# Assessing Structured Light 3D Scanning using Artec Eva for Injury Documentation during Autopsy

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## Abstract

Three-dimensional (3D) scanning is gaining popularity in several forensics and medical settings. The purpose of this study was to determine whether the Artec Eva 3D scanner is appropriate for documenting bullet trajectories and better suited than photographs or manual measurements for measuring the location and size of injuries during autopsies. Eleven injury tattoos on a live participant underwent manual measurements, digital photographs, and 3D scanning with the Eva and FARO Edge ScanArm to document injury size and location. Student's t-tests provided p-values of 0.9513 and 0.9514 for Eva and manual measurements respectively in comparison to reference measurements from the Edge ScanArm. Eva scanning was found to be the easier method to use through a scoring system that rated technical difficulty level and documentation time. The Eva was used to scan a bullet trajectory setup and the benefits of the 3D model outweighed the time taken to create it.

**Keywords:** forensic pathology, autopsy, 3D scanning, injury documentation, Artec Eva, crime scene reconstruction, forensic science

## Article Information

Received: 5 September 2016
Revised: 18 January 2017
Accepted: 23 January 2017
Published: 30 January 2017

Citation: Sivanandan J, Liscio E. Assessing Structured Light 3D Scanning using Artec Eva for Injury Documentation during Autopsy. *J Assoc Crime Scene Reconstr.* 2016;21:5-13.

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## Introduction

Forensic pathology is considered a crucial discipline of the criminal justice system, serving the purpose of determining the cause and manner of death [1]. Forensic pathologists typically fulfil this purpose by performing external and internal examinations during an autopsy [1]. However, there can be numerous mistakes made by pathologists during this process. Dr. Alan Moritz identified many of these errors, including misinterpretation of post-mortem color changes, failure to make adequate external examinations, and failure to take adequate photographs of the evidence [2]. Performing a thorough external examination could alleviate many of these mistakes and prevent essential evidence from being discarded. For example, in a fatal stabbing case, the location and course of the wounds on the body documented through the external examination was largely responsible for the conviction of the assailant [2]. Likewise, in a hit-and-run case, finding green paint on the scalp of the victim during the external examination provided the critical evidence necessary to correctly identify the perpetrator [2]. A pathologist who may not have been experienced with these types of cases may have missed this evidence, thus illustrating the importance of external documentation and evidence preservation [2].

Traditional injury documentation during autopsies involves taking photographs of the injuries at different distances from the area of interest in addition to manual measurements taken by hand using a ruler and/or tape measure [3, 4]. A limitation to the traditional approach is that multiple photographs are necessary to give the viewer a sufficient understanding of the location and size of the injury relative to the entire body. A solution to this problem is to produce a fully rotatable 3D model using a 3D scanner, which can showcase the complete body in a single 3D model. A 3D model of a body presents injuries in a manner that is not only spatially and logically easier to comprehend, but allows viewers to have a clearer understanding of the location and size of injuries relative to other areas of the body.

3D models retain more geometric detail as compared to traditional photographs, which can be referred to later on in an investigation for details missed or for further inquiry into other investigative areas. For example, 3D models of bodies can be viewed alongside photographs when re-examining cold cases, cases that require re-examination of bodily evidence after the body has been disposed of, or solved cases that need to be re-opened due to new evidence being added to the investigation.

A 3D model has many benefits that make it ideal for use in the forensics field. Options to clearly zoom in and out of the area of interest in high quality and rotational capabilities at different angles and orientations allow the viewer to better understand injuries faster than the traditional method of documentation. This is particularly useful for presenting autopsy findings in a court setting to those who may not have a strong understanding of forensic pathology and anatomy. In addition, forensic pathologists currently insert trajectory rods into the body to illustrate bullet path [5]. A 3D scanner can scan these rods while inserted in the body for presentation purposes as well. However, such scanners can be expensive to acquire, require specialized operator training, and additional computer equipment necessary for scanning and processing purposes.

