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Research trends in forensic science: A scientometric approach to analyze the content of the INTERPOL reviews

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Abstract

The use of forensic evidence has become indispensable in many countries and jurisdictions around the world; however, the dissemination of research advancements does not necessarily directly or easily reach the forensic science community. Reports from the INTERPOL International Forensic Science Managers Symposium outline major areas that are of interest to forensic practitioners across the INTERPOL member countries. The information contained in the INTERPOL reports is extensive but can be challenging to process. The purpose of this research is to provide a comprehensive overview of the evolution of trends within the INTERPOL reports over an 18 year period. References relating to 10 evidence types retrieved from the 14th to 19th INTERPOL IFSMS reports (2004–2019) were processed and compared with data exports from the citation database Scopus covering the same evidence types. The results from this work are summarized by investigating the relationships between the 10 evidence types. To explore the outputs a user-friendly R-Shiny application was developed and is freely available at: https://uod.ac.uk/lrcfsinterpolreportsexplorer.

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KEYWORDS

bibliometric analysis, database, evidence type, INTERPOL, publication trends

1 | INTRODUCTION

Science is in a perpetual state of flux and to advance in any given field, existing knowledge and techniques must be accessed, identifying gaps which need to be addressed. One of the many ways forensic practitioners can monitor, access, and review the latest scientific developments across a range of different evidence types is via the triennial International Forensic Science Managers Symposium (IFSMS) reports. Facilitated by the International Criminal Police Organization (INTERPOL), the symposium brings together forensic scientists and forensic science managers from organizations across the INTERPOL countries. At IFSMS, reviews of scientific articles are presented which collate peer reviewed publications, conference presentations, and textbooks prepared across the previous 3 years for a variety of evidence types. This literature is evaluated for impact on forensic science, problem areas are discussed, and recommendations for future areas of research are provided. The INTERPOL reviews are undertaken by multiple authors who, after extensively surveying the literature, summarize all the information in individual reviews covering specific evidence types, which are combined into one final report. The most recent edition from 2019 covered 15 major topic areas reviewed by 43 authors ranging between 1 and 11 authors per area or per evidence type (Almirall et al., 2020; Baiker-Sørensen et al., 2020; Bécue et al., 2020; Butler & Willis, 2020; Chan et al., 2020; Charles et al., 2020; N. S. Jones & Comparin, 2020; Klapec et al., 2020; Lepot et al., 2020; Ludik, 2020; Mattijssen, 2020; Stauffer, 2020). The style and format of the individual reviews vary greatly depending on the topic being covered, some being more descriptive than others in their analyses of the cited references. This creates an opportunity to develop a method of processing the information in a systematic manner leading to further insights into how the research base has developed for different types of evidence across a decade and a half.

Monitoring large amounts of data and literature can be problematic for all research domains and one solution is to visualize recent trends and activity using a bibliometric approach. Bibliometrics aids the measurement of research directions and impact by exploring information relating to research relationships such as: who (authors), what (keywords), where (geographical locations), when (years of interest), and with whom (affiliations). It has several sub-fields including scientometrics (the application of bibliometric techniques to scientific literature; Hood & Wilson, 2001). The term was first established in 1971 by Nalimov and Mulcjenko (1971) and has steadily evolved beyond printed peer reviewed journal articles to include conference proceedings, presentations, and online articles (Mingers & Leydesdorff, 2015).

The reviewing of scientific articles as a measure of progress in research is of course not novel but the use of scientometric methods for such assessments in Forensic science has only recently emerged. Early studies were undertaken by Jones, focused on using scientometric indices, such as the journal impact factor, to determine the most highly cited articles, the most productive authors, the author interconnections, and countries of origin (A. W. Jones, 2002, 2003, 2004, 2005a, 2005b, 2005c, 2007).

