Abstract: The advancement of technology and its developments have provided the forensic sciences with many cutting-edge tools, devices, and applications, allowing forensics a better and more accurate understanding of the crime scene, a better and optimal acquisition of data and information, and faster processing, allowing more reliable conclusions to be obtained and substantially improving the scientific investigation of crime. This article describes the technological advances, their impacts, and the challenges faced by forensic specialists in using and implementing these technologies as tools to strengthen their field and laboratory investigations. The systematic review of the scientific literature used the PRISMA® methodology, analyzing documents from databases such as SCOPUS, Web of Science, Taylor & Francis, PubMed, and ProQuest. Studies were selected using a Cohen Kappa coefficient of 0.463. In total, 63 reference articles were selected. The impact of technology on investigations by forensic science experts presents great benefits, such as a greater possibility of digitizing the crime scene, allowing remote analysis through extended reality technologies, improvements in the accuracy and identification of biometric characteristics, portable equipment for on-site analysis, and Internet of things devices that use artificial intelligence and machine learning techniques. These alternatives improve forensic investigations without diminishing the investigator’s prominence and responsibility in the resolution of cases.

Keywords: forensic science; technologies; extended reality; crime scene

1. Introduction

The forensic sciences are part of the penal system of several countries around the world as a support tool promoting the better administration of justice. When a crime is committed, forensic experts, with their solid scientific training in specialties such as chemistry, anthropology, physics, genetics, and medicine, have the task of clarifying the facts surrounding the commission of the crime by providing expert evidence that is of vital importance in the investigation process [1].

To solve crimes and bring the guilty to justice, the forensic sciences are essential in obtaining solid scientific evidence that guarantees fair and accurate decisions in the courts of law, an aspect that is relevant to carrying out fair processes for both the accused and the victims [2]. Using forensic techniques in conjunction with technological equipment can sometimes aid in preventing future crimes by identifying criminal patterns, connections, and trends [3], allowing law enforcement and judicial systems to act proactively through prediction.

Multidisciplinarity is important for resolving criminal cases because it allows for the thorough collection of evidence, a comprehensive approach and analysis, and the
effective resolution of complex cases. The collaboration of experts from different forensic disciplines allows all relevant aspects of the case to be considered, which can help clarify the main aspects of the facts and ensure the comprehensive identification and collection of evidence [4]. Considering the multiple disciplines that contribute to the forensic sciences and the variety of methods used for the different analyses in the resolution of cases, the Organization of Scientific Area Committees (OSAC) for Forensic Sciences has proposed a Forensic Science Standards Board [5], illustrated in Figure 1.

Figure 1. Forensic Science Standards Board proposed by OSAC.

Figure 1 shows seven areas of the forensic sciences: biology, chemistry: seized drugs and toxicology, chemistry: trace evidence, physics/pattern interpretation, scene examination, medicine, and digital/multimedia. The subcategories that contribute to the research and development of the forensic sciences are described within each of the areas above.

According to the scientific literature, advances in technology significantly impact research and development within the forensic sciences, either directly or indirectly, since several technologies designed for other purposes have ended up favoring forensic work [6]. Technologies have been evidenced that contribute to all the areas presented in Figure 1; the incorporation of new devices and methods of obtaining information provides new possibilities, incorporating, like any measuring instrument, several uncertainties that must be treated with care to reduce gaps in the accuracy and interpretation of information.

This document provides an overview of the technologies used in crime scene investigation, allowing readers to briefly learn about the use of devices and new developments that contribute to the improvement of forensic investigation at crime scenes and in the laboratory.

The following paragraphs present the systematic review methodology used; a description of the main technological innovations that improve the work of identifying, collecting, and analyzing forensic evidence; the impacts of technology on forensic investigation; future perspectives on the use of new technologies that modernize the work of the forensic science expert; a discussion of the ethical and legal implications; and finally the conclusions.
2. Methodology

The systematic review presented in this paper was carried out following the standards of the PRISMA® methodology. The PRISMA® methodology is a guide to improve the transparency and quality of systematic review and meta-analysis reports; it includes a checklist, a structured summary, and flowcharts to document the review process [7]. The dataset with the review details is available at [8]. Scientific papers published in the last five years from databases including SCOPUS, Science Direct, Web of Science, PubMed, and IEEE were considered as reference information.

Table A1 of Appendix A was used, which indicates the pages where relevant information can be found in the sections of this document. The systematic review consisted of three phases: the formulation of the research questions, the delimitation of the scope, and an exhaustive search of reference documents.

The main research question was as follows: What technologies have been developed as a contribution to the forensic sciences in crime scene investigation? This question helps understand how new technologies affect forensic investigations and their various fields. The first objective of this research was to describe, based on information obtained from the scientific literature, the technological developments and their possibilities. The second objective was to describe how these technologies improve result accuracy and resource optimization in forensic investigations. The challenges and limitations of implementing new technologies were analyzed as a third objective. Aspects of the future of the forensic sciences and the greater use of technologies are addressed. Finally, ethical considerations about the use of these technologies are discussed.

The research questions that were posed for the extraction of information in the reference documentation were as follows: RQ1. What new and innovative technologies have been developed for crime scene investigation and forensic science? RQ2. How does technology impact the improvement and accuracy of forensic investigation? RQ3. What are the challenges and limitations of implementing new technologies for solving cases in the forensic sciences? RQ4. What is expected of the forensic sciences in the use of new technologies?

The quality of the scientific articles was evaluated using the criteria described in Table 1.

Table 1. Quality assessment questions for papers.

<table>
<thead>
<tr>
<th>Quality Assessment Questions Answer</th>
<th>Answer</th>
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<tbody>
<tr>
<td>Does the document describe technologies developed and employed in forensic investigation?</td>
<td>(+1) Yes/(+0) No</td>
</tr>
<tr>
<td>Does the document describe the impact of using technologies on improving the accuracy of the results obtained from forensic investigations?</td>
<td>(+1) Yes/(+0) No</td>
</tr>
<tr>
<td>Does the document raise ethical considerations for real cases on using new technologies in forensic investigation?</td>
<td>(+1) Yes/(+0) No</td>
</tr>
<tr>
<td>Is the journal or conference in which the article was published indexed in the SCImago Journal &amp; Country Rank (SJR)?</td>
<td>(+1) if it is ranked Q1, (+0.75) if it is ranked Q2, (+0.50) if it is ranked Q3, (+0.25) if it is ranked Q4, (+0.0) if it is not ranked</td>
</tr>
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Figure 2 outlines the workflow for reviewing and selecting reference documentation obtained from searching for documents containing the words: “technologies forensic sciences crime scene”. The search considered works published in the last five years. Articles published in scientific journals, conference papers, and recent books were accepted for review.
The search for reference documents was conducted using the scientific literature databases Web of Science, MDPI, Science Direct, SCOPUS, Taylor & Francis, and ProQuest. Two review authors selected and included or excluded articles published in the last ten years. Following the PRISMA® methodology guidelines, four steps were performed: (1) relevant articles were identified through a database search; (2) articles were selected based on their abstracts; (3) full texts were reviewed and assessed; and (4) eligibility decisions were made for these articles, as shown in Figure 2.

The search for scientific articles was conducted using the keywords: “technologies forensic sciences crime scene”, specifying the search by title and abstract, and considering publications from the last ten years, including only peer-reviewed articles in English. Articles that consider technological developments in information technologies, nanoelectronics, artificial intelligence, and robotics have increased significantly over the last decade.

