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Research Article

COMPARISON OF THE TEEXMR SOFTWARE WITH PROFESSIONAL BALLISTIC COMPARISON MICROSCOPE SOFTWARE

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COMPARISON OF THE TEEX^{MR}SOFTWARE WITH PROFESSIONAL BALLISTIC COMPARISON MICROSCOPE SOFTWARE

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Abstract: Currently its search solutions easier and more accessible to problem's every time, the innovation had allowed that the technology permeate into various areas, and what technology´s utility could able to makes in different lands of human´s knowledge. And Technological innovation has significantly influenced forensic sciences, introducing tools that enhance efficiency and accessibility in evidence comparison. Traditionally, ballistic comparison relies on high-cost professional microscopes integrated with specialized software, limiting their availability to well-funded laboratories. This study evaluates the functionality and practicality of Teex^{TM}, an affordable digital comparison program originally designed for educational purposes, contrasting it with professional ballistic comparison systems such as Leica^{TM}, Leeds^{TM}, and VisionX^{TM}. Through systematic tests using cartridge cases of common calibers (9×19 mm and .38 Special), the research analyzes core features including image alignment, overlay, contrast adjustment, and real-time visualization. Results indicate that Teex^{TM} successfully replicates essential comparison functions, offering a viable alternative for forensic professionals and students lacking access to expensive equipment. While not a substitute for advanced optical systems, Teex^{TM} demonstrates potential as a complementary tool for training and preliminary forensic analysis, promoting greater accessibility in forensic practice.

Resumen: Actualmente se buscan soluciones más sencillas y accesibles a problemas de todo tiempo, la innovación ha permitido que la tecnología permee en diversas áreas, y que utilidades tecnológicas sean capaces de ser usadas en diversos campos del conocimiento humano. Y la innovación tecnológica ha influido significativamente en las ciencias forenses, introduciendo herramientas que mejoran la eficiencia y accesibilidad en la comparación de evidencias. Tradicionalmente, la comparación balística depende de microscopios profesionales de alto costo integrados con programas especializados, lo que limita su disponibilidad a laboratorios con recursos limitados. Este estudio evalúa la funcionalidad y practicidad de Teex^{MR}, un programa digital económico diseñado originalmente con fines educativos, contrastándolo con sistemas profesionales de comparación balística de equipos como Leica^{MR}, Leeds^{MR} y VisionX^{MR}. Mediante pruebas sistemáticas con casquillos de calibres comunes (9×19 mm y .38 Special), la investigación analiza funciones esenciales como alineación de imágenes, superposición, ajuste de contraste y visualización en tiempo real. Los resultados indican que Teex^{MR} replica con éxito las funciones básicas de comparación, ofreciendo una alternativa viable para profesionales forenses y estudiantes que carecen de acceso a equipos costosos. Aunque no sustituye a los sistemas ópticos avanzados, Teex^{MR} demuestra potencial como herramienta complementaria para la formación y el análisis forense preliminar, promoviendo una mayor accesibilidad en la práctica pericial.

Keywords: Forensic, Comparision, Tool Marks, Microscopy

Palabras clave: Forense, Cotejo, Marcas de herramienta, Microscopia

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ABBREVIATIONS

AFTE: Association of Firearm and Tool Mark Examiners (Association of Firearm and Tool Mark Examiners)

CPEUM: Constitución Política de los Estados Unidos Mexicanos (Political Constitution of the United Mexican States)

CMS: Consecutive Matching Striae (Consecutive Matching Striae is a theory of tool mark identification)

F.G.R.: Fiscalía General de la República (the institution in charge of prosecuting justice at the federal level in Mexico).

AI: Artificial Intelligence

INEGI: Instituto Nacional de Estadística y Geografía (National Institute of Statistics and Geography)

LED: Light-emitting diode (Light-emitting diode for its translation into Spanish)

INTRODUCTION

Technology is one of the main elements that help innovation in processes and, together with it, new paradigms arise that have to be corrected or perfected. Progress in this century has been accelerated, which makes obsolescence an issue to be taken into account, not only in industrial development but also in intellectuality.

Forensic science has not escaped the technological revolution, triggering innovations and developments to streamline work, doing things that were previously impossible. Processes have been improved, resulting in new ways of thinking about forensic examination.

Nowadays, toolmark comparisons are carried out with microscopic equipment, most of which is digital and linked to software with various functions that aid in the demonstration of what is being compared. The equipment used in forensic laboratories is mostly fixed and expensive, and the programs that are attached to it are specific to the equipment and do not allow it to work on other equipment. The equipment used for comparison is useful, since the main need is that the elements to be compared can be observed in real time, that the comfort or ergonomics allow for its comfortable use, as well as the characteristics that allow, in the same equipment, the use of contrast ranges that facilitate the visualisation of elements necessary for identification or discarding (marks).

Knowledge, in conjunction with equipment that was once very large and unaffordable, has now moved towards options that are cheaper and almost as reliable as the high-cost ones.

Information on equipment and technological strategies in the forensic field is crucial to optimise the work of experts, which is why the use of expert witness software (Teex$^{MR)}$ supports training on the subject of matching, but can also be a useful tool for forensic professional development and is intended to be represented in this research.

Sometimes, in forensic science, you have to use your ingenuity to achieve what you want, this is based on trial and error, and to become familiar with multiple tools and applications that were not necessarily created for the area, but that can be techniques that greatly support the process of examination and obtaining results.

Therefore, the objective of this research is the comparison and usefulness of the Teex^{MR}program for the comparison of tool marks, specifically of ballistic elements, in order to be useful for an investigation and expert opinion.

2. RATIONALE AND ARGUMENTATION

Science, as a process of understanding and developing thought, needs to be open to society as a whole. However, this knowledge is often restricted by economic interests. Justice as a science that is supported by other sciences has tried to achieve fairness in the game of scientific development, but this has not been enough to reach everyone and everything.