In the application of such methods to the forensic science literature it was observed that, although forensic scientists generally tend to publish in journals with relatively low impact factors, they must primarily concern themselves with high research quality since the information could be used as supporting evidence in courts (A. W. Jones, 2007). Sauvageau et al. (2009) carried out a bibliometric analysis on (1696) articles published over 25 years (1980–2005) in two North American forensic journals: Journal of Forensic Sciences and the American Journal of Forensic Medicine and Pathology reporting growth in the number of publications, co-authorship, and collaboration. Jeyasekar and Saravanan presented a series of publications using scientometric methods to analyze forensic science research outputs. They established that of 13,626 forensic science documents dating from 1975 to 2011 and available in the citation database Scopus, 30% originated from the United States and were mainly published in Journal of Forensic Sciences, Forensic Science International, and Science and Justice (Jesubright & Saravanan, 2014). A similar approach was focused on Indian forensic science literature (Jeyasekar & Saravanan, 2012, 2014, 2015a, 2015b). More recent scientometric studies in forensic science have researched relationships within and between datasets. For example, Raghunath investigated five topics in forensic science and identified associations between forensic anthropology, genetics, medicine, and toxicology (Raghunath, 2018). An analysis of the literature on gunshot residue was reported by Sobreira et al. which focused on keywords and cross citation in addition to co-authorship and countries of origin to determine research trends and the evolution of the research base (Sobreira et al., 2020). Finally, with the growing user presence on digital platforms, studies summarizing the current research trends in digital forensics have been reported for digital imaging (Baldwin et al., 2018) and cloud forensics (Gokhale et al., 2020).

There are numerous requirements in order to ensure that a scientometric analysis can be effective. Mingers and Leydesdorff discussed some of the points as being: the use of robust and inclusive datasets, unbiased measures, research impact, and comprehensive analysis (Mingers & Leydesdorff, 2015). Even though Mingers and Leydesdorff advocated greater transparency in their work, (e.g., in the way journal impact factors are calculated), the authors did not champion the concept of open data. Searching literature databases to create datasets is straightforward and with sufficient information on how data was obtained, the exported data can be considered robust and reproducible (i.e., the same search parameters would be expected to result in the same output). If some of the information contained in the datasets is non-transparent, it is always reasonable to ask the suitability of such data for interpretation purposes. Transparency in research must also include full information regarding data processing and any manipulation of the original dataset which is undertaken.

A common approach in scientometric studies in forensic science is to use Microsoft Excel or other spreadsheet applications, especially among the non-programming community. Using such an approach can carry a variety of risks including loss of data (this occurred, e.g., with the conversion of gene identifiers to dates [Zeeberg et al., 2004] propagating errors within core databases [Ziemann et al., 2016] forcing a change in how genes are named [Bruford et al., 2020]). Microsoft Excel cannot be automated, making the reprocessing of data a tedious task. In addition, spreadsheets may not allow new datasets with a different number of entries, or if the data sets are too big. Furthermore, data processing in Microsoft Excel is not reproducible; some actions pertaining to data manipulation, for example, click and drag transformations undertaken by the user, are not recorded. A new user may not be able to work out Microsoft Excel templates without knowledge on how they were created. Moreover, further loss of information may occur when saving spreadsheets in alternative formats such as comma-separated values (csv) files. Finally, Excel is proprietary software which may not always be available despite its ubiquity.

The manuscript by Sobreira et al. (2020) on gunshot residue described an approach to investigate trends in a dataset obtained from the citation database Scopus. The analysis was completed using the R statistical programming language and R studio (open source) and the code is available via a permanent DOI (http://doi.org/10.5281/zenodo.3582799) provided in the manuscript (Sobreira et al., 2020). The code was developed as a generic tool which was applied to both the INTERPOL documents as well as to Scopus search results. This created an overview of the generated data which complemented the IFSMS reports, demonstrating how research trends evolved but also potentially exposing research gaps. In addition, with this approach, the strength of relationships between evidence types was demonstrated. Finally, the comparison between the reference lists from the IFSMS reports and similar searches using Scopus highlighted some of the differences in performing literature reviews using keyword searches as well as the importance of using appropriate search terms for any research relevant to forensic practitioners.

2 | METHODOLOGY

The list of records was compiled using the references listed in the six most recent INTERPOL reports: 14th (2004) to 19th (2019) IFSMS reports (previously International Forensic Science Symposium [IFSS] up until 2010), complemented by information available in the citation database Scopus. For scientometric analysis to be meaningful, the data needs to be both comprehensive and accurate (Mingers & Leydesdorff, 2015). Each reference in the INTERPOL reports was therefore systematically searched for in Scopus and the exported references were combined into one table of data per evidence type. References not available in Scopus were manually entered using the information provided in the reports. Missing details (e.g., affiliations, keywords, document type, etc.) were added to make the datasets as comprehensive as possible. Each evidence type was assigned to an individual researcher to compile the data, which were shared within the group as part of a reviewing and cross-validation process.

Scopus was separately queried to generate lists of references associated with each evidence type using specific search terms. The obtained lists were compared with the ones created from the IFSMS review, aiming to examine relationships between the different reference lists as a cross check. The exported list of records was directly processed in R, adapting a previously published methodology (Sobreira et al., 2020). Reference entries such as keywords and document titles were checked for spelling mistakes and corrected to be more consistent within and across all the lists. All the corrections were carried out in R.

