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Three-dimensional reconstruction of a shooting crime scene

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Abstract: The crime scene is technically the place where an illegal act took place. The investigation first starts at the crime scene. Documentation of the crime scene is of great importance in order to make correct decisions in the investigation and prosecution stages, With the development of technology; the use of different devices and different technologies in crime scene investigation and crime scene documentation has created a new working area for many forensic scientists and law enforcement officers. Taking a general view of the crime scene without contamination, low margin of error in measurements can be shown as the main reasons for the use of laser scanning devices at the crime scene. A firearm crime scene was staged using different evidence. In the staged crime scene, a laser scanning device was also used along with the use of photography, sketching and note-taking methods from traditional documentation methods. In this study, the adequacy of the traditional methods alone, the adequacy of the laser scanning device alone, and the adequacy of the two methods together for reconstruction were discussed. The aim of this study is to determine the contributions and limitations of documenting the crime scene with a laser scanning device in combination with traditional documentation methods to the three-dimensional reconstruction of the crime scene.

Keywords: *3D crime scene, Benefits of 3D crime scene, Crime scene investigation, Crime scene reconstruction and CSR, Laser scanning device, Shooting crime scene.*

1. Introduction

A crime scene is briefly defined as the place where one or more illegal acts occur. Although the crimes are similar, each crime scene is unique. Crime scenes are dynamic areas and can change at any moment, willingly or unwillingly. Even the smallest movement at the crime scene can change the course of the investigation and prosecution.

Crime scene investigation is the first and most fundamental point of the investigation. Good protection and examination of the crime scene, careful documentation of the crime scene, and collection and packaging of the physical evidence by their nature are of great importance for the smooth progress of the investigation and prosecution phases. Photographing, videotaping, audio-recording, note-taking, and sketching are common techniques used in crime scene documentation.

The development of technology has affected the field of forensic sciences as in every field. Forensic scientists try different technologies in documenting and examining the crime scene. Laser scanning devices, AR, VR and MR (mixed reality) technologies are examples of different technologies being studied for use at crime scenes and in forensic science.

The Association of Crime Scene Reconstruction (ACSR) defines reconstruction as "the use of scientific methods, physical evidence, deductive and inductive reasoning, and their interrelationships to gain explicit knowledge of the series of events that surround the commission of a crime [1]. Reconstruction should be carried out to ensure that the investigation and prosecution phase is carried

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out objectively, that there are no problems in solving the cases even if the personnel in charge change, and that the case file is not closed due to reasons such as, lack of evidence - crime scene investigation error/deficiency of the police during the investigation and prosecution phase. The crime scene is reconstructed through photographs and videos taken, sketches drawn, and different technologies used. In order for those conducting the investigation and prosecution to better understand the crimes and crime scenes, the crime scene can be digitised using different technologies such as laser scanners, AR, VR and MR technologies. In Turkey and around the world, photographing, videotaping, note-taking, and sketching are commonly used to document the crime scene. Sketches can be drawn at the crime scene and then digitized, but since it is difficult for the investigation-prosecution teams to reconstruct the crime scene only through sketches and photographs, the reconstruction of the crime scene cannot be done carefully.

This study aims to make use of laser scanning devices, which are increasingly used in various sectors with the developing technology, in addition to the techniques commonly used in documenting the crime scene, to see how the use of laser scanning devices at the crime scene contributes to the reconstruction of the crime scene and to identify the missing points. In this study, an indoor shooting death was staged, and the crime scene was investigated and scanned with laser scanning.

In this study, two different hypotheses were identified and answers to these hypotheses were sought. The first hypothesis is named H1 and the second hypothesis is named H2. H1: The use of laser scanning devices at the crime scene with traditional documentation methods is useful in documenting the crime scene in detail. H2: The process of reconstructing the crime scene, when performed with laser scanning devices, leads to successful results in the investigation and prosecution stages.

In the second part of this study; the definition of the crime scene, documentation of crime scene, and the importance of documentation, the definition of staged crime scene will be mentioned. In the third part; the concept of reconstruction, laser scanning devices used in reconstruction, different technologies used and the benefits of reconstruction will be mentioned. In the fourth part, the main subject of this study, the three-dimensional reconstruction process of the scene of a firearm fatality, the differences between laser scanning and traditional documentation techniques, and positive and negative findings; in the fifth part, the results of the experiments and research will be mentioned.

2. The Investigation of Crime Scene

2.1. The Concept of Crime Scene

Crime scenes can occur anywhere, in busy urban areas or on lonely rural tracts of land, inside a house or underwater, involving one person or thousands. Technically, a crime scene is a location where an illegal act occurred; for purposes of the CSI, it is also the location from which physical evidence is retrieved. It is not necessarily where the crime was committed, however. Defining the crime scene is a key stage in an investigation [2].

With the developing technology, the boundaries of forensic events and therefore forensic sciences are expanding day by day. The unlimited variety of crimes committed has led to the expansion of the field of interest of forensic sciences over the years and the use of many new technologies in the elucidation of crimes. A forensic scientist examines the findings and data obtained in a forensic investigation and reaches evidence to be presented to the court by making scientific analyses and evaluations. Forensic scientists aim to serve justice by examining the existence of crime and determining the relationship between suspects and crime. For this purpose, like every scientist, he/she should be inquisitive, dynamic, and in command of technological developments in his/her field and should strive to keep his/her knowledge and skills at international competence [3].