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In the criminal field, sciences such as forensic science are regularly used to assist in the field of evidence, because it has been thought that the best evidence is that which is rigorous in its thinking, and if this is subordinated to sciences of the natural and exact branch, even more so. This is partly a fallacy, and yet it is given inordinate confidence. On the contrary, one of the best justifications for thinking is that which is referred to as scientific.

With regard to forensic science in Mexico, one can start with official laboratories, understood as those that are regulated by the government. In the Mexican Republic, "at the end of 2022, 32 coordinations were reported in the Attorney General's Office (FGR) and 397 units of forensic services and/or forensic medical service in the states" (INEGI, 2023, p.12).

In 2022, the total number of staff in the coordinations and units of the forensic and/or medical forensic services was 13,827. By area, 12.6% (1,737) belonged to the FGR, while 87.4% (12,090) to the state units. Compared to 2021, the number of FGR staff decreased by 5.8%, while it increased by 1.4% in state units (INEGI, 2023, p.17).

During 2022, the FGR received 325,196 requests for expert intervention, all of which were admitted; this figure represented an increase of 17.6% compared to 2021. The state units received 4,505,448 requests, of which 99.97% were admitted and 0.03% rejected; the number of requests received decreased by 1.7% compared to 2021 (INEGI, 2023, p.25).

If we make an imaginary exercise, an average of 188 requests per expert per year would be dealt with at the federal level (FGR), which represents almost one request every two days. For the state level, that would be 373 requests per year, a little more than one per day.

This is without taking into account holiday time, holidays, the working week and disregarding the load by subject matter and by state, speculating that all the personnel contemplated perform expert work. Nevertheless, it serves as an insight into the official expert environment in the Mexican Republic. It demonstrates, at first glance, a lack of human resources. It should be taken into consideration that forensic activity is not similar to an industrial production process, because the examinations depend on many variables to ensure response times, such as the condition of the evidence, the amount of evidence to be examined, the processing time of the evidence, the response time of the equipment, among other things. This involves a large number of experts in various forensic areas.

On the other hand, this is not the case in the area of official or private defence. Although there are already organisations with forensic experts, they do not have the same training or the same financial resources as the organisations dedicated to the judicial investigation. However, the Political Constitution of the United Mexican States (CPEUM) establishes in Article 17 the following:

> The Federation and the federative entities shall guarantee the existence of a quality public defence service for the population and shall ensure the conditions for a professional career service for public defenders. **The salaries of public**

> **defenders shall not be lower than those of public prosecutors** (CPEUM, 2024, Art.17, Para. 8).

While it is true that there are already public entities for the defence and some of them are staffed with experts in different areas and/or forensic disciplines, it is also true that in many cases they do not receive the same emoluments as public prosecutors or official experts. This is noteworthy, all the more so because it is a guarantee established in the constitution and not just an isolated precept.

It is also noted in Article 20 of the CPEUM that: "V. The burden of proof to demonstrate guilt corresponds to the accusing party, as established by the criminal definition. The parties shall have procedural equality to sustain the accusation or the defence, respectively;" (CPEUM, 2024, Art.20 This implies equality of circumstances in the nature of evidence, including expert evidence, which is not balanced, either because of the tools or the access that some places have to the evidence, as it is often not allowed to be taken to a special laboratory for analysis, and is delivered to the offices of the prosecutor's office, which is an inequity in the development of this type of evidence.

At the same time, the CPEUM establishes the following:

> Eighth. The Congress of the Union, the state legislatures and the legislative body of the Federal District shall allocate the necessary resources for the reform of the criminal justice system. The budget allocations shall be indicated in the budget immediately following the entry into force of this decree and in subsequent budgets. This budget should be earmarked for the design of legal reforms, organisational changes, construction and operation of infrastructure, and the necessary training for judges, prosecutors, police, defenders, experts and lawyers (CPEUM, 2024, Art. Eighth transitory article of the 2008 reform).

This is still not what was established, despite the fact that it is a 2008 provision, not only in terms of the expert areas of the public defenders' offices, but also because there is still a budgetary problem and therefore a problem of equipment and training in the expert institutions of the prosecutors' offices and judicial powers in various states of the Mexican Republic.

There is currently no comparison study between the Teex^{MR}programme and programmes coupled to ballistics comparison microscopes, perhaps because the programme was created as a tool for students, but not as a professional comparison tool associated with the work of an expert. It is worth mentioning that, when asking official experts from laboratories in Mexico and Spain, there was no knowledge of this programme and even less of its scope (Juanamaria66, 2020).

3. THE STUDY PROCESS IN FORENSIC SCIENCES

García, Z. and Luises E. (2022), define opinion as: "the issuance of an opinion on a specific problem that has been raised by an expert person, reaching specific points based on the investigations carried out, procedures and technical-scientific foundations" (United States Department of Justice et al., p.216).

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In Mexico, there is a division between what should be understood as an opinion, a report and an expert report, as these three concepts differ not only semantically but also in practice.

In this sense, Romero, Ana (2022) defines report as, "that which results from an intervention that for some reason could not be carried out" (Department of Justice of the United States of America et al., p.277).

It can be understood that an expert opinion is an activity that, after being carried out, requires an opinion or possible hypothesis, while an expert report is one that, after the activity has been carried out and following the ideal process for the case in question, it is not possible to issue an opinion or hypothesis due to some external circumstance, as would be the case in a lofoscopic comparison, due to the lack of ridges to issue a conclusion of identification with any person contained in the database. And a report is simply understood as a report when the request is received, but the activity cannot be carried out, either due to errors in the request, lack of evidence for study, or because it is not within the scope of the laboratory, among other circumstances.

It is also possible to distinguish between two expert or expert processes, one that has the purpose of issuing hypotheses regarding very precise questions and the other that is aimed at distinguishing or identifying.