Artec Eva (Figure 1) is a professional, high-quality 3D scanner which is being used in a variety of medical, industrial, and animation settings [6]. This scanner uses structured light scanning technology to accurately capture objects in a point-and-shoot manner with a point spacing of 0.1 mm [7, 8]. Point-and-shoot scanners work by enabling users to walk around the object intended to be scanned and maneuver the scanner to capture the entire

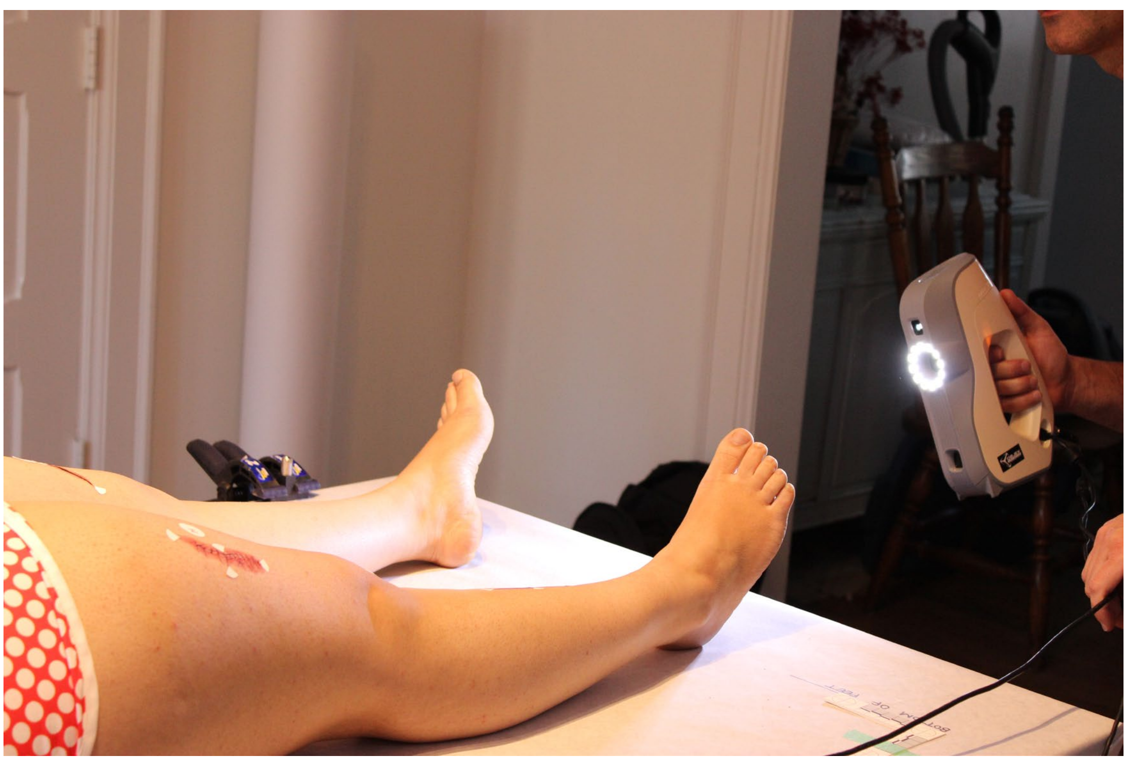

**Figure 1:** An Artec Eva being used to scan a live participant.

object as completely as possible [7]. Structured light scanning is a method of 3D scanning where a known pattern is projected onto an unknown surface and the deformation in the surface is analyzed to reconstruct the shape of the surface [9]. The Artec Eva, when connected to a computer, will provide an output in the form of 3D mesh data or points clouds. Point clouds are a series of points in 3D space which can be viewed at different angles and orientations, and can have different colors applied to them [10]. These point clouds represent the unknown surface and its deformations accurately. Meshed surface data is where the point cloud is often reduced in size before applying a surface which connects 3 or more points. Meshed surfaces have the advantage of having high resolution colour information projected onto each portion of the mesh and provides a realistic representation of the object being documented.