Each dataset corresponding to each evidence type generated figures for country contributions, author networks and keyword trends as well as various output tables (e.g., publication year-by-year change, most cited documents, etc.). Only a few of these results are included in this article but all the individual outputs are available with the R-code, which can be viewed at http://doi.org/10.5281/zenodo.4610544 (Ménard et al., 2021). As an alternative, a simplified version of the code is also available on Binder. Binder is a code depository designed to run the code for a user. No software installation is required, however only specific examples are included because of the limitations of the system. Finally, some of the results are also available on an interactive web application, using the R package Shiny (https://uod.ac.uk/lrcfsinterpolreportsexplorer). This application allows users to perform simple queries of the analyses presented and data export based on keyword search on the references available in the IFSMS reports is facilitated.

3 | RESULTS AND DISCUSSION

3.1 | Overview of data

Across the 6 IFSMS reports, a total of 24 evidence types were presented, with some regularly appearing, listing over 27,000 references (Figure 1). Change in the content of the reports can be seen as a reflection of the scientific interest at the time; in research activities and casework, but also because the writing of the reports relies on the voluntary participation of institutions and practitioners. Some of the evidence types were merged together in later years and some were separated as the research in specific sub areas developed. Some research reviews were specifically focused as part of thematic sessions and were only presented across a number of reports rather than all reports, and this is reflected in Figure 1.

Scientometric analysis can be conducted over any defined period, but to establish relationships between the different evidence types, similar year ranges are required. Ten evidence types were processed in this work, either forming a group on their own or split into specific areas creating a total of 13 reference lists: forensic geoscience, toolmarks, paint and glass, fire investigation, explosives (analysis), explosives (scene investigation), toxicology