Cross-checking is one of the key processes to arrive at an identification or elimination, which consists of comparing one by one (side by side) two or more pieces of evidence, which leads to distinctive results that in turn trigger a conclusion supported by the process, the technique, the method and the results.

This type of activity is commonly observed in forensic disciplines such as ballistics, lofoscopy, document microscopy, graphoscopy, tool marks, among others.

The conclusions that can be reached after matching could be: identification, elimination, inconclusive and unfit for study. These variables may be more or called differently, but their essence is the same.

4. COLLATION TECHNIQUES

Optics has been an invaluable resource for investigation, and has been no exception in the forensic sciences, which, today, such a technique is used in almost all processes and in most of the equipment used in the laboratory. Photography is one such technique that uses optics to obtain reliable images of what is observed.

One of the techniques that assists in comparison is therefore optics, coupled with digital imaging. This technique helps to see smaller objects that cannot be seen with the naked eye. Caution should be exercised, as it is often believed that the image from a device such as a mobile phone is not sufficient to obtain a good resolution and is therefore not good for matching. It is not totally useless, as technological advances have helped to make smaller objects have good characteristics. It should be noted that the ideal for forensic photography, in terms of pixels, is the use of cameras with a resolution above 5 megapixels. Many modern cameras, even in mobile phones, have a higher resolution than this, but this should not be confused, because although it is important, sharpness and colour are also important. So the sensor is the key to having these two good quality features.

Another important ingredient is the optics, so a close-up (zoom) lens is better than a digital (zoom) lens. Transposition can be a good tool when taking photographs for collating purposes, meaning the use of tools used interposed between the camera or lens, which can be a good remedy to achieve better close-ups, such as the use of a magnifying glass.

For photography, either manually or by means of a microscope, at least five photographs per section are recommended. That is, take one photograph with direct light, and four with grazing light, illuminating from the four zones, top, bottom, left and right. It will depend very much on the study, as more photographs can be taken according to the circumstances. For example, in graphoscopy it is recommended to take a photograph with backlighting (light placed on the opposite side of the surface where the graph lies). Various light sources are also recommended, such as white or cold light, yellow or warm light, ultraviolet light, infrared light, among others. First of all, the study must take into account the principle of exchange established by Edmond Locard (Mummery, 2021, p. 512), consequent to this principle, the principle of correspondence of characteristics must be considered, in which the comparison of objects in similar circumstances must be considered, that is to say, if white or cold lighting is used, both indications and/or evidence must be under the same circumstances.

White LED light is a good option, not only for the matching of evidence, but also for eye care, as it is comfortable and gentle on the eyes. "Cold artificial light is the best alternative to natural light, because it is the closest to it. It is less tiring for the eyes" (Optica & Hispania, 2024, para.18).

Other advantages of LED light are:

> They are much more energy efficient, which results in lower energy consumption. In addition, they are characterised by a much longer lifetime than light bulbs. Finally, LEDs emit virtually no heat and this is much more practical both for working comfortably with the microscope and for keeping the sample in good condition (Microscope World, 2024, para.20).

In forensic ballistics or the study of firearms and tool marks, tools such as a magnifying glass, stereoscope and comparison microscope are used for comparison. These tools are used according to the stage of study, being recommended first to observe the object with the naked eye under different angles of light, then under a magnifying glass, and then using a stereoscope to locate smaller and more specific marks, in order to classify the evidence in some group (these steps can also be applied for some other discipline that performs matching), then mounted on the comparison microscope, to perform the matching one by one, that is, side by side, with similar lighting conditions and with the same magnification.

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5. THEORIES FOR MATCHING BALLISTIC ELEMENTS

For the matching of ballistic elements, there are several techniques such as those mentioned above, but they are also accompanied by methodologies, composed of continuous studies that have shown effectiveness in the field of tool marks.

These include AFTE and CMS theory.

Jack Dillon (2008), regarding the history of CMS, points out that:

> CMS was initially proposed in 1959 by Al Biasotti, focused on the need to establish specific criteria for the identification of tool impressions, focusing on the idea that an identification is made on the basis of individual characteristics based on an objective perspective. This theory is based on a study carried out with samples being an analysis of 720 known, non-concordant comparisons of field and groove impressions, and failed to find cases where the CMS exceeded four continuous lines in the matches. In 1997, Biasotti and John Murdock jointly published their paper entitled "Conservative Quantitative Criteria for Identification", using the CMS criteria (Dillon, p.375).

To better understand this theory, it must first be known that there are two-dimensional and three-dimensional markings in the markings to be analysed on ballistic elements.

Two-dimensional markings. These marks are those that are also known as compression marks or stamped marks, produced when a tool applies sufficient force to any object, leaving an impression, which varies by its contour, depth, dimension, etc.

Three-dimensional marks. These marks are also known as friction marks, drag marks, abrasion marks, grooves or scratches, and are produced when a tool is dragged with a certain force over an object to generate grooves or linear marks, these marks or under reliefs have diversity in their contour and depth, sometimes producing micro-scratches within their contour.

The identification of tool marks, normally make a distinction of levels, in the case of tool marks, these levels are classified in three, and are indispensable for the identification of the marks, these are:

Class features, which are those in which marks characteristic of a specific type of mark are observed, which may include a group of tools and exclude others, but only in a general way.

Subclass features, these marks are more specific than class marks, but are not individual, as they may distinguish between a small group of tool types, but in a general way; care must be taken, as these marks may only be due to a specific group of tools, but not to a particular one.

Individual characteristics are the smallest marks that serve to rule out a large group of marks and make them specific to a particular tool.

Finally, this theory states that for three-dimensional marks, one group of five consecutive matching lines or two groups of three consecutive matching lines should be found in each mark, and for two-dimensional marks, one group of eight consecutive matching lines or two groups of five consecutive matching lines (Dillon, 2008). This applies only to comparison of individual features, so attention must be paid to these features.

