAs are manually measured to the nearest thousandth of an inch from a designated starting point on the bullet. New methods such as IBIS BULLETTRAX-HD3D rely on physical quantifications that are typically measured electronically as they provide the basis for designing and conducting statistical comparison algorithms after the examiner manually selects the initial anchor point [2]. Many forensic laboratories such as the Center of Forensic Science insist on replacing the traditional method of analysis with these new automated techniques, however, they require a definitive examination into the suitability of these automated technologies replacing the traditional methods of quantifying the widths of fired bullets. An examination of the two methods and any differences between them is described.

Methods

All samples utilized in this experiment were provided by the Physical Sciences branch of the Center of Forensic Science. The firearms chosen in this experiment represents a variable range of possibilities, including age, cost, and design. All firearms for this experiment are self-loading (semi-automatic) handguns chambered in the 9mm Luger or 9x19mm Parabellum cartridge. The 9mm Luger ammunition used for test fires consisted of three manufacturers: Federal, Remington, and Winchester with the Federal-made ammunition being the most predominant type. No specificities regarding the ammunition, such as grain of the bullet, were provided in this experiment as they would not significantly affect the quality of impressions departed on test samples. Overall, 100 cartridges expended in total, however 3 bullets had to be excluded due to poor quality, resulting in the total sample size of 97.

A starting LEA was chosen and marked by technicians at the Center of Forensic Science to indicate the initial point of measurement for both methods. From this anchor point, the bullet would be rotated clockwise until it reached the starting point ensuring all LEAs and GEAs widths are measured. The were subsequently measured using IBIS BULLETTRAX-HD3D program and manual comparison microscopy methods. The bullet that was measured using the IBIS software was the same bullet that was measured by the examiner using a Leica FSC comparison macroscope and calibrated stage graticule.

The Leica FSC was calibrated using two identical, certified, stage micrometers are used to compare the two sides of the microscope and determine if there's any deviation between the left or right objectives. At objective 2x magnification, the comparison microscope has 0.00 mm bias between the left and right sides, meaning that both stages are identically in focus for the highest quality image. The micrometer would measure the widths to the nearest thousandth of an inch. The estimated measurement uncertainty associated with the micrometer used on the microscope is ± 220 µin.

Technicians from the Center of Forensic Science had performed the measurements using the IBIS BULLETTRAX-3D software to ensure the results were properly obtained. Measurements acquired from the IBIS BULLETTRAX-3D system were taken to the nearest millionth of a millimeter. To compare these results to the widths measured manually, they were converted from millimeters to inches. Using the program XLSTAT^{TM} by Addinsoft, a Bland-Altman analysis for method comparison was performed to determine any possible similarities or differences. To perform these tests, the measurements of both data sets were split to compare methods on a land-to-land and groove-to-groove basis for each bullet sample. The average width measurement (in inches) of each bullet sample for the lands and grooves were used for the subsequent statistical tests comparing the two methods, since the models varied in rifling number.

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Results

Table 1: **Bland-Altman results output for the average *land* measurements of both methods including the bias, or mean difference, between the two methods, confidence interval for the differences, or limit of agreement, and confidence interval for the bias. Pearson correlation coefficient and its confidence interval is included for interpretation.**

Bias (in)	0.0015
Standard error	± 0.0032
CI Bias (95%)	] 0.0008, 0.0021 [
CI Differences	] -0.0048, 0.0077 [
Pearson Correlation	0.2549
CI (95%) for Pearson	] 0.0584, 0.4324 [

Table 2: **Bland-Altman results output for the average *groove* measurements of both methods including the bias, or mean difference, between the two methods, confidence interval for the differences, or limit of agreement, and confidence interval for the bias. Pearson correlation coefficient and its confidence interval is included for interpretation.**

Bias (in)	0.0018
Standard error	± 0.0023
CI Bias (95%)	] 0.0013, 0.0023 [
CI Differences	] -0.0027, 0.0063 [
Pearson Correlation	0.3113
CI (95%) for Pearson	] 0.1125, 0.4861 [

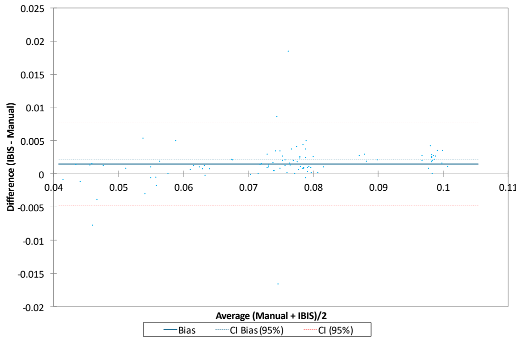

Figure 1: **Bland-Altman plot comparing the average *land* width measurement between IBIS and Manual methods illustrating the bias, 95% confidence interval around the bias, and the Limits of Agreement generated by the program based on the data**

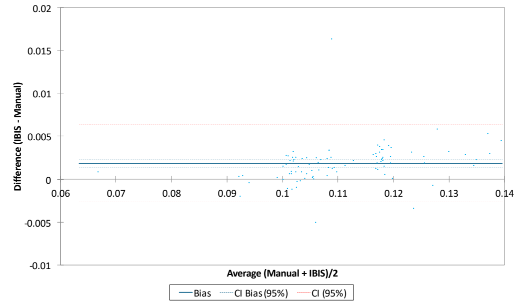

Figure 2: **Bland-Altman plot comparing the average *groove* width measurement between IBIS and Manual methods illustrating the bias, 95% confidence interval around the bias, and the Limits of Agreement generated by the program based on the data.**

Discussion/Conclusion

- Sample size was sufficiently large; therefore, the means of the samples are normally distributed [4].
- Bias, or average difference, between the two methods for LEAs & GEAs was ± 0.002 in indicating that a difference exists between the two methods of measurement.
- The measurements that constitute a majority of the datapoints on the plot are located within 0.065 - 0.085 in and 0.100 - 0.120 in
- The positive bias illustrated in both Figure 1 and Figure 2 as the main bias line being greater than zero indicates that the 0.002-in bias is a positive overestimate, or overmeasurement, for one of the methods.
- Despite the bias being relatively small, we cannot say that the two methods are the same, even for land and groove engraved areas that showed consistent variability.
- Examining the distribution of data points in Figure 1 and Figure 2, the bias is likely a result of land measurements being smaller than 0.065 in or greater than 0.085 in in width, and for grooves that are greater than 0.120 in or smaller than 0.100 in.
- If the Center of Forensic Science deems the ± 0.002 inches measurement bias an acceptable range for their standards, then the IBIS method of quantification would be suitable to replace the traditional, manual form of LEA/GEA width quantification.

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