The purpose of this study is to determine whether the Artec Eva 3D scanner is better than photographs and manual measurements for documenting bullet trajectories and the location and size of injuries during autopsies. Success criteria were based on measurement accuracy, ease-of-use, ability to show a bullet trajectory, and whether the benefits of a 3D model outweigh the time taken to create it.

## Methods

Eleven 2-dimensional, temporary tattoos were applied to a live participant's skin (Figure 2). Locations of these tattoos were the forehead, neck, right shoulder, left shoulder, left upper arm, right forearm, left wrist, right thigh, left thigh and right shin. Four ¼ in (6.35 mm) 3D markers in the form of stickers were placed around each tattoo to define the length and width boundaries, as well as one on the nose, one on each elbow, and one on each knee for location measurements. The participant was lying down on a flat table in anatomical position. Scales were placed on the table to define the top of head and sole of foot boundaries.

The length, width, distance to top of head or sole of foot, distance to the midline of the body, and the distance to a well-established anatomical landmark such as the nose or elbow were taken for each injury with a tape measure having 1 mm increments. Close-up and mid-range digital photographs were taken of each injury with a scale along with full-body photographs. The time taken

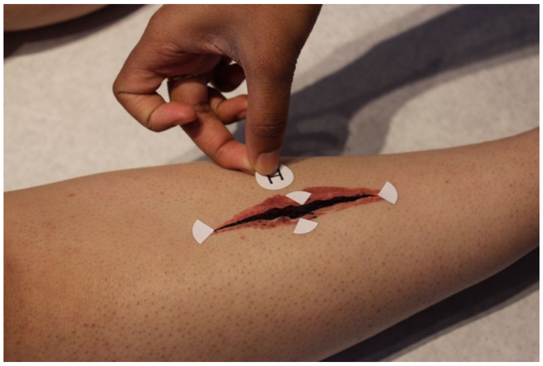

**Figure 2:** An example of a two-dimensional tattoo applied to the participant's skin, along with four three-dimensional markers surrounding it. Three-dimensional markers were necessary for making reference measurements with the FARO Edge ScanArm, as it does not detect color.

for manual measurements and photographs was recorded.

The front of the participant was scanned with the Artec Eva scanner, which was hooked up to a power source and laptop running Artec Studio 9.2 software. Using Artec Studio, several separate scans were initially put together using point picking to get the initial alignment. Artec Studio then completed the alignment using automatic matching. A color map was applied to complete the 3D model using color data that the Artec Eva picked up during the scan. For injuries on a straight surface on the body, the geodesic tool in Artec Studio was used (Figure 3). For injuries on a curved surface, the geodesic tool was used. A tape measure was used for both straight measurements for manual measurements. The time for setup, scanning, processing, and measurements with Artec Eva and Artec Studio was recorded.

A tripod was set up on both sides of the table, each with a mounted steel rod to mimic a bullet trajectory passing through both shoulders. This setup was scanned with the Artec Eva separate from the injury measurements to determine if the scanner is capable of scanning the glossy steel rods for bullet trajectory presentation. Glossy steel rods can be problematic for structured light scanners as light can be reflected back into the scanner which creates unwanted noise in the 3D model.

The FARO Edge ScanArm is a 3D scanner which uses laser technology with a repeatability range between 0.024 and 0.064 mm [11]. The injuries were documented with the FARO Edge ScanArm to create reference measurements as it is more accurate than both manual and Artec Eva methods. This scanner is less suitable on