The Association of Firearms and Toolmarks Examiners (AFTE) theory states that the distinction of these characteristics should be specific and discernible in appearance (discernible and concordant), without giving rise to a quantitative sense of these, as stated in the CMS theory.

Non-consecutive (two-dimensional) individual shapes or features are also subject to comparison, but they must have the same shape and arrangement in location, and if possible the size of the mark must also be taken into account.

Currently there are new techniques that help identification by means of photogrammetry, or images with low and high relief, in some cases combined with programmes or platforms that help in the observation of the marks, although the techniques vary, the principles of identification remain the same. Based mainly on markings ranging from the general (class markings) to the specific (individual markings), thus allowing the exclusion of candidates for identification.

6. THE MATCHING OF BALLISTIC ELEMENTS USING DIFFERENT EQUIPMENT AND PROGRAMMES

Microscopy is one of the devices that have made use of optics and photography, nowadays, it is the best device that has been demonstrated for matching, however, in the past, ingenious devices were used such as the case of the system or photo-comparator Belaunde (Gamarra, G. Skopein, p. 43), alluded to the researcher Ernesto Manuel Belaunde, which took a series of photographs of a bullet, and then matched them and used them to make comparisons by superimpositions or by side-by-side comparison in a more comfortable way, as the images were more extensive.

Philipp O. Gravelle, an expert in microphotography, came up with the idea of inventing the ballistic comparison microscope, joining two microscopes by means of an optical device (Jiménez, J. 2011, para. 8).

Nowadays, all equipment comes with various programmes associated with it, which, depending on their functions, allow different actions to be carried out, such as superimposing images, scanning them, changing colours, among other functions.

There are various programs such as Photoshop® or similar, which help to improve images, but can also be used for forensic comparison, which allows tools that facilitate the visualisation of small details and at the same time, a graphic form for exemplification before a court (Solana E, 2020).

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But there are also programs that facilitate the work of comparison with less budget, which is not always contrasted in price or accessibility with its reliability, one of these programs with functions designed for the forensic area is the expert witness name or Teex ^{MR}.

There are also cameras and microscopes coupled to specific programmes and functions depending on the application, for example, for lophoscopic fingerprints, there is equipment for their improvement and the acquisition of direct images of objects, i.e. the work of transplanting the fingerprint is done by photographic means. As for graphoscopy, there are functions to see the traces in the third dimension, this function is useful for cases of ink cross-linking. As well as these, there are different functions, according to how you want and what you want to check.

7. STUDY METHODOLOGY

Systematic comparisons were developed with the microscopic comparison programs for ballistic elements, with main interest in the programs of equipment usually used for comparison, such as the Leica, Leeds, Vision X^{MR}and the proposed program for analysis with respect to its functionality Teex^{MR}.

Two different samples of 9x19 mm and 38" special calibre cartridge cases were examined, due to the fact that at the time of the study these were the most common calibres used for comparison in the laboratory where the study was conducted, as well as due to the type of weapon (pistol and revolver). The matches were carried out on samples of witness cartridge cases (cartridge cases obtained from a known weapon), and the studies were repeated on the microscopes and their platforms. Microphotographs were taken with the camera attached to the VixionX^{MR}microscope, as well as with a Canon EOS Rebel T7i camera, using a zoom lens with a focal length of 18-55 mm (this is the one commonly used, as the camera is normally sold with this lens).

The samples were placed on each stage side by side of the microscopes under study, image viewing tests were carried out with the tools that each microscope had in its factory program, as well as the Teex^{MR}program, such as the lights, tonalities, the placement of the division between the samples, the functions of pointers and text. The platforms were also matched with a pair of each of the shells (9x19 mm and .38" special), using the tools of each platform, checking the functions: Side-to-side and top-to-bottom, overlapping, highlights, colour ranges, contrasts, close-ups and special image markers.

Mainly attention was paid to the functions of zoom, overlay and side-by-side view of the sample, with the aim of checking this function, which is considered to be the main one when making a collation.

Screenshots of the casing matches were taken in order to exemplify the comparison of casings in the study.

The following steps were followed:

1. Selection of 9mm and 38 SPL calibre centre fire casings.

2. Cleaning of cartridge cases

3. Choice of three most commonly used systems with different light sources, tungsten light (Leica$^{MR)}$, fluorescent light (Leeds^{MR}) and led light (Vision X^{MR}).

4. Loading of photographs obtained from the microscopes and loaded into the Teex^{MR}program.

5. Comparison of basic functions in each programme, the main ones being:

   - Zoom in
   - Image dividers for collating
   - Image overlay
   - Pointer and text functions
   - Contrast range functions

6. Comparison of the results obtained in each programme.

A study was not carried out on the resolution of the image, but only on the improvement of the image with the programmes and the functionalities of each programme, making a comparison between all of them, to find out what each one includes and how easy it is to use.

8. COMPARISON OF THE COMPARISON OF BALLISTIC ELEMENTS USING DIFFERENT PROGRAMMES

The study was done under the assumption of the Teex^{MR}comparison program and its functions, having three references of professional laboratory microscopes and their coupled professional microscopy programs, such as the Leica^{MR}, the LEEDS^{MR}and the Vision X^{MR,}the latter from the company Forensic Technology^{MR}, all of these in contrast with the Teex^{MR}comparison program. Samples of standard casings were taken into account, and the optics were not directly evaluated, but the platform as a whole, because the optics depend directly on the capture tool and not on the programme that generates the visualisation and comparison processes.

In the following, the different functions on the main collation screen of the software coupled to the Leeds^{MR}, Vision X^{MR}and Leica^{MR}microscopes are shown, in that order.