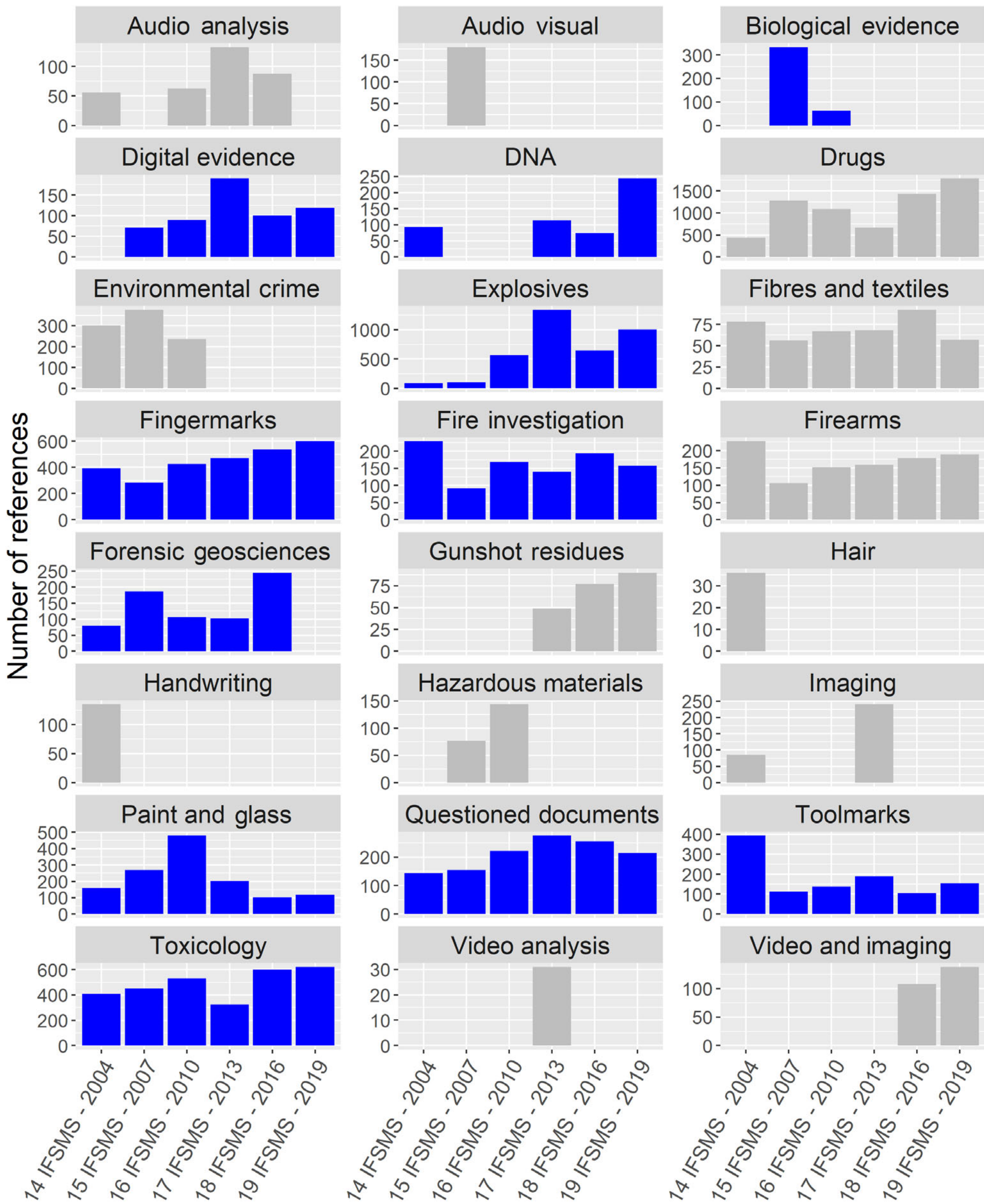

FIGURE 1 Evidence types and the number of references that were listed in the individual evidence reviews as presented in the IFSMS reports (2004–2019). The evidence types analyzed in this work are in blue

(challenge-advances), toxicology (surveillance), digital evidence, fingermark (composition), fingermark (detection), questioned documents, and biological evidence combined with DNA. Where relevant, the subcategories within explosives, fingermarks, and toxicology were merged together to form three categories.

3.2 | Cross-reference between evidence types

Across all 18,254 references (17,979 with a document title) available in the datasets created from the IFSMS reports, 2678 (14.9%) titles were shared across 2 or more of the 13 reference lists, and 341 references were shared across all 10 evidence types. Table 1 reveals common references listed in the reviews across the various forensic evidence types. Not surprisingly, the National Academy of Sciences "Strengthening Forensic Science in the United States: A Path Forward" (National Research Council, 2009). *Strengthening Forensic Science in the United States: A Path Forward*) was most frequently referenced. Other frequently listed references included "Quantitative Scanning Probe Microscopy for Nanomechanical Forensics" by DelRio and Cook, and reviews by Brettell and several authors over the years; 2001 (Brettell et al., 2001), 2003 (Brettell et al., 2003), 2005 (Brettell et al., 2005), 2007 (Brettell et al., 2007), 2009 (Brettell et al., 2009), and 2011 (Brettell et al., 2011).

There are two textbooks called "Forensic chemistry," one by Bell (Bell, 2009) and the other by Houck (Houck, 2015), and some unintentional merging of these text occurred. In total, 49 inadvertent combinations such as this were detected when the available year of publication was included. These unintended merges included "Forensic Fire Scene Reconstruction" (D. Icove et al., 2013; D. J. Icove & DeHaan, 2004), or between books (e.g., "Forensic Interpretation of Glass evidence"; Curran et al., 2000) and their reviews (Maxwell, 2001). Not all the potentially conflicting information listed for documents with the same title could be checked due to the lack of details provided in some cases, but at least 36 (of the above 49) could be differentiated. These unintended associations remained predominately an issue for documents with short and non-specific titles.

Table 1 only includes the topmost cited references across all the evidence types and reveals some differences. Fingermark (detection and composition) have the highest number of references appearing in other evidence types, while forensic geoscience, fire investigation, and toxicology (challenge-advances) had none.

A summary of the number of references shared between all the evidence types can be seen in Figure 2. This table is compiled using titles, with only different (distinct) records being considered after removal of duplicate records appearing more than once within or between reports for an evidence type. Three evidence types; explosives, fingermarks, and toxicology, when split into subgroups, were found to have the highest overlaps, which is unsurprising. Across other evidence types, toolmarks had the highest number of cross-references: 100 references with fingermark composition and 244 with fingermark detection. Fingermark detection and paint and glass shared references with most evidence types (11 out of the other 12 evidence types) while toxicology (challenge-advances) was the most exclusive sharing references with only 4 out of the other 12 evidence types.

These relationships can be explored further using a Jaccard index, Figure 3, to establish the significance of the observed relationships. The Jaccard index, written as $J(A,B) = |A \cap B| / |A \cup B|$, is a coefficient that measures similarity between two sample sets. It is defined by the size of the intersect (i.e., $|A \cap B|$) between the two sample sets divided by the size of the union (i.e., $|A \cup B|$). The Jaccard index is within the range 0–1, with 0 indicating total dissimilarity between the two datasets and 1 perfect overlap.