As shown in Figure 2, 119 duplicate documents were excluded from the total of 403 articles identified. Then, 95 studies were excluded according to the abstract, leaving 189 articles. A total of 116 documents that did not address the benefits of multiple technologies in forensic investigation were eliminated, leaving 73 articles, of which 63 reference articles could be accessed. Two observers selected articles with a kappa coefficient of 0.463, corresponding to a moderate agreement of 91.9%.

2.1. Inclusion Criteria

Articles were included if they discuss technologies that improve the accuracy and benefits of forensic investigations at crime scenes. Based on the research questions and inclusion criteria, we were able to select articles that describe the various technologies, the benefits of their use by forensic scientists, their challenges and limitations, and future developments. This paper is based on a systematic review of articles published in journals and conferences that provide solid answers to the following questions: (1) What new and innovative technologies have been developed for crime scene investigation and forensics? (2) What is the impact of technology on the improvement and accuracy of forensic investigation? (3) What are the challenges and limitations of implementing new technologies to solve cases in forensic science? (4) What is expected for the future of forensic science concerning the use of new technologies?

The extracted information and details of the documents considered in the selection and extraction were documented in an Excel file (data set), which can be viewed at [8].

Figure 2. Workflow in the selection of information documentation.
2.2. Exclusion Criteria

The exclusion criteria used to reject articles that were analyzed are described below. Articles were excluded that explained technical and operational aspects of the technologies, such as (1) algorithms, (2) equations and the mathematical modeling of the technologies, (3) the testing of prototypes of the technologies, and (4) device control systems. In addition, we excluded papers irrelevant to the description of the use of technologies that focused on legal and administrative aspects.

3. New Technologies for Forensic Crime Scene Investigation

This section describes and categorizes the technological advances that support forensic investigation; they have been classified according to the types of techniques or uses within the areas of forensic science. The advances presented in Figure 3 correspond to eleven types of technological advances: 3D scanning and modeling, digital technologies, artificial intelligence (AI) and data analysis, biometric technologies, nanotechnology, autopsy and radiology techniques, 3D printing techniques, genetic identification technologies, voice and audio recognition technologies, illicit substance detection technologies, and extended reality (XR).

![Figure 3. Technological advances by type and contribution to forensic sciences. (AN) nanotechnology; (BT) biometric technologies; (DFT) digital forensic technologies; (3DSM) 3D scanning and modeling technologies; (GIT) genetic identification technologies; (VAR) voice and audio recognition technologies; (ART) autopsy and radiology techniques; (AIDT) artificial intelligence and data analysis; (XR) extended reality; (ISD) illicit substance detection technologies.](image-url)
3.1. 3D Scanning and Modeling

Ever-evolving forensic investigation has witnessed a revolutionary transformation thanks to the integration of various innovative technologies. These tools have improved the efficiency of criminal investigations and raised the quality and accuracy of obtaining evidence at crime scenes. Featured technologies include structured three-dimensional laser scanning [9] and 3D modeling. To improve the visualization of crime scenes, drones have been used to allow image and video visualization and the scanning of the environment [10].

Supporting tools such as the FARO Focus 3D Laser have improved the accuracy of estimating the height of suspects from video surveillance footage [11]. Crime scene scanning technologies, in addition to obtaining data on the site and location of targets used in crime scene reconstruction, also provide information that facilitates medical analysis due to the high resolution and definition of these scanning systems.

Currently, there are technologies in constant development and driven by artificial intelligence whose applications allow the generation of digitized 3D models from videos and photographs captured with any handheld camera, smart device, or mobile phone [12]. Although these applications have not been validated as solid evidence in the forensic field, they promise to be tools that will allow the 3D modeling of crime scenes, traffic accidents, or specific evidence in the future. These applications have tools that allow us to take measurements, calculate volumes, perform photogrammetry, and make comparisons by the superimposition of vehicles, faces, shoe tracks, or tires.

The scanned data are processed and visualized with 3D modeling software such as 3ds MAX, Maya, and LightWave 3D [11]. The 3D models obtained can be presented together with the forensic report to improve the substantiation of the conclusions of the forensic science expert during the trial, with the possibility of also offering an immersive experience to judges through the use of virtual reality glasses, which would allow them to locate themselves at the scene of the crime in first person.

3.2. Digital Technologies

In the field of digital forensic technologies, the recovery of data from electronic devices has proven to be a fundamental pillar due to the increasing number of devices that connect to the internet [13] and from which information can be obtained that provides digital evidence, improving the effectiveness of forensic investigations in solving cases [14]. Triangulation, known as the “three D’s” theory—digital data, digital devices, and digital evidence—has become essential for efficient forensic investigation [15] and relies on digital technologies.

The information on Internet of things (IoT) devices presents new and varied ways to obtain user information. The large amount of digital data provides valuable information for forensic investigation. Wearable devices, such as smartwatches, fitness trackers, or augmented reality glasses, store personal information relevant to solving a criminal act [16]. Smart appliances, such as washing machines, ovens, or thermostats, record energy usage and consumption data that can be used to determine a person’s presence or activity in a given location. This data can be extracted by specialized equipment that connects directly to the devices or via the cloud, provided that the principles of legality, necessity, and proportionality are respected.

The use of digital technologies involves the handling of large amounts of data, which is why forensic investigators rely on specific tools for data recovery using cloud services such as the last versions of Dropbox Plus, Google Drive Premium, or iCloud Drive.

New forensic technologies for retrieving and extracting digital information from electronic devices (encrypted or unencrypted) allow for more efficient data retrieval and adapt to the constant evolution of other technologies, providing experts with the necessary tools to face the emerging challenges of the digital age [17].
3.3. Artificial Intelligence and Data Analytics

Artificial intelligence (AI) currently provides support to multiple forensic areas, such as the area of forensic anthropology, in which AI applications have been proposed for the determination of the sex of the victim, for which a convolutional neural network (CNN) has been used to learn the dysmorphic sexual characteristics of skulls using 3D skull reconstructions derived from computed tomography scans as a reference. When it comes to forensic dentistry, AI technology has been used to predict age and gender based on dental characteristics and to characterize bite marks \[18\]. Artificial neural networks (ANNs) have been used to predict age and gender with 90% accuracy. In forensic pathology, AI has been studied as a support tool for the quick and easy identification of diatom taxonomy, for which a convolutional neural network (CNN) has been used to classify diatoms in water samples and human tissues with an accuracy of 95%. In forensic genetics \[19\], AI has been applied to process and interpret the large amounts of genetic data used in forensic DNA typing. In one study, an artificial neural network (ANN) was used for DNA profiling identification from massive sequencing data, achieving 99.9% accuracy \[20\].

The good use of AI applications can help reduce subjectivity and human error in the interpretation of data, improving the quality of evidence presented in court. An example of the good use of AI in image analysis is the identification through modeling and recognition of 3D ears from video footage using the shape of the pinna from shadows \[21\].

Language models powered by AI and disseminated in applications such as ChatGPT or Llama are being leveraged as a revolutionary tool in forensic science. Applications with language models make it possible to analyze large amounts of textual data, extract crucial information from case notes, and discover patterns in testimonies, making them a valuable resource for research \[22\]. In cybercrime, the integration of artificial intelligence in decoding encrypted messages, understanding cybercriminals’ modi operandi \[23\], and the identification of patterns of criminal behavior have been highlighted \[3\].