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Figure 1

Comparison photograph of the Leeds^{MR}microscope system bushing assortment showing the general functions at the top and right-hand side.

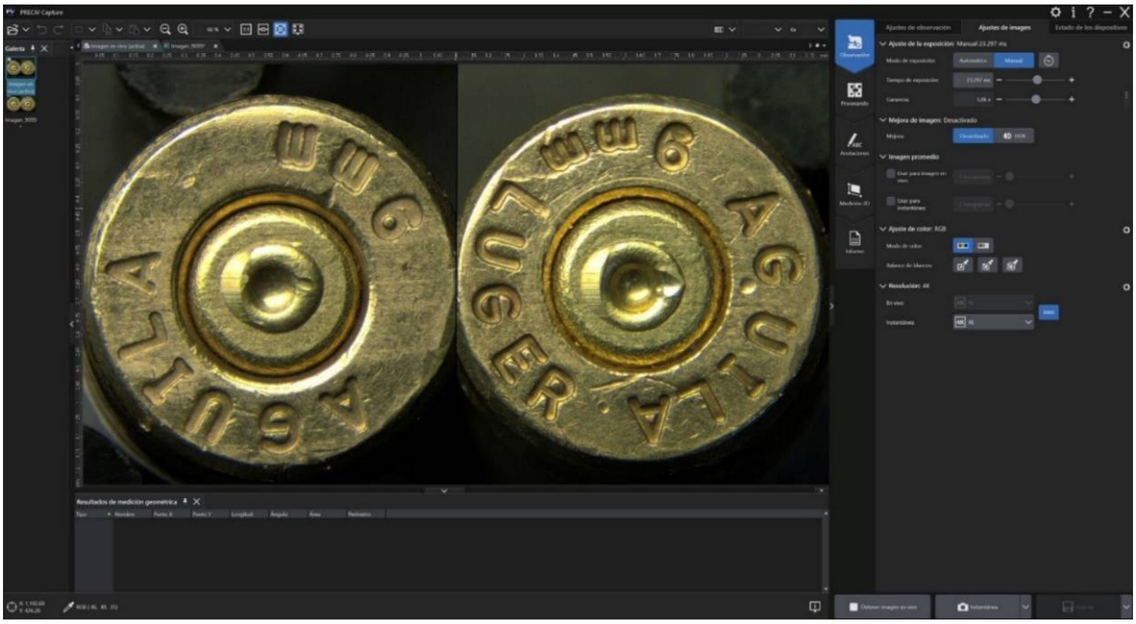


Figure 2

Photograph of a comparison of the bushing comparison of the Vision X^{MR}microscope system showing the general functions at the top and on the right-hand side.

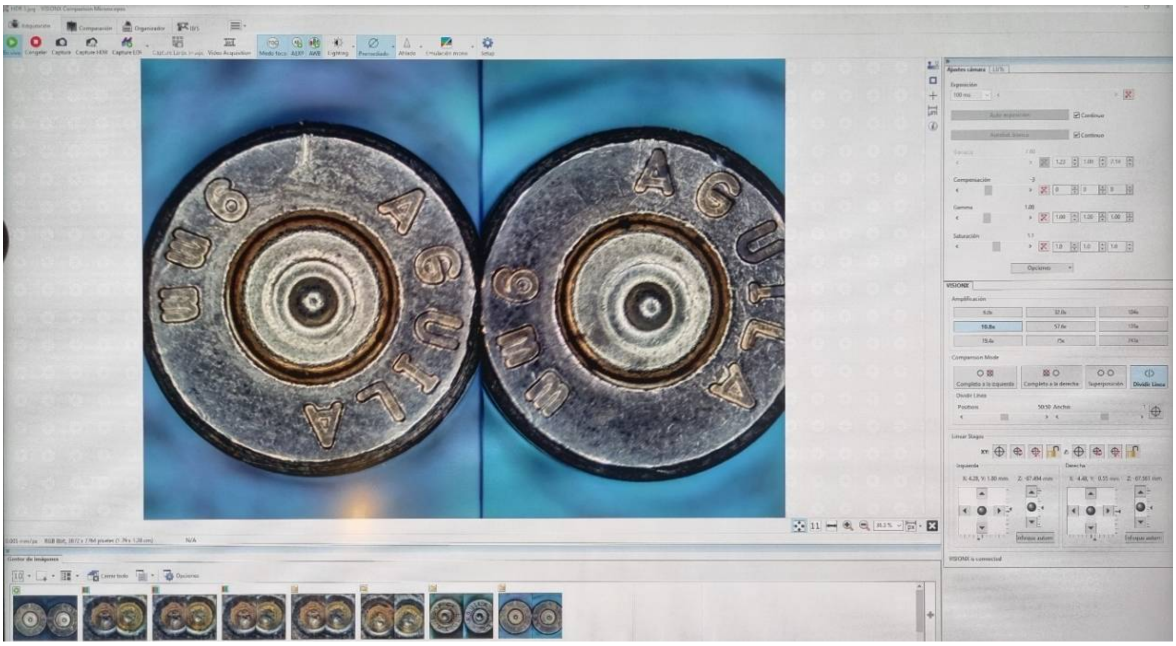
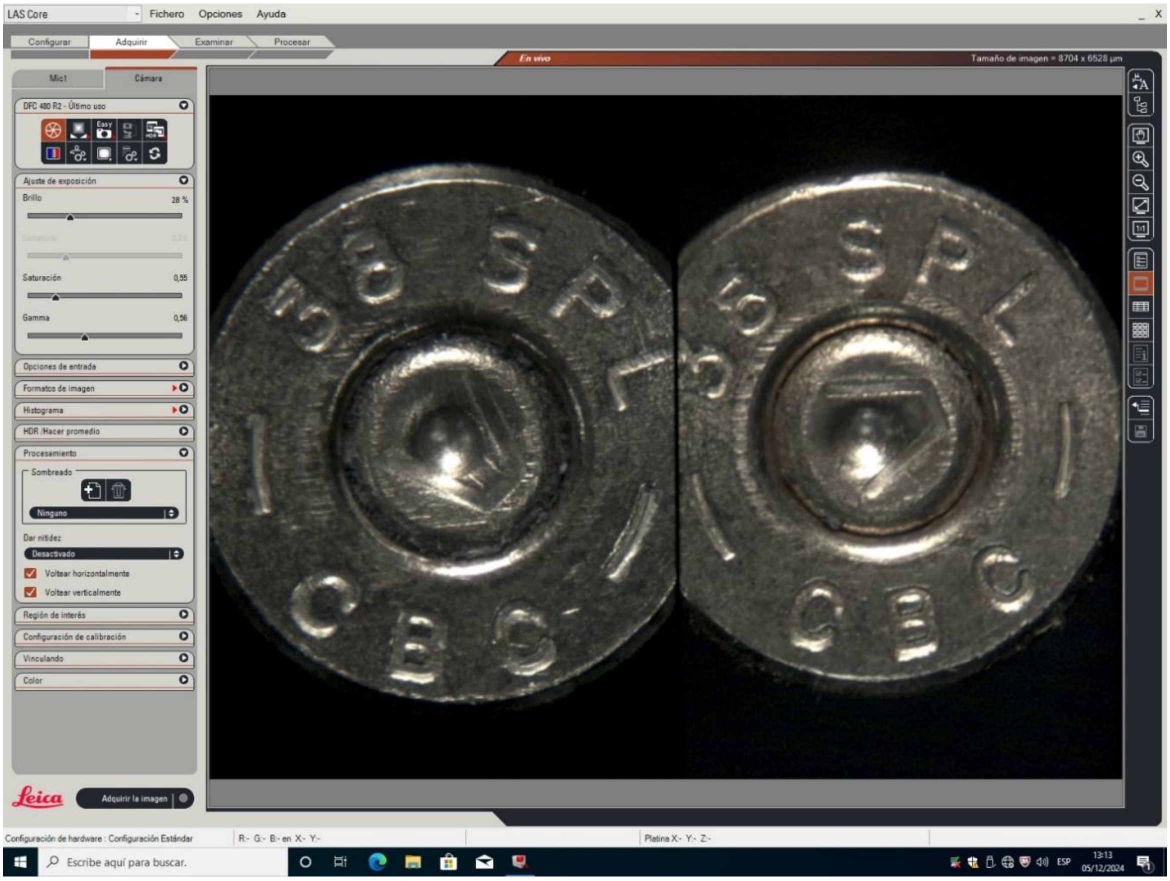