Given that the majority of cross-references were very low, the calculated Jaccard indexes are predictably found to be zero or close to zero. Explosive analysis and explosive scene investigation have the highest Jaccard index (0.499), but this still suggests a poor similarity between the two evidence types. All the other Jaccard indices being less than 0.41 also indicated poor correlations. Despite references appearing across evidence types, the calculated Jaccard indices point toward a literature base for all the individual evidence types being fairly distinct, even for those created using the same overall reference lists. It is, however, important to state some caution in using Jaccard indices on their own for dataset analysis, as there is a susceptibility to errors when it comes to datasets of different size.

3.3 | Authors' keywords

Each Scopus record includes two lists of keywords; one being provided by the authors at the time of publication and an "index" list generated by the bibliographic database at a later stage. The Index keywords provided by Scopus are specific

TABLE 1 Most commonly found references listed across all evidence types in the IFSMS reports

	Strengthening forensic science in the United States: A path forward (committee on identifying the needs of the forensic sciences et al., 2009a)	Forensic science[a]	Quantitative scanning probe microscopy for nanomechanical forensics (DelRio & Cook, 2017)	Use of low copy number DNA in forensic inference (Lowe et al., 2003)	STR genotyping and mtDNA sequencing of latent fingerprint on paper (Balogh et al., 2003)	Nanoplasmonic imaging of latent fingerprints with explosive RDX residues (Peng et al., 2015)	Surface modification for the collection and identification of fingerprints and colorimetric detection of urea nitrate (Cross et al., 2015)	Forensic chemistry[b]	Forensic potential of atomic force microscopy (Smijs et al., 2016)	Identification of authorship using lateral palm print—A new concept (Chaudhry & Pant, 2004)
Fingermark detection	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Fingermark composition	✓		✓	✓	✓	✓	✓	✓	✓	✓
Explosive analysis		✓	✓			✓	✓	✓	✓	
Explosive scene		✓	✓			✓	✓	✓		
Toolmarks	✓			✓	✓					✓
Biological evidence–DNA	✓			✓	✓					
Questioned document			✓						✓	✓
Paint and glass	✓	✓								
Digital evidence	✓									
Toxicology surveillance		✓								
Forensic geoscience										
Fire investigation										
Toxicology challenge-advances										

[a]Various review updates cited (Fingermark Detection: (Brettell et al., 2007, 2009, 2011; Brettell et al., 2005), Explosive Analysis and Scene: (Brettell et al., 2007, 2011), Paint ad Glass: (Brettell et al., 2007; Brettell et al., 2001; Brettell et al., 2003), Toxicology Surveillance: (Brettell et al., 2003).
[b]see main text for further discussion