Crime scene investigation is usually the starting point of a chain of forensic procedures and analyses carried out in a criminal investigation. Within the scope of crime scene investigation; all findings are collected with scientific methods and techniques, recorded, preserved, and sent to the relevant laboratories for examination. It has a very important role in the investigation as it covers the search, detection, and collection of samples to be examined. Crime scene investigation aims to understand

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whether there is a crime in the incident, to determine how the crime was committed, the identity and location of the perpetrator(s) and to prove guilt with evidence [1, 2, 3, 4, 5, 6]. The findings obtained through crime scene investigation turn into evidence in the hands of forensic scientists and become "mute witnesses" in solving the case. In 1877, the principle of change developed by the French criminalist Prof. Edmond Locard is the main basis of crime scene investigation. According to the principle of exchange, people always leave something of themselves in the environment they enter; likewise, when they leave the environment, they take something of themselves with them. This principle can be briefly expressed in the phrase "Every contact leaves a trace", which has become the motto of forensic sciences and crime scene investigation [2, 3]. Every crime scene is unique; each comes with its own problems and complexities [1].

The crime scene and its surroundings may change completely or partially due to the passage of time. This means that elements that are considered to be part of the background of the events may change, as well as elements that turn out to be important for the case [7]. Crime scene investigation, which is the first step of forensic investigation, is a process that cannot be repeated. For this reason, crime scene conditions should be determined correctly, and the identification, documentation and packaging of evidence should be done carefully and completely. Solving the incident is only possible through a crime scene investigation conducted in accordance with the law, using the right methods and techniques. Every investigation is different and unique. What must be done to minimize the impact of these differences is to apply the stages of crime scene investigation systematically and in accordance with the procedure. In investigations carried out without following the workflow, it is inevitable to reach a common end, i.e. failure to achieve justice, with different setbacks according to the characteristics of each crime scene. Before all the steps, the first thing to do after arriving at the crime scene is to determine the boundaries of the crime scene and ensure its security. Entrances and exits should be under control and unauthorized persons should be kept away from the scene. Otherwise, findings may be lost with a change in the crime scene. After security is ensured, the documentation of the crime scene begins. This process, which consists of 4 stages: preparing a report, taking photographs, video recording and drawing a sketch, is also called identification [3].

2.2. Crime Scene Documentation

The main purpose of documenting the crime scene is to record the crime scene as it was originally found before any changes were made and to define the relationship between all the evidence. Measurement and numbering will increase the comprehensibility of these relationships [3].

Crime scene documentation is the detailed, systematic and permanent recording of the crime scene and evidence, including the techniques of recording the crime scene in writing (taking notes), photographing, sketching and videotaping the crime scene to record the status of the crime scene and physical evidence. All of these four techniques should be used in crime scene documentation; one documentation technique does not replace the other [8].

In the note-taking technique, the investigator is required to record in detail his/her observations, actions, and explanations about the crime scene. These records should be detailed and complete about the crime scene and the evidence. Information such as the color, type, number, what it looks like, location, size, brand, and model of the evidence should be written in detail. In addition, information such as the location of the crime scene, air temperature, potential witnesses, objects that may be evidence (including transients), victim information, and actions taken by the investigator should be recorded in full. The purpose of recording the crime scene by video is to make it easier to understand the crime scene. The video should not contain audio recordings and comments. The crime scene should be filmed in general, evidence should not be zoomed in, and the crime scene should also be videotaped from the position of the victim. Photography, on the other hand, aims to provide a real and accurate visual record of the crime scene and evidence in a method from general to specific. The purpose of video and photography is to provide a permanent record for investigators and courts. In the sketching of the crime scene, the main purpose is to realize the measurements between the objects in the crime scene. Because

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in photographs or videos, there may be distortions in the spatial relationship between objects. Distances and dimensions between objects can be confused. With the sketching of the crime scene, these problems are tried to be prevented by recording the necessary measurements [8].

Measurements are another important component of documentation and should be included in the investigator's notes. As the science of crime scene investigation evolves and many practitioners and their parent organizations move towards personal certification and institutional accreditation, the one constant is that there can never be too much documentation. Through a comprehensive documentation exercise, the crime scene investigator captures the original state of the crime scene and then records changes to the crime scene as items of evidence are recovered. Documentation forms the basis of the final crime scene reports [2]. Complete and accurate crime scene documentation (such as sketching, photographing, and videotaping), careful collection of physical and biological evidence, and reconstruction of the crime scene/moment by utilizing many different crime scene investigation disciplines will greatly facilitate the work of the forensic medicine physician who will perform the autopsy and investigators and prosecutors who do not have the opportunity to see the crime scene [9, 10]. It can be expressed simply as follows: Reconstruction/recreation of the crime scene is not possible without adequate documentation [2].

These are two-dimensional (2D) representations of a three-dimensional (3D) crime scene environment, although basic skills such as photography and drawing through manual measurements will always remain critical. Accordingly, parameters such as image perspective, lens distortions, and focal length can distort the apparent spatial relationships between an object and its surroundings. While highly skilled crime scene investigators will be aware of these challenges and develop their skills accordingly, it means that even the most diligent investigator will occasionally make mistakes [11].