Figure 3

Comparison photograph of the Leica^MR microscope system's cap assortment, showing its general functions on the top tabs and on the right and left side of the screen.



It should be noted that the Teex^MR expert witness application is a resource to assist in the collation, but it is not a microscope platform, so it is necessary to have microscopes or simply cameras to capture evidence. The interesting thing is that the cameras or microscopes can be mounted to a computer with the software, which allows you to see in real time what is being recorded on the attached devices. As far as resolution is concerned, this will depend largely on the peripheral devices that are attached. The design of the platform is intended for the collation of various pieces of evidence, not only for ballistic elements. Figure 4 shows a computer with two microscopes attached.

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Picture 4

Teex^MR program with hand-held microscopes attached on each side

Note: Image provided by forensic ballistics supplier and author Cibrián, O. 2024, [11].

If it is not possible to attach a device, there is also the option of loading previously captured images from a file, which allows for practicality in handling the images when it is not in real time.

The company Arfus^MR, supplier of this system, describes it as a:

> Digital comparator oriented to develop skills in comparison techniques in students and future professionals of criminalistics, criminology and forensic sciences, such as the identification of firearms and tool marks, as well as other subjects related to specialised knowledge that provide informed opinions to the courts of justice on litigious points that are the subject of expert opinions (Delgadillo, 2020).

Although it is a programme or application mainly oriented to education, it is also really practical in the professional field, especially for those cases where there is no comparator equipment or where it is not possible to move the evidence to the place where the special equipment could be available.

The uses depend mainly on the user, but everything that requires a comparison can be used through this platform, for example, the comparison of documents, handwriting, fingerprints, tool marks, injuries, among others.

The minimum specifications to run this system are, a PC, Mobile, Surface hub, HoloLens, Windows 10 or later device, minimum memory of 2 Gb and 4Gb as a recommendation, a camera attached and recommended video memory of 1 Gb (Delgadillo, 2020). Image 5 shows a side-by-side comparison of two shells and various functions of the programme on the left side.

Figure 5

Ecosystem of the Teex^MR programme in a comparison of two shells, where its functions can be seen on the left side and bottom.

Note: Image provided by forensic ballistics supplier and author Cibrián, O. 2024 [15].