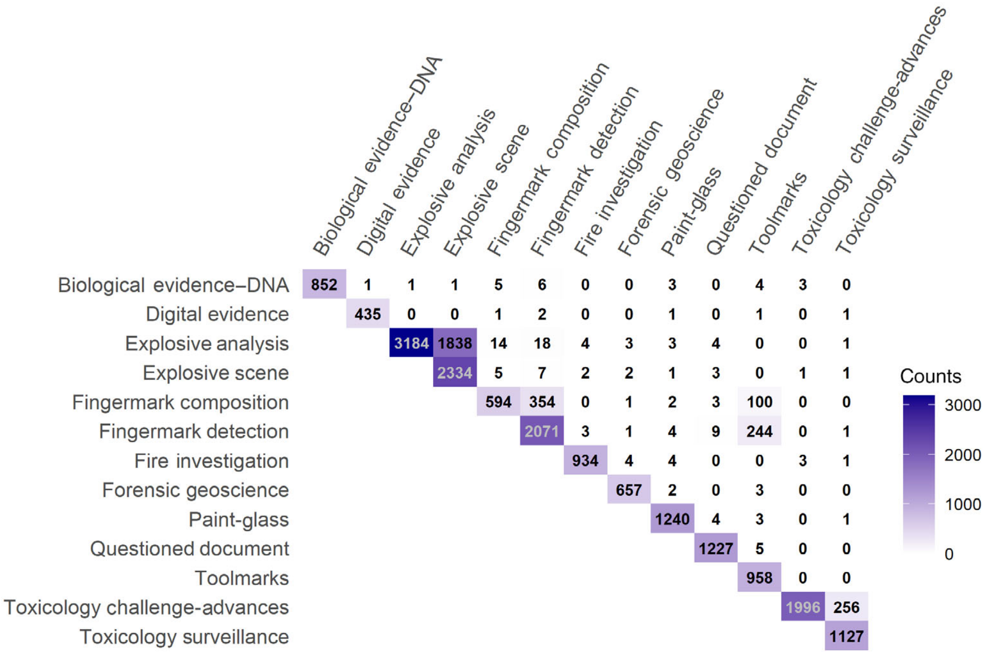

FIGURE 2 Number of references shared with other evidence types. Only documents with a title were considered. Different (distinct) references used only after removal of duplicates if appearing more than once across all the reports for an evidence type

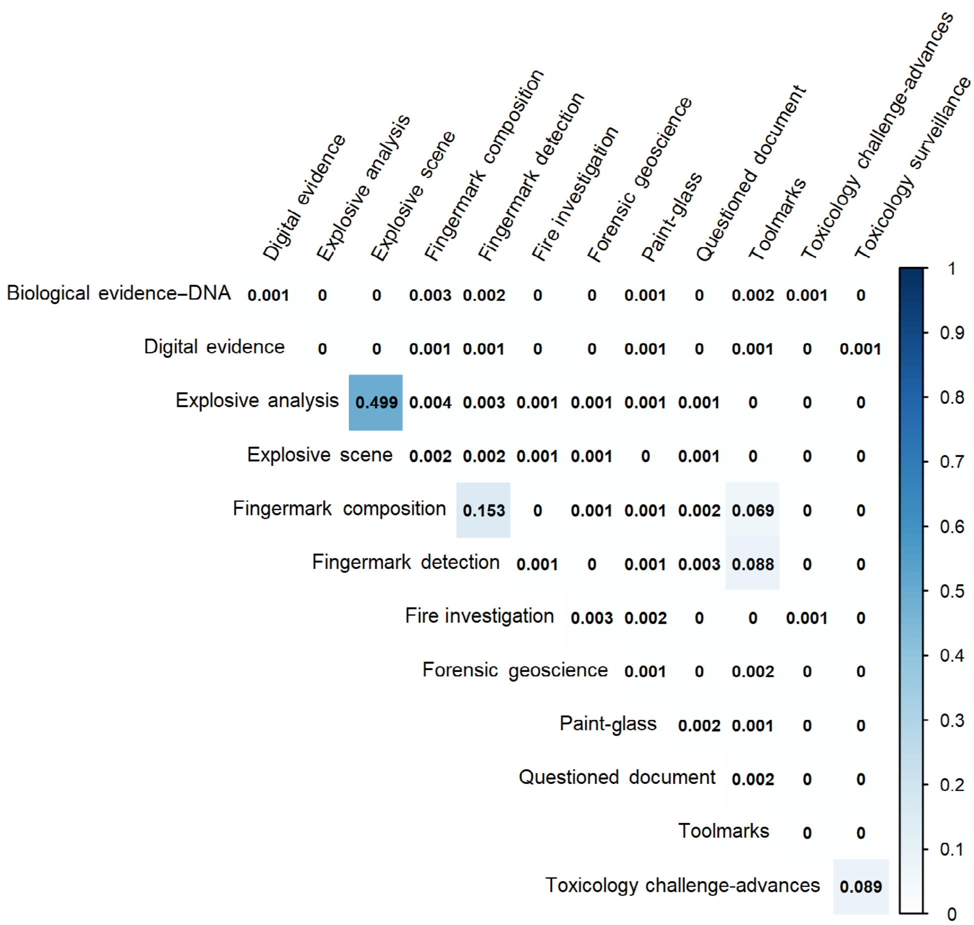

FIGURE 3 Jaccard index matrix calculated between all evidence types

to the database and they will differ from lists available in other databases. Sobreira et al. combined both the Authors and the Index keywords to populate the keywords figure while acknowledging the bias such an approach creates (Sobreira et al., 2020). However, since six reference lists (i.e., explosives analysis and scene, fingermarks composition and detection, and toxicology challenges-advances and surveillance) were created from the references given for three evidence types (explosives, fingermarks, and toxicology), it is reasonable to assume multiple keywords will be shared between the related reference list pairs. Consequently, considering all 13 reference lists and the most frequently shared keywords would most likely favor the output from the 6 reference lists.