Traces, signs, clues, and evidences related to the case under investigation are generally considered evidence. It can be macroscopic (visible to the human eye), microscopic (very small and impossible to see without assistance), living or dead, solid, liquid, or gas. Literally, anything can become evidence. To start a systematic search for physical evidence, first of all the evidence need to be able to recognized. Physical evidence can be anything from a 500-pound engine block falling on someone's head to microfibers 10 μm thick, hidden fingerprints, or DNA that cannot be seen. To ensure that these findings are not missed at the scene, the crime scene must be systematically searched, documented, and recorded at every stage. There are several different methods of systematically searching for evidence. The most commonly used of these are as follows [2]:

- Strip search method,
- The grid or checkerboard method,
- Spiral method; and
- Tracking method.

According to Article 217 of the Code of Criminal Procedure [1] [12, 13], the "principle of freedom of evidence" applies in the Turkish Legal System. The principle of freedom of evidence;

- It is obtained by law,
- Reliable, realistic,
- Material,
- It is rational and logical,
- It should be representative of the event and
- Available/accessible,

any evidence can be used in the investigation and prosecution phase.

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[1] The power of discretion in relation to evidence
Article 217 – (1) The judge shall only rely upon evidence that is presented at the main hearing and has been discussed in his presence while forming his judgment. This evidence is subject to free discretion of the conscious opinion of the judge.
(2) The charged crime may be proven by using all kinds of legally obtained evidence.

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2.3. The Concept of Staged Crime Scene

The concept of a staged crime scene is a situation where a murder or suicide at a crime scene is staged like a theater play. It is a criminal act that intentionally and deliberately causes a secondary crime to be committed by obscuring evidence, and at such times changes the dimension of the original crime to the extent that the victim is declared guilty. A staged crime scene is an attempt to mislead investigators and obstruct the criminal justice process. This manipulation can be done verbally or in writing about facts or situations, or by physically reconstructing a scene, body, or environment [14].

At the same time, the concept of the staged crime scene is also used to show an unrealized event as if it has taken place. The stages of investigation, investigation, and prosecution can take place as if there is a crime even though there is no crime.

3. Crime Scene Reconstruction

3.1. The Concept of Crime Scene Reconstruction

According to the Cambridge Dictionary definition of reconstruction [15] the concept of reconstruction is:

- The process of building or creating something again that has been damaged or destroyed,
- An attempt to get a complete description of an event using the information available, or an attempt to repeat what happened during the event.

as two different definitions. Crime scene reconstruction is based on the second basic definition. The Association for Crime Scene Reconstruction (ACSR) defines reconstruction as "the use of scientific methods, physical evidence, deductive and inductive reasoning, and their interrelationships to obtain explicit information about the sequence of events surrounding the commission of a crime" [1]. Looking at these two definitions, the expected and targeted elements of crime scene reconstruction are clearly seen.

3.2. Benefits of Crime Scene Reconstruction and Techniques Used in Crime Scene Reconstruction

3D technology is gaining popularity over 2D documentation methods, as depth and spatial information are preserved to help visualize and plan critical scientific activities. Three-dimensional (3D) scanning and printing initially began as an industrial tool used largely for prototype development. Limited to research and development in manufacturing, aerospace, and automotive industries, these technologies are now being used effectively in engineering, astronomy, mining, geology, archaeology, medicine, forensic science, and dentistry [16, 17]. Interest in 3D visualizations has been particularly evident in fields related to human bodies/remains, such as forensic pathology, forensic odontology, and forensic anthropology, as well as in accident investigation or evidence recovery scene documentation [18].

Three-dimensional reconstruction allows measurements to be calibrated automatically. This feature enables more accurate and faster data collection from any object or sample under analysis. The accuracy and repeatability of digitization techniques are considered to be higher than traditional linear methods [19].

Traditional means of forensic and crime scene documentation include digital media (photography and videography), hand drawings, manual measurements, and sketching. However, traditional methods of recording crime scene information are insufficient to ensure or preserve the necessary integrity of crime information [4, 5]. Traditional crime scene data capture and reconstruction methods have proven to be effective to a certain degree, but neglect many details related to the accurate capture and visualization of all 3D crime scene data. Traditional crime scene data collection methods play a vital role in law enforcement. However, disadvantages of traditional crime scene data collection methods have been identified. Many researchers have turned to useful methodologies to supplement or enhance traditional data collection methods. 3D imaging technologies are an extremely powerful method that allows an investigator to capture crime scenes in precise detail and then analyze them [4].

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There are many different 3D modeling techniques in crime scene documentation. Laser scanning, photogrammetry, projection-based sensors, virtual reality, and drones are some of the 3D modeling tools and techniques used at crime scenes. Photogrammetry is the process of taking images of the object from various angles under different lighting conditions using a camera and creating a 3D image of the object with the scanned data. Laser scanning is the calculation of the shape and dimensions of the target object using laser beams after which detailed 3D models can be created [8].

It has led to the development of solutions such as the application of LiDAR (Laser Imaging Detection and Ranging) scanning and the use of immersive technologies such as AR and VR. This development, together with the importance of forensic evidence in the criminal justice system, has motivated many forensic researchers and investigators to research and implement reliable crime scene data collection tools, methods, and approaches [4].