The large amount of information provided by new technologies also requires careful and precise handling, which is why AI, together with big data, makes it possible to handle information from multiple applications such as total station \[24\], photogrammetry, and laser scanning, which provide details with exceptional precision \[11\]. Thanks to big data, information from applications such as automated facial recognition and identification through voice and audio analysis can also be documented more accurately and dynamically, allowing for greater operational efficiency and the possibility of standardizing information collection and documentation processes \[21,25\].

The use of AI for analyzing images and information obtained from satellites has strengthened the field of forensic investigation by providing a wide range of benefits and applications. The technology has allowed forensic investigators to access detailed and up-to-date information on areas of interest, significantly improving their ability to solve complex and varied forensic cases. Some ways in which satellites have contributed to forensic investigation include monitoring changes in the environment over time, detecting incremental changes, identifying important sites, and applications in various forensic disciplines and crime prevention and resolution \[26\].

Monitoring changes in an environment over time can be achieved by high-resolution images captured by satellites, allowing us to learn about cases of deforestation, urbanization, or natural disasters, which can be crucial information for long-term forensic investigations. Detecting incremental changes can provide relevant information, such as illegal deforestation or alterations in the natural environment, which can be crucial for forensic investigations in areas such as ecology and national security. Identifying important sites can reveal information about specific land, water, or air features that differ from the surrounding environment, such as mass graves, oil spills in the water, or buried sites of historical value, providing important evidence for forensic investigations. Satellite imagery processed with artificial intelligence is useful in investigating crimes and finds applications in forensic disciplines such as forensic anthropology, geophysics, pedology, oceanography, and chemistry, thus expanding its reach in the forensic field. Incidents of mass murders,
vehicular crimes, natural disasters, the location where a crime was committed, the estimation of the postmortem interval of a victim, the determination of the geographical origin of evidence, finding buried human remains, and reconstructing historical facts from soil analysis can also be achieved with the same technologies mentioned above, all of which improve the efficiency of forensic investigations [27].

In a significant breakthrough in the forensic field, automated systems have been implemented that manage vast amounts of data, marking a substantial transformation in fingerprint identification and ballistic analysis. These advances are reflected in the efficiency and reduction of processing times made possible through technologies such as the Multi-Biometric Identification Solution (MBIS) [28], known in its previous version as the Automated Fingerprint Identification System (AFIS) [29], and the Integrated Ballistic Identification System (IBIS), which allow faster and more accurate analysis when handling large volumes of data.

The Integrated Ballistic Identification System (IBIS) has revolutionized the ballistic field by facilitating the matching and correlation of bullets and casings [30]. This system manages large ballistic datasets and allows a wide variety of bullet features to be analyzed, improving the ability to correlate them accurately and efficiently. This automated approach to ballistic analysis has been essential to advancing the resolution of firearm-related cases.

3.4. Biometric Technologies

In the realm of biometric identification, facial recognition techniques have evolved to address challenges such as changes in lighting and variations in position. Deep learning algorithms have improved the accuracy of facial recognition, making it easier to identify individuals in extensive databases. Despite this, ethical and privacy concerns surround the widespread use of facial recognition technology [21].

Thanks to technological advances in the field of computer vision analysis, more efficient pinna, iris, and fingerprint recognition techniques have been developed, and these are currently driving forensic investigation [31]. Portable breath detectors for drug detection have also proven to be useful tools in law enforcement, especially in cases involving driving under the influence of alcohol [14].

To streamline the results of DNA analysis when dealing with complex cases with large amounts of elements where it is necessary to compare reference profiles with evidence profiles, including their mixtures, an innovative technology has been designed that incorporates an expert system called CaseResolver [32]. Big data forensics has emerged as a crucial field in the digital age. Managing, analyzing, and extracting meaningful insights from massive datasets has proven vital to better understanding the chronology of events in forensic investigations [10].

One of the most prominent biometric technologies is the Multi-Biometric Identification Solution (MBIS), which is limited to fingerprint identification and facial analysis and comparison [28]. This functionality extends the system’s usefulness, offering a versatile capability for biometric identification based on different modalities [33].

3.5. Advances in Nanotechnology

Technologies based on advances in nanotechnology, such as MALDI MS and multimodal forensic imaging, have been used to obtain relevant chemical information in criminal investigations [34]. In substance identification, nanotechnology enables the creation of highly specialized nanometer sensors that can detect minuscule traces of substances, even in complex environments. These sensors can quickly identify materials such as explosive residues, drugs, or specific chemical compounds, facilitating accurate identification in forensic scenarios.

In the field of sample collection, nanomaterials offer a significant improvement. Porous nanomaterials allow DNA or other biological evidence to be absorbed and concentrated, maximizing the amount of material recovered and optimizing analysis processes. Notable improvements have been made in fingerprint development technologies, especially in
cases considered to be challenging, such as the so-called “impossible prints” present in deflated casings. Equipment such as Foster and Freeman’s Recover system has excelled at overcoming these difficulties, enabling the identification and development of fingerprints in contexts that were previously considered extremely complicated [35].

Nanotechnology applied to forensic investigation enables the development of nanometer tags to track and mark evidence uniquely. These labels can be used for real-time tracking and to ensure the authenticity of samples throughout the various stages of the forensic process [36].

3.6. Autopsy and Radiology Techniques

An alternative technology that has been developed to eliminate the need to perform traditional autopsies that can destroy important evidence is the virtual autopsy, known as the “virtopsy”, a diagnostic technique that allows, in a minimally invasive way, access to certain parts of the human body without the need for the traditional autopsy. Its advantages include greater precision and accuracy, evidence preservation, reviewability, the minimization of invasiveness, efficiency, and safety.

The increased precision and accuracy that are promoted by virtual autopsies, which use techniques such as computed tomography (CT) [6] and magnetic resonance imaging (MRI) [37], allow for the detailed, three-dimensional visualization of anatomical structures, making it easier to identify injuries and determine a victim’s cause of death more accurately. In addition, evidence can be preserved more effectively by not requiring physical manipulation of the body; virtual autopsies preserve forensic evidence intact, which is especially beneficial in cases where the destruction of evidence could occur during a traditional autopsy. Unlike in traditional autopsies, the data obtained from a virtual autopsy can be stored and reviewed at any time, allowing for continuous analysis and the possibility of further investigations without the need to repeat the procedure, which may result in a less traumatic experience for the relatives of the deceased and be an acceptable alternative in cultures where the autopsy is objected to for religious reasons [38].

The ability to perform virtual autopsies quickly and accurately can improve the efficiency of forensic investigations by reducing wait times and minimizing the risks associated with handling cadavers.

One technique developed and proven to be effective in forensic investigation is post-mortem angiography [39], which involves the injection of a contrast agent into the blood vessels of a cadaver, followed by radiological imaging to detail the vascular network. Crucial information about blood circulation can be obtained through this method, and it is especially valuable in the identification of vascular lesions and pathologies associated with the circulatory system and in the reconstruction of traumatic events. By enabling the three-dimensional visualization of the vascular network, postmortem angiography facilitates the reconstruction of traumatic events, revealing the extent of vascular lesions and offering details about the intensity or nature of the trauma. This ability is essential for understanding the dynamics of incidents such as car accidents, stab wounds, or gunshot wounds [40].