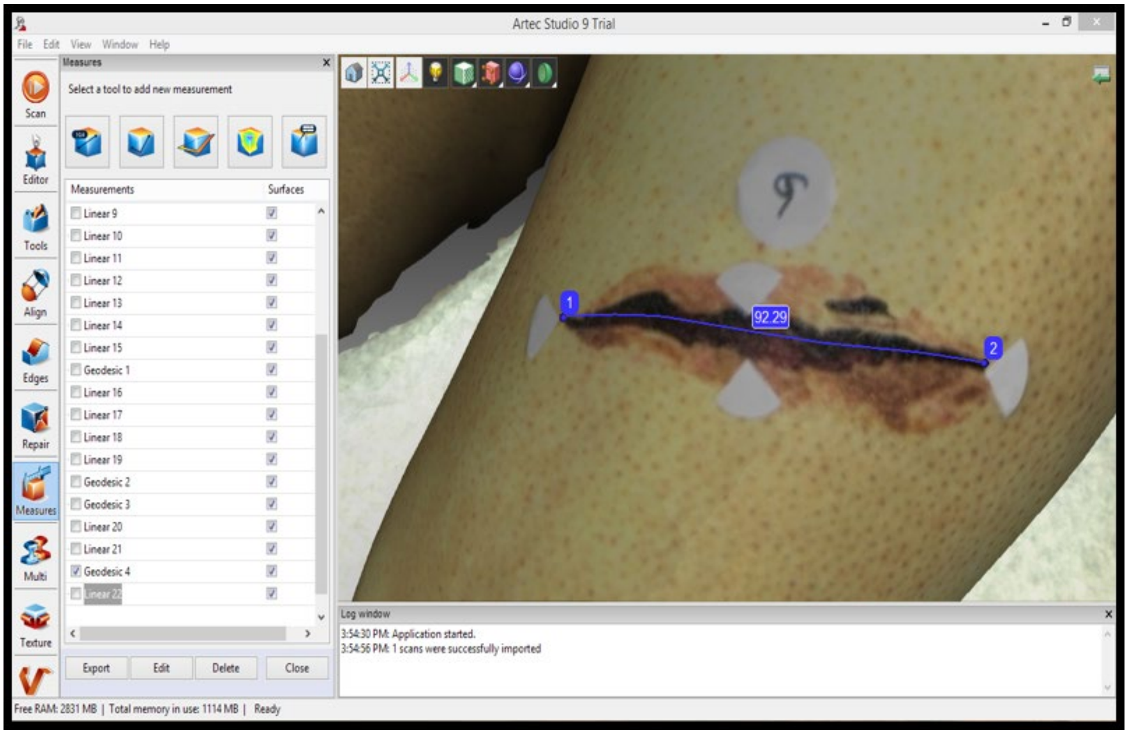


**Figure 3:** An example of the geodesic tool being used to measure a tattoo on a curved surface of the body.

its own than the Eva for autopsy use because it does not capture color, which is a crucial detail in injury documentation. CloudCompare v2.6.0 software was used to take digital measurements on the 3D model originating from the FARO Edge ScanArm. To do this, two points on the 3D model were manually picked which defined the distance to be measured (Figure 4).

## Statistics

Two-sample student's t-tests assuming equal variance were performed in Microsoft Excel to test the measurement accuracy of manual and Artec Eva measurements in comparison to the FARO Edge ScanArm measurements (Table 1).