At its core, AR is a technology that can overlay digital perceptual information into the real world. This technology can assist in crime scene investigations by providing information overlay and enhancements for law enforcement crime investigation processes [4]. VR represents a computer technology for creating a simulated three-dimensional (3D) environment. Compared to traditional user interfaces, VR places the user inside an experience [20]. Some of the VR tools used in different studies for crime scene reconstruction are HTC Vive [21] and Oculus Rift [22]. MR is the combination of the digital environment and the physical world to produce new environments and visualizations. In crime scene reconstructions, MR provides researchers with the ability to revisit a virtual crime scene and interact with relevant points in the virtual crime scene without fear of contamination or time constraints [4].

Unlike other sectors, forensic information needs to be collected within an acceptable timeframe and with a certain level of precision, using reliable measurement techniques. Such information should be non-invasive, complete, and compatible with digital storage for future access and use. 3D crime scene reconstruction is a crucial component in the law enforcement process of serious crime investigation because it helps to collect real 3D information to solve criminal problems. It is important to recognize that crime scenes are a relatively more sensitive area to manage compared to other sectors. Some of the issues associated with being physically present at a crime scene include the risk of contamination and destruction of evidence, which can prevent criminal investigators from accessing or revisiting the scene as often as necessary. Therefore, it is appropriate to visually capture the crime scene to document the crime scene and possible evidence to aid the criminal investigation and to ensure the longevity of the crime scene [4].

Se et al. proposed an approach for 3D modeling of crime scene reconstructions using a camera [4, 17]. The approach aimed to improve on traditional methods of taking photographs and drawing by hand. Sieberth et al. proposed a virtual reality application for forensic science that allows crime scene navigation [4, 23]. This approach also improved paper documentation and image acquisition methods. The developed system was formally evaluated by using it in three practical homicide cases. Süncksen et al. proposed an approach for preparing and guiding forensic crime scene investigations in virtual reality [4, 24]. This method aims to improve traditional picture taking and manual measurements. Abate et al. proposed the use of a low-cost panoramic camera for 3D documentation of contaminated crime scenes and aimed to improve traditional image acquisition and paper documentation [4, 25]. Liu et al. proposed the use of unmanned aerial vehicle (UAV) photogrammetry for traffic accident scene reconstruction [4, 26]. This approach aimed to improve traditional methods of collecting digital media (2D images and videos) by reconstructing 3D models from 2D UAV sequential images.

Hołowko et al. [8, 27] demonstrated the ability to analyze complex bloodstain patterns with 3D laser scanning and structured light scanning, Urbanová et al. [8, 28] and Cunha et al. [8, 29] discuss the integration of drone technology and crime scene documentation, Norman et al. [8, 30] developed the use of virtual reality in the detection of crime-related stimuli. Buck et al. [8, 31] argued that the integration of photogrammetry, tomography scanning, and other 3D modeling techniques will provide a better understanding of the dynamics and causes of injuries in traffic accidents, thus improving the

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accuracy of forensic examinations and legal proceedings. Osman and Talar [8, 32] also stated that 3D modeling provides increased flexibility in capturing and analyzing complex accident scenes and consumer-grade cameras can be adapted for medium-accuracy forensic measurements. It has also been stated that inaccurate operations such as sizing and scaling due to human error in crime scene sketching can be prevented [8, 27].

Documentation and analysis of the crime scene have been the general outcome of studies on its use in educational and training tools for forensic sciences. 3D modeling has been shown to produce successful results in many different types of crime scenes such as bloodstain pattern analysis in complex areas [8, 27], ballistic analysis or footprint analysis [8, 33], forensic analysis of large outdoor crime scenes [8, 28, 29, 34], forensic investigations involving dynamic scenes in the reconstruction of accidents involving moving vehicles or objects [8, 35], forensic analysis and reconstruction of traffic accidents [8, 31, 32, 36].

Utilizing 3D scanning for crime scene documentation may require preparation before scanning. For example, rapid documentation is necessary to preserve event traces (e.g. footprints, tire tracks) that may be degraded by weather conditions [5]. Modern tools such as the 3D scanner can collect, organize, and provide analytical tools with sufficient quality and methodology to organize and analyze evidence for forensic investigations, alleviating the often heavy burden of taking photographs from general establishment shots to numerous details. It complements, not replaces, the traditional crime scene photographer, allowing the entire crime scene to be recorded, identifying all potential evidence at once at the very beginning of the investigation. This "freezing" of crime scene images establishes the crime scene - the crime that literally "happened" - and provides a basis for checking in case of tampering or alteration. It not only secures a documented record of the process (what changes were made to the data) but also provides data for later analysis for audit or reconstruction purposes. The scan only records what is visible and does so with a normal photographic approach; objects behind other obstacles or other objects will not be recorded. However, 3D scanners are becoming an inevitable tool at crime scenes due to their ease of use, complete recording, and the possibility of detailed analysis at a later date [2]. Advances in the capabilities and availability of 3D technologies offer significant advantages for the investigator recording and mapping a crime scene, while at the same time opening up a range of more advanced ways of analysis and investigation to help uncover the truth behind the crime [11].