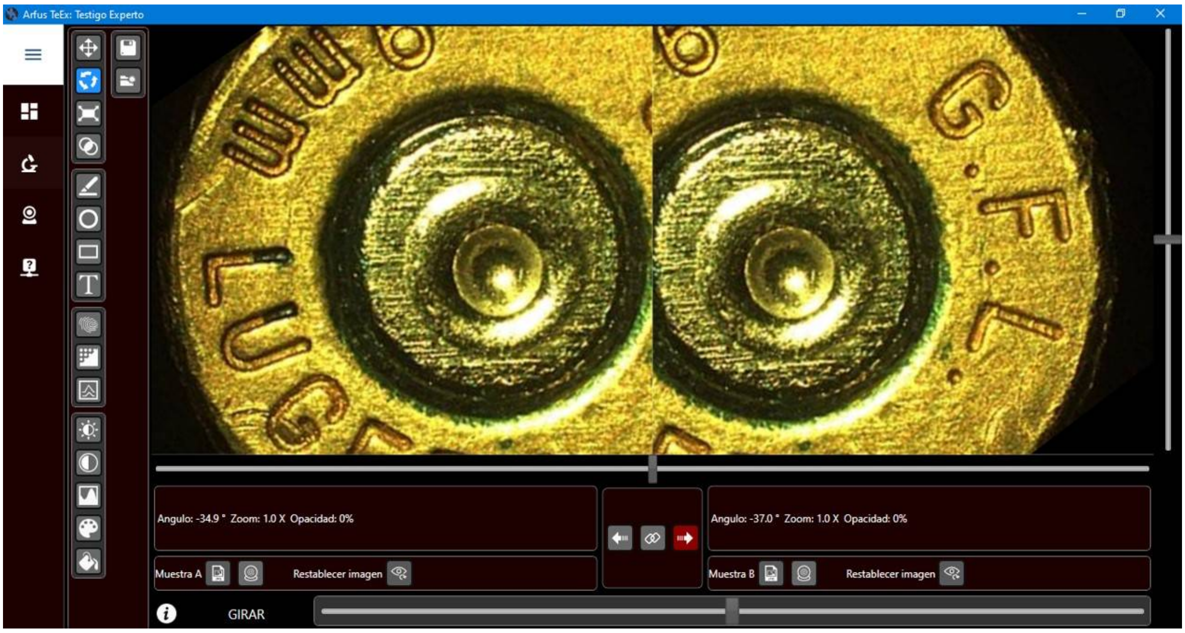
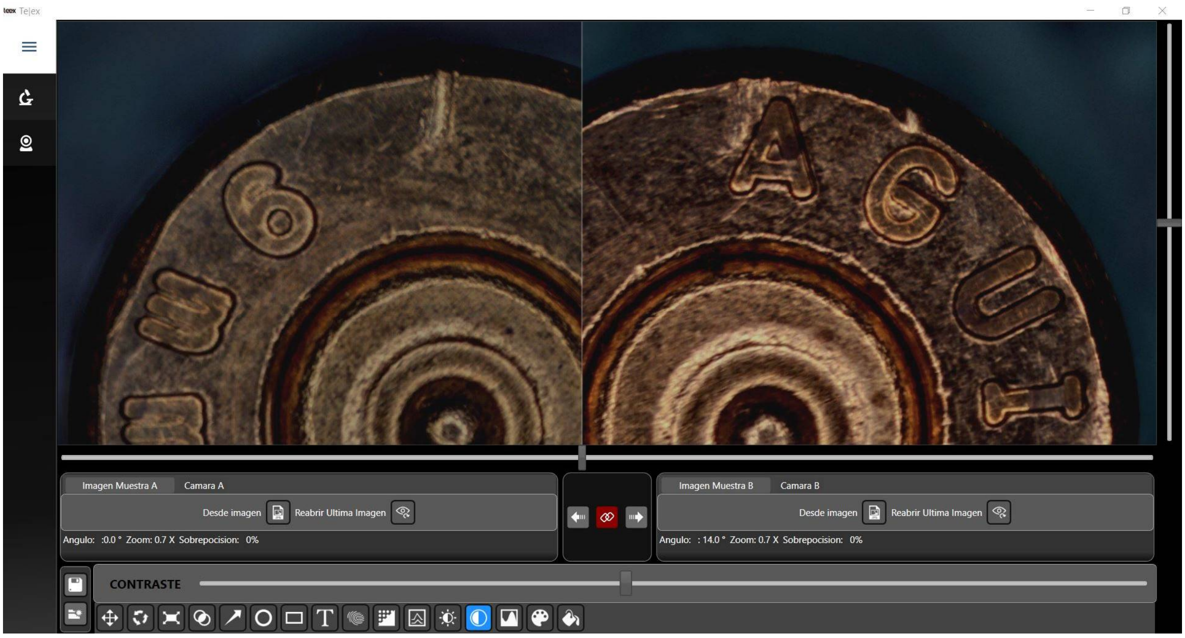


Figure 6

Comparison of extractor marks on the upper margin of two casings with Teex^MR software.



Note: Image taken directly from the program with a comparison with photographs taken by microscopy.

After testing the visual environment of various professional equipment and the Teex^MR program, a general comparison of the qualities of the programs of each microscope and the Teex^MR program was made, which can be seen summarised in Table 1, where the main functionalities of each system and their main characteristics are shown,

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with the main purpose of outlining the functionality of the Teex^{MR}system with respect to those of professional microscopes.

Table 1

Comparison of the features of the software for collation of various brands of microscopes and the TeeX^{MR}software

CHARACTERISTICS ASSOCIATED WITH THE SOFTWARE	**NAME OF EQUIPMENT AND/OR SOFTWARE**			
	VISION X^{MR}	LEICA FS C^{MR}	LEEDS LCF3^{MR}	TeeX^{MR}
Image	Vertically and laterally correct	Vertical and laterally correct	Vertical and laterally correct	Vertical and laterally correct
Comparison	side to side, left or right side complete, overlapping	side to side, left or right side complete, overlapping	side to side, left or right side complete, overlapping	side to side, left or right side complete, overlapping
Split line	Full motorised and memorised position and width settings in the controller	Manual configuration for position and width	Manual setting for position and width	Digital with manual setting for position and width
Live image from digital cameras*.	HDMI camera with image. memory on SD card, 1920x1080 pixel resolution, including basic Software functions	Various digital live cameras available	Various digital live cameras available	Depends on the attachment of photographic equipment, which can be attached to the system.
Program functions	VisionX SW includes its camera control, image capture, image annotation, image analysis, image archiving, measuring and comparison capabilities. Remote control function	LAS software package, controls the camera, captures and manages images, and supports measurements	LAS software package, controls the camera, captures and manages images and supports measurements.	