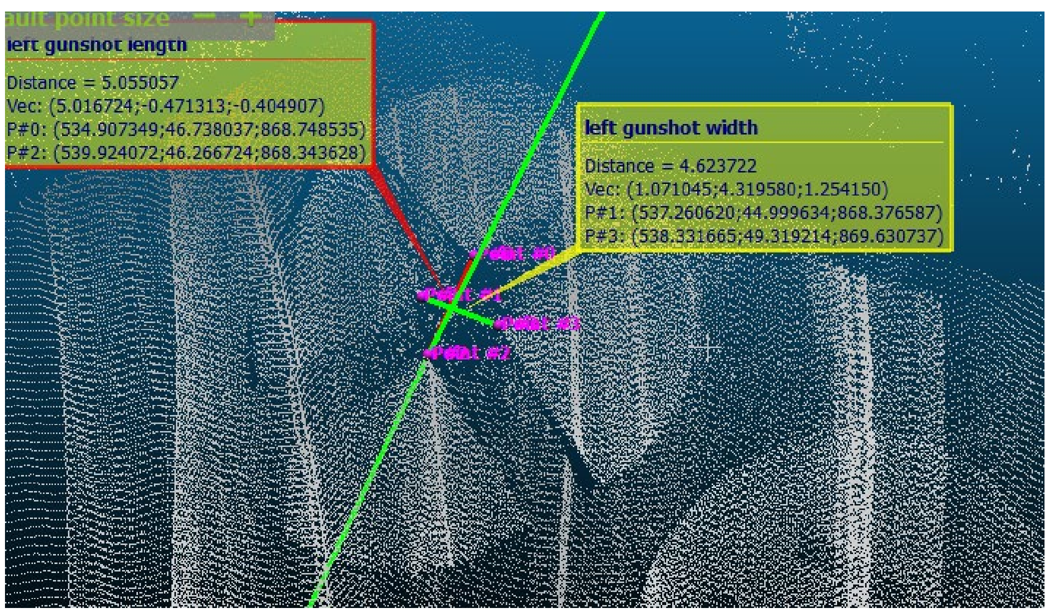


**Figure 4:** An example measurements taken on a tattoo in CloudCompare v2.6.0. The purple dots represent points manually picked to define the distance being measured. The four three-dimensional markers can be seen surrounding the tattoo, and the tips of the markers allowed for accurate point picking.

**Table 1:** All measurements taken manually and using models created from the FARO Edge ScanArm and Artec Eva.

| Injury | Type | FARO Edge ScanArm (mm) | Manual measurements (mm) | Artec Eva (mm) |
|---|---|---|---|---|
| A | Length | 45.71 | 51 | 47.47 |
| | Width | 24.75 | 27 | 24.18 |
| | Distance to top of head | 43.89 | 40 | 41.42 |
| | Distance to midline | 10.24 | 12 | 9.43 |
| | Distance to landmark (nose) | 70.47 | 70 | 69.48 |
| B | Length | 35.47 | 38 | 37.35 |
| | Width | 4.97 | 4 | 4.60 |
| | Distance to top of head | 221.39 | 220 | 205.77 |
| | Distance to midline | 44.96 | 60 | 42.95 |
| | Distance to landmark (nose) | 147.17 | 180 | 159.77 |
| C | Length | 39.77 | 43 | 41.97 |
| | Width | 4.90 | 9 | 4.82 |
| | Distance to top of head | 223.98 | 220 | 201.73 |
| | Distance to midline | 49.78 | 50 | 50.49 |
| | Distance to landmark (nose) | 143.90 | 175 | 154.09 |
| D | Length | 18.55 | 18 | 18.23 |
| | Width | 12.30 | 13 | 12.86 |
| | Distance to top of head | 557.26 | 550 | 542.76 |
| | Distance to midline | 331.10 | 330 | 382.38 |
| | Distance to landmark (nose) | 183.30 | 189 | 180.73 |
| E | Length | 20.21 | 20 | 19.27 |
| | Width | 12.27 | 13 | 11.35 |
| | Distance to top of head | 406.89 | 400 | 409.23 |
| | Distance to midline | 344.21 | 330 | 362.57 |
| | Distance to landmark (nose) | 90.23 | 90 | 89.42 |
| F | Length | 54.69 | 54 | 53.19 |
| | Width | 26.11 | 28 | 26.27 |
| | Distance to top of head | 637.91 | 620 | 627.19 |
| | Distance to midline | 422.25 | 420 | 427.09 |
| | Distance to landmark (nose) | 203.18 | 205 | 202.66 |
| G | Length | 96.03 | 96 | 96.26 |
| | Width | 7.56 | 18 | 7.16 |
| | Distance to top of head | 524.18 | 540 | 533.81 |
| | Distance to midline | 163.83 | 140 | 146.01 |
| | Distance to landmark (nose) | 128.23 | 139 | 127.33 |
| H | Length | 72.59 | 75 | 71.67 |
| | Width | 12.90 | 14 | 12.83 |
| | Distance to top of head | 534.59 | 530 | 558.59 |
| | Distance to midline | 136.38 | 160 | 165.66 |
| | Distance to landmark (nose) | 141.93 | 144 | 141.00 |