Laser scanning is a practical and effective way to obtain a 3D overview of the scene. This type of input provides the possibility to document the scene without intervention and remotely. More importantly, the procedure is automated, and the resulting reconstruction evidences high accuracy. However, in complex environments, several scans may be required. This process requires very little effort, as the only action required by the user is to place the scanner in a new position [5].

The reconstruction of an event such as a homicide, a plane or train crash, and the reconstruction of a traffic accident is a collaborative interdisciplinary effort. Various agencies such as law enforcement, forensic scientists, or expert witnesses are involved in answering forensic science questions. The use of imaging techniques in forensic science, modern 3D documentation methods in forensic science and law enforcement, and morphometric 3D reconstruction open completely new horizons and perspectives, allowing for an interdisciplinary evaluation of existing traces and findings [37]. The crime scene can be reconstructed so that information can be obtained about how the crime was committed, and the location and status of the actors before, during, and after the crime. Reconstruction is not only useful in evaluating the evidence at the crime scene, but it can also fill in some of the gaps in the crime [38]. As forensic sciences continue to evolve and reap the benefits of new technologies, the scope and use of three-dimensional (3D) tools in the analysis, interpretation, and presentation of crime scenes and forensic materials in the criminal justice system is increasing [39].

Three-dimensional reconstruction of the crime scene should be carried out for many reasons such as preventing the possible error of law enforcement officers at the scene, shaping the crime scene as real as possible for the decision of law enforcement officers, prosecutors, and judges involved in the investigation and prosecution phase, and not closing the case file due to lack of evidence. Many forensic

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scientists who are experts in their fields have also stated the necessity of three-dimensional reconstruction of the crime scene with different technologies they use in their studies.

Crime scene documentation with 3D modeling has some limitations as well as benefits. Time-consuming data processing, inability to accurately capture certain materials on transparent or highly reflective surfaces [8, 27], human errors in data collection [8, 34], environmental limitations [8, 28, 29, 36], limited technical competence of the devices used [8, 32], high cost and complexity of some equipment used [8, 27, 36] have been some of the limitations in the studies. However, the high cost can be reduced with the use of drones [8, 29].

A picture is worth a thousand words. The power of pictures can be used but should not be abused. Everything must be done to ensure that 3D reconstruction visualizations are not misinterpreted as a 3D visualization of the real event. How results are presented is very important and should be done carefully and thoughtfully [37].

4. Reconstruction of the Scene of a Fatal Shooting in an Indoor Area

4.1. Materials and Method

Civilians are estimated to own 857 million small arms and light firearms, armed forces 133 million, and law enforcement agencies 22.7 million. In other words, it is estimated that civilians own approximately 85% of the more than 1 billion small arms and light firearms in circulation worldwide. Every year, more than 200,000 people lose their lives due to gun violence, approximately 150,000 homicides, over 65,000 suicides are committed using firearms, and more than 20,000 gun accidents in which individuals lose their lives are estimated to occur. In Turkey, a total of 3,682 incidents of armed violence occurred in 2020 [40].

According to the Turkish Statistical Institute, Distribution of criminal records of convicts entering penal execution institutions by type of crime, 2020-2022, the number of people violating the law on firearms, knives and other tools is increasing day by day. The number of people who violated the law on firearms and knives and other instruments was recorded as 11 181 people in 2020, 15 211 people in 2021, and 20 737 people in 2022 [41].

The necessary permissions and approvals were obtained from the University Ethics Commission and Gendarmerie General Command. The Gendarmerie Forensic and its personnel, and the Gendarmerie Forensic Training Branch and its personnel provided support and assistance in providing the necessary environments and materials for the crime scene, preparing the crime scene, staging the crime scene, and providing information about the crime scene. Access to and use of the FARO Focus S+150 laser scanning device was provided by the Gendarmerie General Command Traffic Department and its personnel.

Due to the increasing use of firearms and the increasing number of crimes against persons committed with firearms, this study recreated the scene of a firearm death. The crime scene was staged before the laser scanning device was used. Documentation was done during and after the discovery and examination of the crime scene. The crime scene was examined with the strip inspection method. In the crime scene investigation, both photography and laser scanning were performed, and it was observed to compare the photography and laser scanning processes and to measure the benefits of using them together. The FARO Focus S+ 150 Laser Scanning Device of the FARO brand, which is shown in Figure 1 in its uninstalled state, was used as the laser scanning device. Although the laser scanning device takes a 360° image of the scanned area horizontally, due to the use and installation of the device, a 270° image of the scanned area is taken vertically. While scanning with the laser scanning device, the place where the device is installed is seen as a blind spot. Since the device took a large number of images at different points, there was no area in the crime scene where no image was taken. In this way, 360° images of the crime scenes were obtained and the crime scenes were visited with the help of video.

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Figure 1.
FARO Focus S+ 150 laser scanner.

The crime scene was staged in one of the crime scene simulation areas of the Gendarmerie Forensic. The Gendarmerie Forensic also provided evidence appropriate to the crime scene and its nature. A male mannequin in pajamas, an empty soda bottle, a cartridge case, a firearm suitable for the structure and size of the cartridge case, a screwdriver, and red paint to be seen as blood stains were provided by the Gendarmerie Forensic.