3.7. 3D Printing Techniques

Developments in 3D printing technology have led to significant advances in replicating physical evidence, such as weapons, bones, ballistics, and other objects related to criminal cases. The ability to create accurate reproductions of physical evidence provides a valuable tool in presenting evidence in court [41]. 3D printing has also been applied in creating anatomical models for autopsy planning and forensic education. These reproductions can be used in the courtroom for an impactful visual presentation and to allow jurors to better understand the evidence.

3D printing technology has been used to produce detailed three-dimensional models of crime scenes. These models consider topographic aspects, the disposition of evidence, and the location of relevant elements, thus providing an accurate representation that facilitates
the visualization and understanding of the dynamics of forensic incidents [42]. When evidence is damaged or incomplete, 3D printing is used to reconstruct and restore objects, a practice that can be essential for identifying patterns, marks, or details that may have been lost. In traffic accident situations, 3D printing technology is used to create models of the vehicles involved, allowing for the simulation and detailed analysis of collisions. This approach facilitates the more accurate understanding of the mechanics of the accident and contributes to the determination of liability.

For the study of physical injuries, such as those caused by stab wounds or gunshot wounds, 3D printing becomes an accurate tool for the replication of these injuries. This approach facilitates comparison and detailed analysis, which are instrumental in identifying the type of weapon used and deeply understanding the nature of the injury [43]. 3D printing also plays a key role in creating anatomical models used in the training of forensic professionals. These models allow for realistic and detailed practices in autopsy techniques and evidence analysis.

3.8. Genetic Identification Technologies

With the support of AI, more accurate applications have been developed in the interpretation of DNA analysis. Expert systems based on deep learning algorithms can analyze complex DNA profiles, contributing to faster and more accurate identification [44].

Advances in nano-electronics have made it possible to develop small devices that integrate multiple functions of an analysis laboratory, allowing the detection of traces of DNA at the crime scene itself, transforming crime scene investigation, and making it more dynamic [45,46]. DNA on a chip is another technology that is based on the miniaturization of analytical instruments and integrated forensic platforms; in this case, they are used to analyze the differential expression of genes whose technique uses fluorescence as an indicator and which also allows portability and ease of use in crime scene investigation [1]. The validation and standardization of the aforementioned genetic identification technologies are still critical aspects that must be addressed to ensure their reliability in forensic settings.

3.9. Speech and Audio Recognition Technologies

Advances have been made in speech and audio recognition when it comes to identifying individuals. Voice forensics, which uses techniques such as spectroscopy and magnetic resonance imaging, has improved the ability to identify and authenticate in criminal cases [25].

The methods most used by specialists in the forensic identification of speakers are as follows: (1) the perceptual-auditory method, which highlights the parameters to be analyzed and presents a subjective aspect through a qualitative approach; (2) the acoustic method, which uses the spectrogram to analyze the waves produced at the time of the vocal emission, allowing a quantitative analysis; and (3) the automatic method, which involves the use of automatic technologies for the identification of speakers [47].

Due to advances in artificial intelligence related to the creation of artificial voices that are very similar to human voices, challenges have arisen, and it has become essential to establish clear guidelines for the use of these voice and audio identification technologies in forensic investigations [25].

New, more advanced voice biometrics systems have been developed that incorporate multifactor analysis to evaluate different characteristics of the voice; specific artificial intelligence algorithms for recording authentication; more advanced techniques to analyze intrinsic characteristics of the voice, such as the vibration patterns of the vocal cords or the unique characteristics of the vocal tract; and cryptographic methods and acoustic markings to ensure the authenticity of audio recordings [48].

The constant evolution of voice and audio forensics technology is critical to preserving confidence in the evidence presented in the legal arena, especially in the face of the continued development of artificial speech synthesis capabilities.
3.10. Technologies for the Detection of Illicit Substances

Advances in the detection of illicit substances have been linked to the contributions of nanotechnology, whose advances have provided technology for taggants, chromogenic sensors, fluorogenic sensors, electrochemical sensors, and microarray-based sensors for the detection of drugs and illicit substances at crime scenes [49]. Nanotechnology, in particular, has enabled significant advances in analyzing and eliciting chemical information relevant to criminal investigations [34]. Forensic chemical analysis has registered a great technological evolution, favoring the investigation and analysis of microindications, including technologies such as mass gas spectrometry, chromatography, and X-ray photoelectron spectroscopy. These analyses make it possible to analyze the composition, age, origin, and provenance of the samples found at a crime scene [50].

Faced with the increasing complexity and variety of crimes, forensic toxicology services have implemented highly sensitive detection techniques with greater and more efficient data processing that allow them to work with a wider range of compounds in a wider range of matrices. These techniques are based on using technologies that employ artificial intelligence or chemometric techniques [1].

3.11. Extended Reality (XR)

The application of extended reality (XR), which encompasses the development of augmented reality (AR), virtual reality (VR), and mixed reality (MR), has extended into the forensic field, providing significant advances in the teaching methods and practices of forensic science. Some technological advancements in XR for forensics include forensic visualization in virtual reality, the training of first responders and digital forensic investigators, crime scene scanning, remote case analysis, and the inclusion of multimedia information in forensic reports.

XR has expanded the possibilities of recreating crime scenes and providing an immersive perspective for investigators. These technologies allow detailed visualization for the reconstruction of traffic incidents, reassociating fragmented human remains, achieving more significant evidence, and a deeper understanding of the disposition of evidence at the scene [24].

Incorporating AR into forensics has emerged as an exceptionally valuable tool for investigating and solving crimes. This technology enables the inclusion of multimedia information, such as video, audio, 3D modeling, 3D reconstructions, and photographs, in forensic reports and introduces significant innovations in collaboration and documentation during the investigative process [51].

Advances in AR have allowed digitally viewable virtual markers to be inserted over the crime scene, representing clues and objects identified during the initial inspection. The virtual markers, accessible through AR, can be integrated as evidence entered into the collection centers, maintaining the chain of custody through a blockchain registry. This functionality allows the visualization of photographs or 3D modeling of the object that would not otherwise be visible to the naked eye. This innovation ensures the detailed observation of evidence, preserving the integrity of the process and improving the ability of researchers to evaluate and analyze the information collected.

In order to increase the skills of forensic personnel, forensic simulators have been developed through the use of VR that allow multiple scenarios to be incorporated and the techniques and procedures of forensic science experts to be evaluated. Virtual reality has enhanced forensic training by offering an immersive, hands-on, and flexible experience that helps students gain skills and knowledge effectively in a safe and controlled environment. The use of VR technologies reduces training costs since multiple virtual scenarios can be created in the same physical space and allows for the indefinite use of inputs, reagents, and forensic equipment without exhausting them [52]. In addition, educational forensic games have been developed in virtual reality so that students can learn forensic science more effectively.
Magnetic resonance imaging (MRI) and radiology can be enhanced with the use of virtual reality (VR) in forensics by reconstructing detailed 2D and 3D forensic findings [53]. Advanced devices such as Microsoft’s HoloLens have revolutionized how crime scene documentation is approached. Mixed reality is not limited to static information capture but enables the interactive and immersive reconstruction of crime scenes, providing multidisciplinary forensic teams with a visually stunning tool to collaborate remotely. This feature streamlines the investigation process and improves the quality of collaboration between experts by providing a three-dimensional representation of the crime scene [54].