| | | | | |
|---|---|---|---|---|
| I | Length | 80.69 | 81 | 79.76 |
| | Width | 7.72 | 9 | 7.20 |
| | Distance to top of head | 302.87 | 260 | 263.28 |
| | Distance to midline | 110.87 | 135 | 141.57 |
| | Distance to landmark (nose) | 136.93 | 140 | 139.20 |
| J | Length | 5.06 | 6 | 6.64 |
| | Width | 4.62 | 5 | 5.43 |
| | Distance to top of head | 232.61 | 245 | 250.57 |
| | Distance to midline | 211.30 | 200 | 205.44 |
| | Distance to landmark (nose) | 274.32 | 278 | 273.90 |
| K | Length | 5.54 | 6 | 5.60 |
| | Width | 3.10 | 4 | 4.45 |
| | Distance to top of head | 241.52 | 230 | 247.75 |
| | Distance to midline | 212.99 | 240 | 227.78 |
| | Distance to landmark (nose) | 270.56 | 280 | 274.83 |

## Results

Two-tailed p-values indicate that both methods were equally as accurate for both long and short distance measurements (Table 2). However, the percentage error was higher in manual measurements. Since manual measurements are equally as accurate as the Artec Eva measurements, this is not an advantage of the scanner, and other factors such as ease-of-use and benefits of the model must be taken into consideration.

Ease-of-use was rated using a scoring system with the variables of technical difficulty level and documentation time (Table 3). A technical difficulty is any unexpected delay in the methodology of completing a task. For example, unforeseen software issues which prevent work being completed can be considered a technical difficulty. For every technical difficulty encountered, the technical difficulty variable increased by 1. The Artec Eva scanner had some difficulty being detected by Artec Studio and

**Table 2:** Results of the student's t-tests and percentage error calculations performed to test the measurement accuracy of manual and Artec Eva measurements in comparison to the FARO Edge ScanArm measurements.

| | Artec Eva vs. Faro Edge ScanArm | Manual vs. Faro Edge ScanArm |
|---|---|---|
| **df** | 108 | 108 |
| **p-value** | 0.9513 | 0.9514 |
| **Average % Error** | 6.25 % | 11.5 % |

**Table 3:** Ease-of-use of manual measurements and the Artec Eva was scored using technical difficulty level and documentation time as variables.

| | Artec Eva | Manual Measurements and Photographs |
|---|---|---|
| **Technical Difficulty Level** | 1 | 1 |
| **Documentation Time** | 1.7 | 3.6 |
| **Total** | 2.7 | 4.6 |

long distance manual measurements needed additional attention due to an irregular body surface. The total time taken for Artec Eva setup, scanning, and measurements was 26 minutes and 1 second, whereas manual measurements and photographs took 54 minutes and 30 seconds. The total time for each method was divided by 15 to provide a value between 1 and 5, and the values for the two variables were added up to determine total ease-of-use. Artec Eva is shown to be the easier method to use, mainly due to its reduced documentation time. It should be noted that the processing time of 85 minutes with the Artec Eva model was not included in the ease-of-use analysis. Artec Eva still has the advantage of reducing documentation time as post-processing of the point clouds can be completed post-autopsy.