After the crime scene was staged, the crime scene was photographed with the iPhone 11 device belonging to the Apple Brand using the light of the crime scene itself, without flash. Photographing the crime scene was done from general to specific. The crime scene was photographed as a general view from the entrance of the room, then evidence numbers and evidence were photographed. The pixel and aperture settings of the photographs taken with the phone were kept constant and set as 3024 x4032 pixels, 1.8 aperture setting. The ISO settings of the photographs varied depending on the illumination of the area where the evidence was found. Information about the room where the crime scene was staged and the crime scene was noted and a sketch drawing of the crime scene was made.

The settings of the FARO Focus S+ 150 device were set as internal shooting 10 m range. The transverse length and longitudinal length of the simulation room were measured as 4 m and 7 m, respectively. The laser scanning device was placed at five different points of the crime scene and a five-minute image scan was performed from each point using the light of the crime scene itself. While scanning the crime scene with the laser scanning device, control was performed from the phone used with the device. While using the device, the device must be fixed and centred in order to obtain a smooth image after each change of location, and the control of whether the device is fixed and centred or not was made through the application on the phone. The laser scanning device was used both by fixing it with its own tripod and by placing it perpendicular to the ground in order to clearly visualise the findings on the ground.

After the scanning of the crime scene with the laser scanner was completed, the images were uploaded to the laser scanner's own programmes for processing. In order to obtain clear images, two programmes belonging to the brand of the laser scanning device were used. The crime scene images scanned by the laser scanning device were first uploaded to the FARO Scene programme, where the point clouds were merged. After the processing of the point clouds, the crime scene images were

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uploaded to the FARO Zone programme, the other programme of the laser scanning device. Here, after the processing and merging of the images, images that can be used were obtained.

4.2. Three Dimensional Reconstruction With Laser Scanning Device And Results

Figure 2.
General view of the staged crime scene.

As a result of the examination of the crime scene shown in Figure 2, six different items of evidence were found:

- ***Evidence No. 1:*** A 1.55 m tall male body standing parallel to each other with right and left palms facing towards the body, lying face down on the left side of the body, left leg curled inwards, right foot facing inwards, a wound flowing from the right ear of the individual towards the ground, a gray colored and patterned upper and lower pajama set on a white background, and a blood trail on the right side of the body (Figure 6 and Figure 7)
- ***Evidence No. 2:*** 220 ml empty green soda bottle labeled Saka with yellow label (Figure 9)
- ***Evidence No. 3:*** 0.02 m 9 mm cartridge case on dark brown wooden parquet floor, (Figure 11)
- ***Evidence No. 4:*** MKEK 9mm Parabellum pistol with a barrel length of 0.18 m and a pistol grip length of 0.13 m, embroidered-embroidered, cherry wood grip, and light gray safety (Figure 13)
- ***Evidence No. 5:*** Screwdriver found on the right end of the bed, 0.09 m with red plastic parts, 0.10 m with metal parts, a total 0.19 m in size (Figure 15)
- ***Evidence No. 6:*** Individual droplet stains and blood pools on the left-wall side of the bed against the wall with a gray duvet cover (Figure 17)

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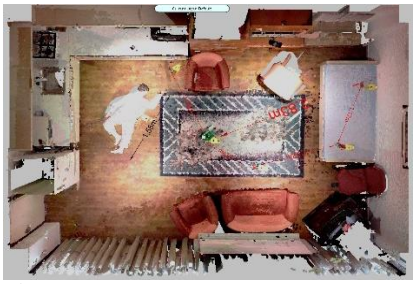

Figure 3.
Sketching the crime scene by laser scanning device -1

Figure 4.
Sketching the crime scene by laser scanning device -2

Figure 5.
Sketching the crime scene by laser scanning device -3

Figure 6.
Camera photography of Evidence No. 1

Figure 7.
Detailed camera photography of the right side of Evidence No. 1

Figure 8.
Photographing Evidence No. 1 with a laser scanning device

Since the white pajamas on the male body, which is the number one evidence, are in contrast to the background color of the crime scene, the body can be seen clearly as seen in Figure 6. In Figure 7, it can be seen that the body fell on the left side of the face and there was a wound with blood flowing from the right ear to the ground, and a blood trail and a scar were also detected in the right abdominal cavity of the body. When the laser scanner scans the crime scene, it also measures the size of the evidences, and as shown in Figure 8, it correctly measured the length of finding number one to be 1.55 meters. The posture of the body is also clearly seen in the sketch shown in Figure 3, Figure 4, and Figure 5, which is thought to ensure that the interpretations will be made correctly with the posture of the body. However, the wound with blood flowing from the right ear to the ground and the blood and scar in the right abdominal cavity were not clearly visualized as a result of the scanning of the laser scanning device.

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Figure 9.
Camera photography of Evidence No. 2.

Figure 10.
Photographing Evidence No. 2 with a laser scanning device

Evidence number two is an empty 220 ml soda bottle, coloured green and labelled Saka with a yellow label, as shown in Figure 9. During the laser scanning process, the device accurately measured the height of the soda bottle to be 0.20 m as shown in Figure 10. The soda bottle on the carpet floor was not clearly visible in the scanning process due to the colour of the floor and the bottle and the structure of the bottle. Due to the reflection of light by glass surfaces, the clarity of the image was distorted during scanning. Recording evidence only with a laser scanning device can lead to image loss and therefore errors in the documentation of the crime scene, as shown in Figure 10, evidence two.