Figure 4 outlines multiple technologies applied in crime scene investigation. Considering the type of analysis and evidence, the devices have been grouped into biometrics, chemicals, 3D technologies, artificial intelligence, big data, on-site laboratories, and satellite image analysis.

**Figure 4.** Forensic technologies in crime scene investigation.

The crime scene has multiple types of information that require technologies that are often more effective due to the implementation of computational tools such as AI, big data, and machine learning.

Several methods and techniques illustrated in Figure 1 have already been used traditionally; however, miniaturization technology is making analysis systems more portable and capable and their operation less complex. A greater number of technologies developed for biometric analysis are visualized.

3D technology has focused on improving the visualization and reconstruction of crime scenes, while AI is seeing greater interest in the use of satellite imagery information. Developers of forensic technologies have been interested in developing more efficient methods and technologies to better use information from IoT devices, which have increased exponentially in recent decades.

The effort that the developers of technologies have made in creating systems that can be transported to the crime scene is evident; these analysis technologies embrace mobile laboratories, computed tomography equipment, and technologies for the realization of virtopsies.
The analysis of evidence and cases offers a level of detail and accessibility that enhances the accuracy and efficiency of the forensic process, thus contributing to a more informed and evidence-based justice. Some of the ways technology has improved forensic science include improved visualization, the possibility of immersive evaluator interaction, more accurate identification of evidence at the crime scene, and the automation of procedures through the use of machine learning and deep learning [55].

4. Impacts of Technology on Forensic Investigation

This section describes and categorizes the impacts evidenced in the processes carried out in forensic investigation. Eight processes have been identified in which technology has had a strong impact: documentation, validation, and the application of technologies; efficiency in the identification of suspects; the use of innovative technologies; advanced data analysis; evidence collection; biometric identification; reconstruction; and the visualization of the crime scene (Figure 4). Some technologies have a high impact, while others have a moderate impact; they are presented color-coded in Figure 5.

![Figure 5. Impacts of technologies on forensic crime scene investigation.](image_url)

The first aspect in which the moderate impact of technology predominates is the documentation of a large number of data and information generated by technologies and their various analyses. Applications of AI-powered language models, such as the ChatGPT model or Llama, have excelled at analyzing large amounts of textual data, discovering patterns, and generating potential clues [23]. There has been evidence of the increased speed and accuracy with which documentation is organized in an automated way, better visualization, higher accessibility to researchers, and the more efficient classification of large volumes of data [14,56].

Implementing technologies requires processes that allow them to be validated and their advantages and disadvantages identified. Due to the growing technological advances that criminals and/or cyber criminals take advantage of, forensic investigation teams must adopt new technologies that allow a better investigation despite the adulteration of digital information that sometimes compromises satellite information [57]. The technology also
allows advanced data analysis to evaluate the accuracy and reliability of other technologies. This aspect has become necessary to eliminate human error in interpreting tests with fuzzy results [58].

The identification of suspects has been strongly impacted by technology due to the multitude of alternatives that have been incorporated into image analyses carried out on security camera videos, satellite information, advances in biometric identification technologies, and even the involvement of AI for the identification of patterns and suspicious activities [59], to decrypt encrypted messages, and to understand the modi operandi of digital criminals [23].

The ability to access more realistic and immersive virtual environments has generated greater impact and interest in implementing and using technologies such as digital crime scene scanning and reconstruction. There is a great expectation on the part of forensic actors who consider it pertinent to extend the analysis of the crime scene to experts from other nations, thus facilitating the incorporation of other criteria and expert points of view in cases of uncertainty or the resolution of complex cases [56]. The efficiency of taggant-based technology and its versatility have driven the adoption of these technologies in the identification and rapid analysis of substances at crime scenes [41,49].

The advanced data analysis that drives the adoption of AI, big data, and machine learning has provided an improvement in the rapid analysis of large amounts of data, and in order to provide competitive answers, forensic teams are forced to adopt these tools in addition to their respective training and updating [21].

The efficient collection of biological data obtained by increasing advances in biometric technologies has required increased processing and analysis capacities that are sometimes compared to large databases. Automation and soft biometrics reduce human bias and improve the data quality used in forensic investigations [31]. Technologies that use lasers to recreate crime scenes operate with high three-dimensional resolution, generating files that require computers with high computational capabilities [54].

The recognition and identification of the identity of victims and suspects have become more efficient through virtual and physical reconstruction techniques with the employment of 3D printing, as well as the accuracy of facial identification and fingerprints [14,29].

3D scanning and printing technologies have revolutionized the visualization of crime scenes, significantly improving the capabilities of documentation and forensic analysis. The integration of these tools has allowed investigators to obtain accurate and detailed three-dimensional representations of criminal environments [10]. In addition, the combination of technologies such as 3D scanning and printing with the perspective provided by drones optimizes the scene’s documentation and streamlines the investigative process. The accurate three-dimensional representation obtained using these tools allows investigators to thoroughly examine every aspect of the crime scene, improving identification and evidence collection.

The use and implementation of new technologies involve continuous training in the development of skills and abilities, which is fundamental and can often be promoted with the use of virtual reality (VR) resources; these technologies have introduced more precise and detailed training opportunities in forensic investigation, allowing practical and controlled experiences [60]. The forensic community needs to be aware of the importance of adapting these technologies to maximize their potential and ensure an efficient administration of justice.

5. Challenges and Limitations in the Implementation of Case Resolution Technologies in Forensic Sciences

The exponential advance of technologies, the development of disruptive technologies, and solutions that are generated daily pose a series of challenges that must be faced and solved by the forensic science expert. While the use of new technologies offers some advances, disadvantages at the technical level must be mitigated.
Table 1 summarizes the challenges in the use of technology in forensic science and investigation. The aspects that represent challenges are multiple and have been classified into seven categories, as corroborated in the scientific literature: regulatory frameworks and standards, technical limitations, cost and accessibility, awareness and understanding, ethical and legal challenges, the adaptation and integration of technologies, and privacy and ethics.

The lack of regulations and standards referred to in Table 2 relates to the lack or non-existence of legal requirements for the accreditation of forensic services based on the use of technologies, which creates a gap in the definition of operational standards and clear procedures. The absence of regulations contributes to the lack of uniformity in the quality of services and the need to establish policies that ensure the integrity and validity of forensic results [56].