To reduce this potential over dispersion only the outputs from the 10 evidence types were considered. It should be noted that the R code developed for this study does allow analysis across all 13 evidence types, an action done by selecting the sub-evidence entry option. The 10 evidence types had a total of 16,026 different references and 46,780 author keywords, of which 21,689 are distinct. The topmost commonly shared keywords across all 10 evidence types are presented in Figure 4, where only keywords with a minimum of six occurrences are reported.

Fingermarks had the greatest number of keywords shared with other evidence types; 96 out of 101. Digital evidence shared the fewest number of keywords, 15 out of 101, and has the fewest number of references with only 113 authors keywords. Such a low number may explain the poor cross referencing with other evidence types. Furthermore, recovering and analyzing digital information does not require access to the many scientific techniques listed in Figure 4, further distinguishing digital evidence from the other evidence types.

From the keywords in Figure 4, many are techniques, demonstrating the versatility of the scientific instruments used in forensic scientific analysis. The majority of these techniques remain instrument-based, primarily used for the detection of materials recovered from the scene and used as confirmatory tests to the presumptive diagnostics performed by the practitioners at the crime scene. For practical reasons, many scientific instruments are currently not field-deployable; however, advances in technology has seen greater availability of field portable instrumentation. Raman spectroscopy has become field-portable as reported in the study by Shand on analyzing samples (chemicals, drugs and explosives) at the crime scene (Shand, 2008). Other portable devices reported in the IFSMS references lists include: PLOT-cryoadsorption (Bruno, 2016; Harries et al., 2016), GC-TMS (Fredeen et al., 2010), GC–MS (Bednar et al., 2012), GC–MS/MS (Prieto et al., 2005), XRF (Bergslien et al., 2006; Roldán et al., 2010), and OR NIR (Morillas et al., 2018).

In relation to the evaluation of evidence, keywords such as “interpretation,” “likelihood ratio,” “reproducibility,” “principal component analysis,” or “statistics” were shared between all the evidence types (Figure 4) although “reproducibility” did not appear in the top 100 keywords for any evidence type. Several related keywords are also observed in Figure 4, for example, “Proficiency test” and “Proficiency testing,” or “Trace evidence” and “Trace.” There are only 22 keywords (highlighted in red) not present in any of the top 100 words listed for each evidence type but that are still shared between multiple evidence types, suggesting potentially strong relationships between the evidence types based on the authors' keywords.

The IFSMS reviews are written by multiple authors where references predominantly containing literature that is specific and focused on the evidence type of interest are independently collated. From the IFSMS reference lists, it was observed that there was a limited relationship between the evidence types based on the referenced literature listed in each review, implying the research activities acknowledged in the reviews infrequently cross reference multiple evidence types. Stronger connections were noted across the keywords listed in each publication implying that more generic links do exist.

3.4 | Scopus search

Search queries were also made on Scopus to provide reference lists related to the evidence type of interest. The search criteria and the number of references they generated are listed in Table 2 and presented in Figure 5. The selected entries in Scopus were chosen to be as simple as possible while best reflecting the evidence type.

In creating the datasets from the IFSMS reports, all of the references were searched in Scopus, with their citation details exported if they were available. The Scopus electronic identifiers (unique academic work identifier assigned in the Scopus bibliographic database and labeled Scopus EID) for the records were exported, making it possible to count the Scopus listed documents but also search for possible matches in place of a text comparison of the output title. Overall, the majority (14,718 out of 18,085, 81.4%) of references in the IFSMS reports were also found in Scopus, with some evidence types better represented than others (e.g., Biological Evidence–DNA vs. digital evidence). When the results of