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Figure 11.
Photographing Evidence No. 3 with a camera

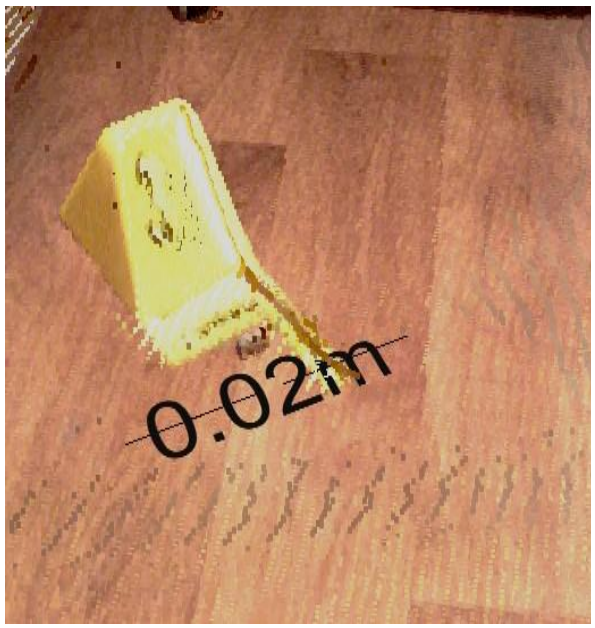

Figure 12.
Photographing Evidence No.3 with a laser scanning device

Evidence number three is a 9 mm cartridge case as seen in Figure 11. As a result of the laser scanning, a casing with a length of 0.02 m and accurately measured as shown in Figure 12 was detected. The casing is the main part that holds the bullet core, powder, and capsule together and protects the powder from external factors [42]. In firearms, when the firing process takes place, while the bullet core goes to the target, the cartridge case is ejected and can be found around the firing point. In Figure 12, it can be seen that the color of the casing is close to the ground color, so it is not very distinguishable in the scanning process. Documenting the crime scene only by laser scanning, as in the case of evidence number two in Figure 10, would be a loss for such evidences.

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Figure 13.
Photographing Evidence No. 4 with a camera.

Figure 14.
Photographing Evidence No.4 with a laser scanning device.

Evidence number four in Figure 13 is a firearm with a red grip. According to the image in Figure 14, although a clear image could not be obtained due to the proximity of its colors with the carpet floor on which it was found, as a result of the measurements, the length of the grip was correctly measured as 0.13 m, and the length of the barrel as 0.18 m. As with the evidence number two shown in Figure 10 and the evidence number three shown in Figure 12, it was observed that the documentation of the crime scene would be inaccurate as long as only laser scanning was performed.

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Figure 15.
Photographing Evidence No. 5 with a camera.

Figure 16.
Photographing Evidence No.5 with a laser scanning device.

Evidence number five is a screwdriver, which is a piercing-cutting[2] tool with red plastic parts as seen in Figure 15. In the measurements made, the red plastic part was measured as 0.09 m and the metal part as 0.10 m, totaling 0.19 m. As can be seen in Figure 16, the laser scanning device did not distinguish between metal parts and plastic parts but reported the measurement of all of them correctly.

[2] Tools that penetrate into the tissue by separating the fibers of the skin with their pointed ends and work with their depths are called piercing (stabbing) tools and the wounds caused by them are called piercing (stabbing) tool wounds. Screwdriver, needle, pin, safety pin, burlap, hairpin, skewer, awl, nail, bayonet, compass, rasp, file and similar tools can be given as examples [43].

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Figure 17.
Camera Photography of Evidence No. 6.

Figure 18.
Photographing Evidence No.6 with a laser scanning device.

Evidence number six is the individual droplet stains and traces of blood found on the left wall of the bed as seen in Figure 17. As can be seen in Figure 18, due to its contrasting color with the ground, no negative elements were observed in the photographing of the laser scanning device and in the identification of the evidence.

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Figure 19.
Different uses of the laser scanner-1

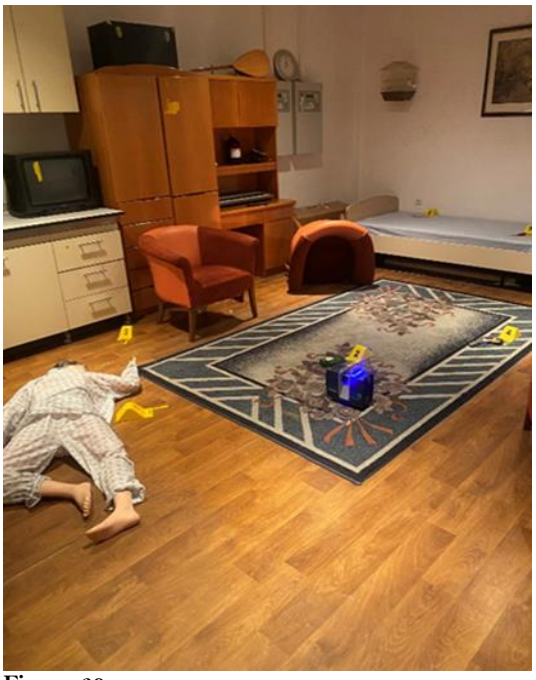

Figure 20.
Different uses of the laser scanner-2

The FARO Focus S+ 150 laser scanner was used at four points on a tripod as shown in the photograph in Figure 19, but it also scans when placed on the floor as shown in Figure 20 in order to clearly see the findings on the floor and to clearly scan under the seats and beds.