## Discussion

It should be noted that the tape measure caused measurement variations across large distances since it may have travelled over other body parts. Manual and Artec Eva measurements for the midline, top of head, and sole of foot measurements were approximated as done during traditional autopsies as there was no plane to determine the exact boundaries of these measurements. Future studies can study how depth of an injury can be documented with the Artec Eva. Although point clouds obtained by the Artec Eva can document depth in an external examination, scanning during the internal examination of an autopsy would be better suited for this purpose. The depth of an injury can be more easily visualized during an internal examination of the body and thus digital measurements would be easier to complete on a 3D model of the internal body. Curved measurements, such as the length of a curved incision, take significantly longer to process with the computer algorithm in Artec Studio's geodesic tool, affecting documentation time. A computer with a high processing power is recommended when working with 3D models. This directly reduces documentation time as high processing power can build the 3D model quicker and computer algorithms can be computed in a shorter amount of time than computers with low processing power.

In this study, a live participant was used to mimic a human cadaver in an autopsy setting. The body texture and contour is similar in both a live participant and a cadaver, and thus a live participant is suitable for the study. Nonetheless, natural breathing patterns caused movement of several millimeters during the scanning process. Upon close examination of the 3D models, it was concluded that the effect of breathing movements was only minimally seen in the models. This would not be an issue during autopsy as there would be no movement of the cadaver. Although the Artec Eva was able to scan the glossy steel rods in the bullet trajectory setup, non-glossy rods are recommended for future use to limit any light being reflected off the rods into the scanner.

In the future, the back side of the body can also be scanned because artefacts such as color changes due to post-mortem lividity can contribute to the case as essential evidence. This study can be repeated on several different participants to account for varying body structures and surfaces. In addition, the scanning can be repeated by other people to study variations in technical difficulty and documentation time ratings between different individuals. Other structured light 3D scanners with similar capabilities can also be tested for use during autopsy.

## Conclusion

The Artec Eva was successfully able to scan the bullet trajectory setup, making it ideal for autopsy situations where a bullet trajectory needs to be documented (Figure 5). Since the 3D model was successfully created, it provided the options to zoom and rotate, and could be saved on a computer for future access, it was concluded that the benefits of the 3D model outweigh the time taken to create it.

As the Artec Eva had equivalent measurement accuracy as manual measurements, it was easier to use than the traditional method of injury documentation, had the ability to portray bullet trajectories, and created a 3D model with benefits outweighing creation time, the null hypothesis was rejected, indicating that the Artec Eva is better than manual measurements and photographs for injury documentation during autopsy.

Findings from this study are useful in many contexts including medical and engineering settings. For example, the Artec Eva can be used in plastic surgery documentation where accurate measurements need to be taken. In conclusion,