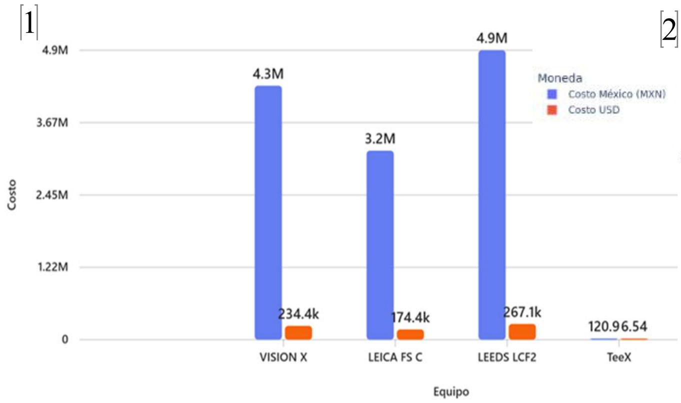
Note . The table represents the features of the software and only some of the hardware. Information extracted from the VISION X^{MR}, LEICA FS C^{MR}and LEEDS LCF3^{MR}devices *were extracted from the Projectina^{MR}comparative catalogue (*Visionx & Comac, 2017).

Figures 1 and 2

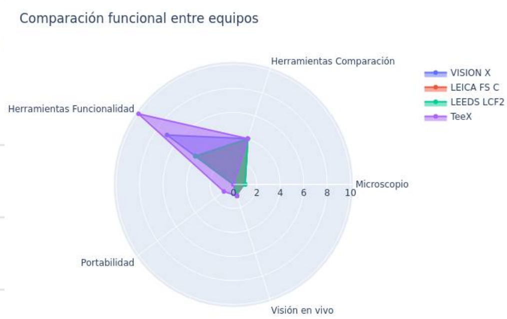
Comparison of the advantages and disadvantages of the comparison hardware and software of various brands of microscopes and TeeX^{MR}software.

Note: The prices are estimates obtained from the suppliers in the year 2025, the only one with

[1]



[2]



portability is the TeeX^{MR}programme as shown in graph 2.

9. DISCUSSION

The resolution of the images will depend on the camera with which they are taken. The purpose of this study, as mentioned, was never to compare the sharpness of the image but the efficiency of the services offered in their system or platform. The functions with which the vision X, Leica^{MR}and Leeds^{MR}devices are presented contain functions that aid in matching, coupled with their multiple lenses and the efficiency of their platform. However, the functions of matching, one-to-one comparison in real time, superimposition, rotation, change of illumination and contrast, are functions that are also available in the Teex^{MR}programme, so in this sense, it meets the conditions of any of the platforms examined.

The analysis shows that technology has substantially transformed the processes in forensic sciences, offering more accessible tools that reduce the gap between laboratories with limited resources and those with high-end equipment. The Teex^{MR}software, although initially conceived for educational purposes, proved to be a functional alternative for ballistic evidence matching, replicating the main features of professional systems such as side-by-side comparison, overlay and contrast adjustment. While it does not replace the optical precision of specialised microscopes, its low cost and ease of use make it a viable option for academic training and for scenarios where access to advanced equipment is limited.

This finding reinforces the importance of technological innovation aimed at the democratisation of knowledge and forensic practice, without losing sight of the fact that professional expertise and methodological rigour remain essential elements to ensure the validity of the results.

Integration with artificial intelligence: Explore the incorporation of AI algorithms for the automatic detection of individual characteristics in ballistic marks, optimising the matching process and reducing analysis time. 2. Evidence in judicial environments: Analyse the feasibility of using Teex^{MR}in hearings and courts, evaluating its acceptance

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as an auxiliary tool in the presentation of expert evidence. 3. Expansion to other forensic disciplines: Investigate the application of the programme in areas such as document microscopy, lophoscopy and injury analysis, to determine its versatility in different forensic scenarios. 4. Economic and social impact study: Measure the impact that the adoption of accessible tools such as Teex^{MR}would have on laboratories with limited resources, considering the reduction of costs and the democratisation of technological access. 5. Development of validation standards: Propose protocols and regulations that guarantee the reliability of the results obtained with digital platforms, aligned with international standards in forensic sciences.

10. CONCLUSION

The use of technology has evolved rapidly since the year 2000, allowing sciences, arts, disciplines, professions and others to benefit from new techniques. The forensic area has become more technical, improving studies and making them more efficient. Advances in microscopy combined with computer technology mean that things that were not possible before are no longer possible.

Although it is true that technology has helped forensic sciences, it is also true that many of the advances have not been in the hands of everyone, there are laboratories with technology that is still old, but not for that reason not functional, but which do not help with the efficiency of the processes. Given the above, alternatives have been implemented to make these benefits more and more accessible.

In this research, it was possible to show the use of accessible technology for collation, in contrast to the technology currently used by some official laboratories. This programme (Teex^{MR}) allows the user to make a comparison either directly with the evidence or indirectly with the photographs provided of the evidence. Although this program is designed for education and the most realistic approach to teaching the comparison of evidence such as shell casings, bullets, fingerprints, documents, among others, it can be concluded that it is also practical and useful for the established laboratory. Not only does it allow for real-time comparison, but it can also be used anywhere, even in a court of law.

It should not be forgotten that science has always tended towards communication and accessibility of its knowledge and more and more, this idea can be achieved with the help of technological advances, which allow the accessibility of tools that were previously impossible to have.

It is worth mentioning that the use of a piece of equipment or software does not in itself provide the knowledge and experience, so it must always be combined with knowledge of the subject matter and internationally accepted methodologies, the latter of which can be found in the publications of various organisations dedicated to forensic specialities on an international level, which publish advances and standards for the study of specific cases in each science or discipline. The theories expressed in this research are an example of standards for firearms and toolmarks.

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