Photographing, sketching and notes kept at the scene are the main stages of crime scene documentation. With the FARO Focus S+ 150 laser scanning device used here, it was observed that the crime scene could be recorded in photographs and videos and the crime scene could be sketched as seen in Figure 3, Figure 4, Figure 5.

The basic rules in forensic sketch drawing are to determine the north direction, to write the name, surname and registration number of the person drawing the sketch, to determine the date, time and weather conditions of the day of the incident, and to write the findings one by one in a descriptive manner. In forensic sketching, the evidence is not fixed to the evidence and measurements are not made in this way. However, as can be seen in these three sketches given in Figure 3, Figure 4 and Figure 5, the laser scanning device has created these sketches to provide basic information about the crime scene. How the crime scene and the findings were found and their proximity to each other made it easier to visualize in the mind. Although forensic sketches do not replace the basic sketches drawn by crime scene investigation teams, it has been observed that the use of laser scanning devices together with photographs, notes kept at the scene, and sketches drawn can be useful for reconstruction.

5. Discussion and Conclusion

Forensic sciences is a multidisciplinary science that renews and develops itself with the development of technology, just like other branches of science. Crime scene investigation is seen as the first and most fundamental stage of the investigation. It is not possible to physically freeze the crime scene. The crime scene is a dynamic area and may undergo small and large changes continuously.

Meticulous documentation of the crime scene is of utmost importance for the fair conduct of the investigation and prosecution phases. Traditional crime scene documentation methods include photography-videoing, note-taking and sketching. It has been observed that these traditional methods, which have been used for many years, are no longer completely sufficient. With the development of

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technology, three-dimensional reconstruction of crime scenes with different methods such as laser scanning devices, AR, VR, MR are being tried. These methods are being tested and studied by forensic scientists.

Crime scene reconstruction is of great importance for the investigation and prosecution phases. The benefits of three-dimensional reconstruction of crime scenes are firstly, more objective interpretation of events and crime scenes, and secondly, the reduction of errors that can be made in crime scene investigations.

Through the analysis and observations, answers to the two hypotheses were sought. The results show that hypothesis H1 is valid and correct. Using the laser scanning device alone or using traditional documentation methods alone is not sufficient for detailed documentation. However, it was observed that detailed information about the crime scene was obtained when both were used at the same time. Based on the analysis and observations, hypothesis H2 is also valid and correct. It has been observed that the use of laser scanning devices in the reconstruction of the crime scene will prevent possible negative situations such as insufficient evidence, inadequate examination of the crime scene, change of persons conducting the investigation and prosecution stages, and therefore insufficient control of the case file during the investigation and prosecution stages.

The scenario in this study and the use of laser scanning devices show that laser scanning devices alone are not sufficient. In addition to traditional documentation methods, the use of laser scanning devices was seen as a possible way for three-dimensional reconstruction of the crime scene. As a result of the laser scanning process, evidence number one in Figure 8 did not show blood and wound marks. The images of evidence number two seen in Figure 10, number three seen in Figure 12 and number four seen in Figure 14 were not clear due to the area where they were found. Although the images were not clear, the fact that the size of the findings did not give an error show that the device reliability is at a level that can be used at crime scenes. At the same time, the margin of error of the device to be used in the reconstruction of the crime scene should be calculated by testing. In this study, the device was used indoors and no error was made when measuring the size of the evidence, but this may not be valid for different evidence and different areas, scientists who will use this technology should know the limitations of the devices beforehand.

It has been observed that the laser scanning device is not comfortable for use at crime scenes due to its expensive cost, the need for trained personnel for its use, the possibility of the scanned findings not giving a clear image according to their environment, and the processing process of the images. In addition to these limitations, it is clearly seen that a clear three-dimensional reconstruction of the crime scene will be very useful in the investigation and prosecution stages, and that these images will be very useful for the solution of cases in case files.

This study supports the ideas of other scientists who have studied the three-dimensional reconstruction of crime scenes. Traditional documentation techniques are not sufficient for crime scene reconstruction and need to be improved. However, the laser scanning device alone is not sufficient for crime scene documentation, but when used in combination with traditional documentation techniques, three-dimensional reconstruction of the crime scene has been observed to be very successful and easy.

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Key Points

- More objective interpretation of events and crime scenes is one of the benefits of crime scene reconstruction.
- The main purpose of crime scene documentation is to record the crime scene as it was originally found before any changes were made and to identify the relationship between all the evidence.

- Laser scanning is a practical and efficient way to obtain a highly accurate 3D overview of the scene.
- Traditional documentation techniques are not sufficient for crime scene reconstruction and need to be improved.
- In addition to traditional documentation methods, the use of laser scanning devices was seen as a possible way for 3D reconstruction of the crime scene.

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