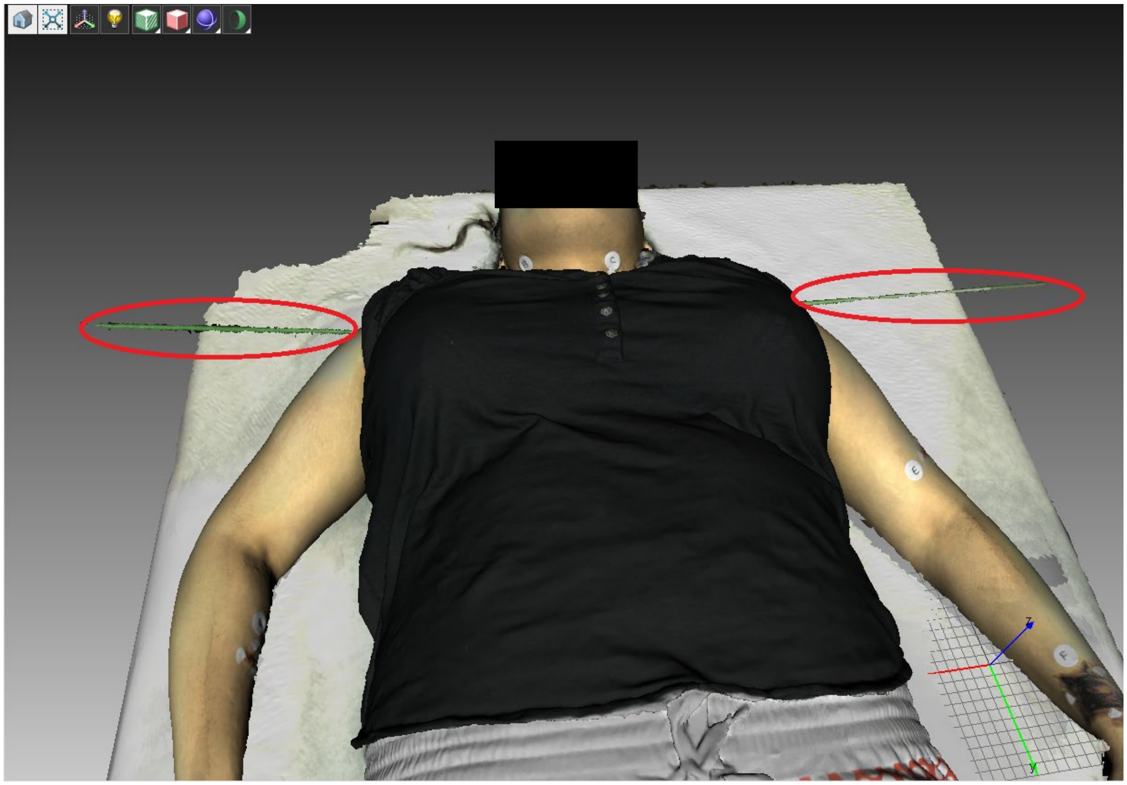

**Figure 5:** Screenshot of the bullet trajectory setup in Artec Studio 9.2. The green lines circled in red represent the trajectory rods that were successfully scanned by the Artec Eva.

3D scanning enters a different paradigm for injury documentation, and the Artec Eva is recommended for injury documentation during autopsies.


## Acknowledgements

We would like to thank Dr. Tracy Rogers for her critical review of the study proposal. We would also like to thank Genevieve Maltais-Lapointe and Patrick Bozek for all their guidance and support with this study.


## Supplemental Material

A supplementary video titled BodyAnimation.mov has been included as a download on the www.acsr.org webpage for this article.

## References


1. Soltanzadeh L, Imanzadeh M, Keshvari H. Application of robotic assisted technology and imaging devices in autopsy and virtual autopsy. *Int J of Comput Sci*. 2014;11(4):104-109.
2. Moritz AR. Classical mistakes in forensic pathology. *Am J Forensic Med Pathol*. 1981; 2(4):299-308.
3. Spitz WU. The Medicolegal Autopsy. *Hum Pathol*. 1980;11(2):105-112.
4. Henham AP, Lee KAP. Photography in forensic medicine. *J Audiov Media Med*. 1994; 17(1):15-20.
5. Sapse D, Kobilinsky L. Forensic science advances and their application in the judiciary system. Boca Raton: Taylor & Francis, 2012.
6. Artec Group. Applications [Internet]. 2015. Cited 2016 Nov 20. Available from: https://www.artec3d.com/applications/
7. Artec Group. Artec Eva [Internet]. 2015 .Cited 2016 Nov 20. Available from: https://www.artec3d.com/3d-scanner/artec-eva
8. Artec Group. Artec Eva: Specifications [Internet]. 2015. Cited 2016 Nov 20. Available from: https://www.artec3d.com/3d-scanner/artec-eva#specifications
9. Massachusetts Institute of Technology. How to scan objects into 3D using structured light? [Internet]. Cambridge (MA): 2010. Cited 2016 Nov 20. Available from: http://fab.cba.mit.edu/content/processes/structured_light/
10. Mike James. Kinect SDK1 - A 3D Point Cloud [Internet]. 2012. Cited 2015 Feb 24. Available from: http://www.i-programmer.info/ebooks/practical-windows-kinect-in-c/4126-kinect-sdk1-a-3d-point-cloud.html

11. FARO. FaroArm [Internet]. 2012. Cited 2015 Feb 24. Available from: http://www.faro.com/en-us/products/metrology/measuring-arm-faroarm/features#main