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
<th>References</th>
</tr>
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<tbody>
<tr>
<td>Regulatory Framework and Standards</td>
<td>- Lack of regulation and legal standards.</td>
<td>[42]</td>
</tr>
<tr>
<td></td>
<td>- Absence of requirements for accreditation of forensic services.</td>
<td></td>
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<tr>
<td></td>
<td>- Lack of operational standards and standardized procedures.</td>
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<tr>
<td>Technical Limitations</td>
<td>- Accuracy and resolution in images and 3D models.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Persistent technical barriers in various technologies.</td>
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<tr>
<td>Cost &amp; Accessibility</td>
<td>- Onerous investment and need for specialized equipment.</td>
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<td></td>
<td>- Limitaciones financieras generadoras de desigualdades en el acceso.</td>
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<tr>
<td>Awareness and Understanding</td>
<td>- Lack of knowledge amongst the law enforcement community.</td>
<td></td>
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<td></td>
<td>- Challenges in understanding the value of technology services.</td>
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<tr>
<td>Ethical and Legal Challenges</td>
<td>- Need for rigorous ethical standards.</td>
<td>[14,22,42]</td>
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<tr>
<td></td>
<td>- Risks of misinformation and potential miscarriages of justice.</td>
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<tr>
<td></td>
<td>- Lack of ethical and legal regulations for using drones in forensic investigations.</td>
<td>[25,31]</td>
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<tr>
<td>Adaptation and Integration of Technologies</td>
<td>- Complexity in choosing appropriate technologies.</td>
<td>[24,49]</td>
</tr>
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<td></td>
<td>- Financial and training barriers.</td>
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<td></td>
<td>- Need to adapt to emerging technologies and change the roles of forensic scientists and crime scene examiners.</td>
<td>[25,57]</td>
</tr>
<tr>
<td>Privacidad y Ética</td>
<td>- Ethical and privacy concerns.</td>
<td>[25,57]</td>
</tr>
<tr>
<td></td>
<td>- Less accurate identification of certain ethnic groups.</td>
<td>[1,33,60]</td>
</tr>
<tr>
<td></td>
<td>- Challenges in virtual reality regarding cost, accessibility, and ethics.</td>
<td></td>
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</table>

The technical limitations that are presented depend on the characteristics of the technological equipment used, such as in the case of cameras, which have limited precision and resolution in images and 3D models; a similar case is presented by the 3D printing of complex structures whose definition may not always be sufficient for very complex and small details [63].

Despite technological advances, obstacles remain in overcoming technical limitations to ensure the reliability of forensic results. In terms of cost and accessibility, the significant investment required to implement advanced technologies poses financial challenges. Acquiring specialized equipment and software can be prohibitively expensive, leading to disparities in access to crucial technologies between forensic labs. The lack of understanding amongst the law enforcement community leads to a lack of knowledge about the benefits and applications of technology services, hindering their adoption. This lack of understanding can translate into poor management decisions in the acquisition of new forensic technologies, negatively impacting the effectiveness and efficiency of applying new
tools in the forensic field [56]. This mismatch between expectations and reality can result in widespread discontent, as users and decision-makers may perceive that new technologies do not meet their initial needs or expectations.

The use of artificial intelligence poses ethical and legal challenges. Multiple questions have led to the implementation of rigorous ethical standards. Concerns about the potential for misinformation underscore the importance of viewing AI as a complementary tool rather than a substitute for human judgment. The challenges in digital forensics have raised concerns that increased digital media can be used to commit sophisticated crimes; therefore, it is necessary to employ preventive measures. Implementing safety protocols and understanding the negative implications are essential to the mitigation of these risks [22].

The complexity of the selection and implementation of technologies creates challenges in choosing the most suitable one to be used in specific cases. The cost and need for training can represent significant barriers, especially for organizations and laboratories with limited resources [25]. A lack of clear standards and regulations can hamper the effective implementation of forensic technologies. The lack of regulatory frameworks can hinder technology adoption and appropriate use, especially in terms of ethics and privacy.

Despite improved sensors and increased data processing capacity, the accuracy of some forensic technologies remains a challenge. Rigorous validation is essential to ensure reliable results before widespread implementation. Technologies that generate large amounts of data, such as 3D laser scanning, pose challenges to effective information management. Data processing capacity is crucial to avoid application saturation [11].

Concerns have been raised about the privacy and ethics of data obtained in biometric feature analyses and surveillance systems [31]. Ensuring the privacy and security of information becomes a crucial aspect in this context, given that computer systems without proper monitoring can present cyber vulnerabilities. A lack of coordination in research and development can limit technological advancement in forensic sciences. Integrating and optimizing scientific functions becomes crucial to improving the efficiency and quality of forensic services [6], but this often requires a change in the paradigms and roles of forensic professionals and represents significant challenges.

Mobile communication presents challenges when transmitting large amounts of information, such as DNA analysis, which must be compared with large databases and presents a high complexity of identification parameters [64]. A similar case occurs with sending crime scene information recreated through laser scanning, whose information and processing require enormous computational costs [1] and high data transfer rates.

Considering the labor aspect, the high workload limits the viability of research and new approaches, hindering the integration of technologies, so it is advisable to generate an adequate space or a project with people completely dedicated to the implementation of technologies and their socialization, updating, and training [60,61].

6. Future Perspectives on the Use of New Technologies in Forensic Sciences

According to the scientific literature, there are several future expectations regarding the use of technology in forensic investigation. Technology contributes in various ways to the forensic sciences; these can be summarized into eight main aspects that are presented in Figure 1.

As seen in Figure 6, one of the aspects that will have the greatest impact on technology in the future is the strengthening of forensic training and practice with the use of virtual and augmented reality technologies. Unlike other disciplines, crime scene investigation cannot be a rehearsal for practitioners, so the contributions of extended reality will emulate these scenes, allowing practitioners to strengthen their technical skills.

Due to the large amount of information that will be obtained with new technologies, quality management in the use of technologies becomes essential to discriminate which information is useful and which is not; this aspect will be crucial to avoid the saturation of information systems with unnecessary or redundant data. The management of quality management systems will require the development of legal and ethical standards that allow...
for greater confidence in the continuous adoption of new technologies to strengthen crime scene investigation.

Figure 6. Future developments in the use of technologies in forensic investigation.

In order to foresee possible ethical dilemmas regarding the use of artificial intelligence in the future, it has been recommended [23] that the results obtained through the use of artificial intelligence be used as a complementary tool and not as a replacement for human judgment and discernment. It is important that this responsibility always falls on trained forensic experts.

The establishment of standards and regulations for the accreditation and validation of forensic services and deliverables based on 3D technologies is expected to occur in the future. The guidelines that will be proposed in the future should be aimed at ensuring reliable, ethical, and accurate practices in the presentation of forensic evidence in judicial environments [42]. It is predicted that the foundations of ethics will provide greater reliability in using these technologies, increasing their operational value and reliability in managing physical and digital models [63].

The technologies that will contribute the most to the forensic sciences are (1) the integration of drones along with the use of XR, (2) the adoption of biometric identification technologies along with the automation of these tasks, and (3) the greater use of AI and big data analytics. Emerging technologies such as AI and machine learning will significantly impact forensic investigation. The standardization and validation of forensic technologies, together with the adequate training of investigators, will improve the accuracy and efficiency of the investigation process [14]. An increase in the integration of drones to facilitate processes of documentation, the reconstruction of scenes, and the detection of evidence is on the horizon, overcoming the current challenges [10]. These technologies, along with virtual, augmented, and mixed reality, artificial intelligence, blockchain, and big data analytics, will play a key role in improving the efficiency and accuracy of forensic investigation.

New advances in biometric technologies, advances in sensors, and greater computational capacity in data handling will make feasible the adoption of soft biometric technolo-
gies, the development of standards and protocols for the collection and evaluation of more accurate biometric data, and the greater automation of tasks in forensic investigations [65].

The development of footwear brand identification through real-time satellite technology has been proposed [6]. This development could provide a faster and more accurate response at the crime scene, optimizing evidence collection.

The deployment of forensic response vehicles equipped with a full range of capabilities, such as DNA analysis, the chemical analysis of explosives and illicit substances, and digital evidence analysis, together with the support of drones, forensic robots, and portable 3D scanning devices, will allow the execution of comprehensive investigations in the forensic field. Not only will these vehicles be capable of performing DNA analysis, but they will also carry out the chemical analysis of explosives and suspicious substances, as well as the extraction and analysis of digital evidence, all supported by the incorporation of drones, forensic robots, and portable 3D scanning equipment that enable the execution of multiple field forensic analyses in a comprehensive manner [45]. This holistic approach to forensic technology in the field of crime scenes stands as a significant advance. The combination of capabilities, from genetic analysis to chemical and digital inspections, provides forensic teams with a versatile and comprehensive tool to address various situations in real time.

Including drones, forensic robots, and portable 3D scanning equipment allows for the exploration of hard-to-reach areas, accurate sample collection, and the creation of detailed three-dimensional models of the crime scene. This combination of technologies facilitates a more agile response during investigations and expands the ability to obtain detailed and contextualized information.

It is still too early to fully recognize the importance of carefully addressing the challenges of ethics, accountability, and the proper implementation of technologies. Despite the uncertainty, technological advancement, standardization, and multidisciplinary collaboration are expected to improve investigators’ ability to effectively and accurately solve cases in the forensic setting [15,34,66].

7. Discussion

Technological advances are profoundly transforming the landscape of forensic investigation, providing innovative tools that improve efficiency and accuracy in obtaining evidence at crime scenes. For example, three-dimensional scanning, 3D printing, and 3D modeling allow the detailed visualization and accurate reconstruction of crime scenes from different perspectives. In addition, drones equipped with scanning technology provide aerial vision and accurate data collection for a more complete forensic reconstruction [9,10].

In the realm of digital technologies, data retrieval from electronic devices and the triangulation of digital data, devices, and digital evidence are critical for efficient forensic investigations [13–15]. In addition, artificial intelligence is revolutionizing various areas of forensics, from anthropology to genetics, improving accuracy in determining the victim’s sex, predicting age and gender, and interpreting genetic data [20].

Biometric techniques, such as facial recognition and fingerprint identification, have been refined with deep learning algorithms, increasing accuracy in identifying individuals [21,31]. In addition, nanotechnology has enabled significant advances in obtaining relevant chemical information in criminal investigations [34].

Extended reality (XR) has expanded the possibilities of recreating crime scenes and providing an immersive perspective to investigators, improving the visualization, training, and reconstruction of incidents [24,52]. These technological advancements are strengthening the field of forensic investigation by providing more accurate and efficient tools for collecting and analyzing evidence in solving criminal cases.

Technology implementation in forensic practices faces various challenges that must be addressed to ensure its effectiveness and reliability. One of the main obstacles is the lack of regulation and clear standards, which creates uncertainty about the quality and validity of the results obtained through these technologies. This absence of regulations contributes to the lack of uniformity in forensic services and the need to establish policies that ensure the
integrity of processes [56]. In addition, the technical limitations of technological equipment, such as the limited accuracy of cameras and resolution in 3D printing, pose challenges in obtaining reliable results [63].

The ethical and legal challenges related to using artificial intelligence are also prominent. There are concerns about the possibility of misinformation and the need to establish rigorous ethical standards to mitigate risks. In addition, the complexity in the selection and implementation of technologies and concerns about data privacy and security add additional layers of difficulty to integrating technology into forensic practices [22,62]. The lack of coordination in research and development, coupled with the high workload and need for training, represent additional challenges that must be addressed to effectively implement technology in the forensic field [60,61].

The future of technology implementation in forensic science promises major breakthroughs that will transform the way investigations are conducted in the field. The significant strengthening of forensic training and practice through emerging technologies is anticipated, allowing practitioners to improve their technical skills and abilities in investigating crime scenes safely and effectively [22]. In addition, quality management in using technologies is expected to be essential to discriminating relevant information and avoiding the saturation of information systems with unnecessary data [41]. The continued adoption of new technologies will be supported by the development of legal and ethical standards that provide confidence in the integrity of forensic processes [54].

In the field of artificial intelligence, a focus on its use as a complementary tool under the supervision of trained forensic experts is envisaged, which will help prevent potential ethical dilemmas and ensure data interpretation accuracy [23]. In addition, the future establishment of standards and regulations for the accreditation of forensic services based on 3D technologies is expected, ensuring reliable and ethical practices in presenting evidence to judicial environments. Emerging technologies such as drones, extended reality, 3D printing, blockchain, robotics, taggants, biometric identification, and artificial intelligence will play a crucial role in improving the efficiency and accuracy of forensic investigation [14,65].

The synergy between 3D scanning and printing and drones’ strategic involvement has raised the bar in crime scene visualization. These combined technologies offer a complete, detailed, and accessible perspective, enhancing forensic professionals’ ability to conduct more accurate and effective investigations. In addition, the development of more advanced biometric technologies and greater computational capacity will allow for the more efficient automation of tasks in forensic investigations.

This dynamic approach and the integration of expert systems are expected to drive the efficiency and accuracy of investigations, marking an important milestone in the evolution of forensic tools and their impact on solving criminal cases.

8. Conclusions

Technological advancements provide innovative tools for forensic investigation, increasing the efficiency and accuracy of obtaining evidence at crime scenes. From portable three-dimensional scanning to drones equipped with scanning technology and artificial intelligence, new forms of visualization and data collection are being developed that allow for the more detailed and accurate reconstruction of incidents. The integration of digital technologies such as artificial intelligence and big data analytics promises to further improve the accuracy of data interpretation and the identification of individuals through advanced biometric techniques. Extended reality expands the possibilities for recreating crime scenes, providing an immersive perspective to investigators by improving training and viewing incidents.

The lack of a solid understanding of the adoption of forensic technologies can lead to a chain of adverse effects, from poor management to unmet expectations and the inefficient use of forensic resources and services. It is crucial to address this gap in understanding to optimize implementation and maximize the benefits of technological innovations in forensics.
In operational terms, utilizing forensic response vehicles with these multifaceted capabilities promises to streamline police investigations and the treatment of suspects at the time of arrest. The anticipated development of expert systems for interpreting sample analyses in the field aims to improve the accuracy and efficiency of data interpretation, bridging the gap between obtaining and analyzing information, which has profound implications for evidence-based decision-making. This future focus on forensic technologies promises to redefine how criminal investigation is approached and strengthen the quality of evidence collected in the field.

The future of technology implementation in forensic sciences faces diverse challenges, from a lack of regulation and clear standards to ethical and data security concerns. It is critical to address these challenges to ensure the effectiveness and reliability of technology-based forensic practices. However, with the development of legal and ethical standards, along with the increased integration of emerging technologies and the proper training of investigators, the forensic field is expected to experience significant advances in solving criminal cases more accurately and efficiently.

**Author Contributions:** Conceptualization, X.C.; methodology, X.C. and O.F.-U.; software, X.C. and O.F.-U.; validation, X.C. and O.F.-U.; investigation, X.C.; resources, X.C.; writing—original draft preparation, X.C. and O.F.-U.; writing—review and editing, X.C., O.F.-U., P.G.-J. and H.G.-M.; visualization, X.C.; supervision, X.C. and O.F.-U.; project administration, X.C.; funding acquisition, O.F.-U. All authors have read and agreed to the published version of the manuscript.

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**Informed Consent Statement:** Not applicable.

**Data Availability Statement:** Datasets for the review are available at [7] Chango, Xavier; Flor-Unda Omar Cristóbal (2024), “(Dataset) Technology in Forensic Sciences: Innovation and Precision”, Mendeley Data, V1, doi: 10.17632/gsm53nrgvb.1 and are cited in the paper.

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**Conflicts of Interest:** The authors declare no conflicts of interest.

**Appendix A**

**Table A1.** Preferred reporting items for systematic reviews and meta-analyses extension for systematic review (PRISMA) checklist [7].

<table>
<thead>
<tr>
<th>Section and Topic</th>
<th>Item #</th>
<th>Checklist Item</th>
<th>Reported on Page #</th>
</tr>
</thead>
<tbody>
<tr>
<td>TITLE</td>
<td>1</td>
<td>Identify the report as a systematic review, meta-analysis, or both.</td>
<td>1</td>
</tr>
<tr>
<td>ABSTRACT</td>
<td>2</td>
<td>See the PRISMA 2020 for Abstracts checklist.</td>
<td>1</td>
</tr>
<tr>
<td>INTRODUCTION</td>
<td>3</td>
<td>Describe the rationale for the review in the context of existing knowledge.</td>
<td>1, 2</td>
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<tr>
<td></td>
<td>4</td>
<td>Provide an explicit statement of the objective(s) or question(s) the review addresses.</td>
<td>3</td>
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<tr>
<td>METHODS</td>
<td>5</td>
<td>Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.</td>
<td>3</td>
</tr>
<tr>
<td>Section and Topic</td>
<td>Item #</td>
<td>Checklist Item</td>
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<tr>
<td>Information sources</td>
<td>6</td>
<td>Specify all databases, registers, websites, organisations, reference lists, and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.</td>
<td>4</td>
</tr>
<tr>
<td>Search strategy</td>
<td>7</td>
<td>Present the full search strategies for all databases, registers, and websites, including any filters and limits used.</td>
<td>3</td>
</tr>
<tr>
<td>Selection process</td>
<td>8</td>
<td>Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.</td>
<td>4</td>
</tr>
<tr>
<td>Data collection process</td>
<td>9</td>
<td>Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.</td>
<td>4, 5</td>
</tr>
<tr>
<td>Data items</td>
<td>10a</td>
<td>List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g., for all measures, time points, and analyses), and if not, the methods used to decide which results to collect.</td>
<td>4</td>
</tr>
<tr>
<td>Data items</td>
<td>10b</td>
<td>List and define all other variables for which data were sought (e.g., participant and intervention characteristics and funding sources). Describe any assumptions made about any missing or unclear information.</td>
<td>4</td>
</tr>
<tr>
<td>Study risk of bias assessment</td>
<td>11</td>
<td>Specify the methods used to assess the risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.</td>
<td>-</td>
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<tr>
<td>Effect measures</td>
<td>12</td>
<td>Specify for each outcome the effect measure(s) (e.g., risk ratio and mean difference) used in the synthesis or presentation of results.</td>
<td>-</td>
</tr>
<tr>
<td>Synthesis methods</td>
<td>13a</td>
<td>Describe the processes used to decide which studies were eligible for each synthesis (e.g., tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).</td>
<td>4, 5</td>
</tr>
<tr>
<td>Synthesis methods</td>
<td>13b</td>
<td>Describe any methods required to prepare the data for presentation or synthesis, such as the handling of missing summary statistics or data conversions.</td>
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<tr>
<td>Synthesis methods</td>
<td>13c</td>
<td>Describe any methods used to tabulate or visually display the results of individual studies and syntheses.</td>
<td>4</td>
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<tr>
<td>Synthesis methods</td>
<td>13d</td>
<td>Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s) and method(s) used to identify the presence and extent of statistical heterogeneity and software package(s) used.</td>
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<tr>
<td>Synthesis methods</td>
<td>13e</td>
<td>Describe any methods used to explore the possible causes of heterogeneity among study results (e.g., subgroup analysis and meta-regression).</td>
<td>-</td>
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<tr>
<td>Synthesis methods</td>
<td>13f</td>
<td>Describe any sensitivity analyses conducted to assess the robustness of the synthesized results.</td>
<td>-</td>
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<tr>
<td>Reporting bias assessment</td>
<td>14</td>
<td>Describe any methods used to assess the risk of bias due to missing results in a synthesis (arising from reporting biases).</td>
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<tr>
<td>Section and Topic</td>
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<td>Checklist Item</td>
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<tr>
<td>Certainty assessment</td>
<td>15</td>
<td>Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.</td>
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<tr>
<td>RESULTS</td>
<td></td>
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<tr>
<td>Study selection</td>
<td>16a</td>
<td>Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.</td>
<td>3, 4, 5</td>
</tr>
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<td></td>
<td>16b</td>
<td>Cite studies that might appear to meet the inclusion criteria but were excluded, and explain why they were excluded.</td>
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<tr>
<td>Study characteristics</td>
<td>17</td>
<td>Cite each included study and present its characteristics.</td>
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<tr>
<td>Risk of bias in studies</td>
<td>18</td>
<td>Present an assessments of the risk of bias for each included study.</td>
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<tr>
<td>Results of individual</td>
<td>19</td>
<td>For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g., confidence/credible interval), ideally using structured tables or plots.</td>
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<tr>
<td>syntheses</td>
<td>20a</td>
<td>For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.</td>
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<td></td>
<td>20b</td>
<td>Present the results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g., confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.</td>
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<td></td>
<td>20c</td>
<td>Present results of all investigations of possible causes of heterogeneity among study results.</td>
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<td></td>
<td>20d</td>
<td>Present the results of all sensitivity analyses conducted to assess the robustness of the synthesized results.</td>
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<tr>
<td>Reporting biases</td>
<td>21</td>
<td>Present the assessments of the risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.</td>
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<tr>
<td>Certainty of evidence</td>
<td>22</td>
<td>Present the assessments of certainty (or confidence) in the body of evidence for each outcome assessed.</td>
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<tr>
<td>DISCUSSION</td>
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<td>Discussion</td>
<td>23a</td>
<td>Provide a general interpretation of the results in the context of other evidence.</td>
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<td></td>
<td>23b</td>
<td>Discuss any limitations of the evidence included in the review.</td>
<td>16, 17</td>
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<tr>
<td></td>
<td>23c</td>
<td>Discuss any limitations of the review processes used.</td>
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<td></td>
<td>23d</td>
<td>Discuss the implications of the results for practice, policy, and future research.</td>
<td>16, 17</td>
</tr>
<tr>
<td>OTHER INFORMATION</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Registration and protocol</td>
<td>24a</td>
<td>Provide registration information for the review, including register name and registration number, or state that the review was not registered.</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>24b</td>
<td>Indicate where the review protocol can be accessed, or state that a protocol was not prepared.</td>
<td>3</td>
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<td>24c</td>
<td>Describe and explain any amendments to information provided at registration or in the protocol.</td>
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Table A1. Cont.

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<td>Support</td>
<td>25</td>
<td>Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.</td>
<td>21</td>
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<td>Competing interests</td>
<td>26</td>
<td>Declare any competing interests of review authors.</td>
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<td>Availability of data, code and other materials</td>
<td>27</td>
<td>Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; and any other materials used in the review.</td>
<td>3</td>
</tr>
</tbody>
</table>

From [7].

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