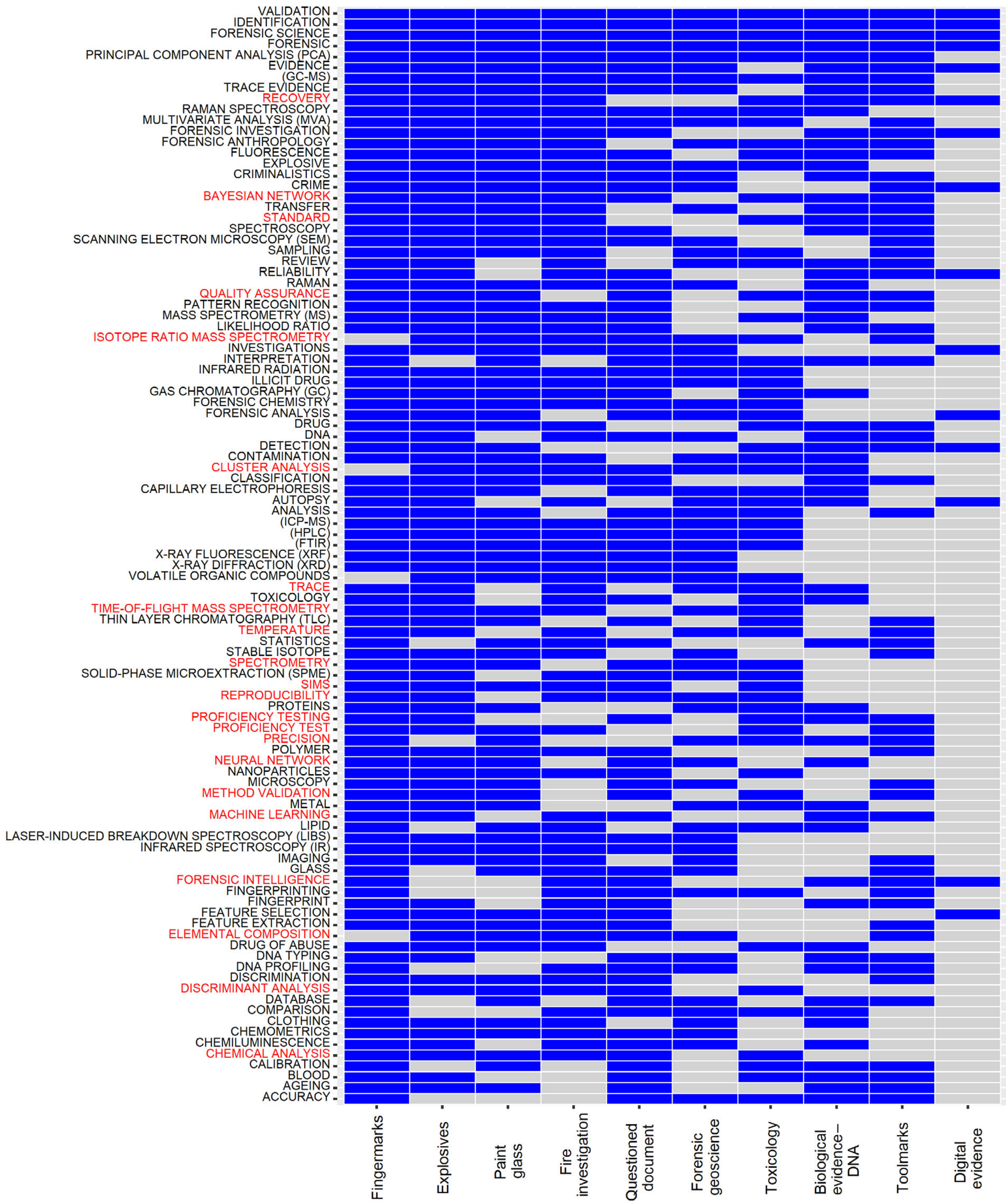

FIGURE 4 Most commonly shared keywords ($n = 101$) across all 10 evidence types. Evidence types organized from left to right by decreasing order of the total number of keywords shared with others. Keywords ordered (top to bottom) from the most frequently shared (from 10 occurrences to 6 occurrences across all evidence) and alphabetically (for keywords with the same number of occurrences). The blue rectangle indicates the keyword appears at least once in all the keywords listed for the specific evidence type. Keywords highlighted in red are not listed in the top 100 keywords of any evidence type (groups or sub-groups)

the Scopus literature review were examined for cross references within the IFSMS reviews, overall only 3216, 21.9%, references were found to be shared between the lists. Again, the comparison significantly varies between evidence type. At one end of the spectrum, for Biological Evidence–DNA, of the 868 references listed in the IFSMS reviews, 571 (65.7%) were found within the 15,352 outputs generated when searching Scopus, however these references only accounted for

TABLE 2 Scopus search entries for the evidence types listed in the IFSMS reports (Datasets accessed and exported on November 4, 2020)

Evidence type IFSMS reports	IFSMS total (distinct) number of references	IFSMS references available in Scopus	Scopus search: Article title, abstract, keywords, all years to 2019 included	Scopus number of references	IFSMS references found in Scopus search
Forensic geosciences	708	431	Forensic AND (soil OR geology OR geoscience)	1691	240
Toolmarks	1066	750	Forensic AND marks AND NOT medicine	1421	116
Paint and glass	1292	855	(Paint OR glass) AND forensic	1745	223
Fire investigation	970	682	Fire AND investigation	10,078	146
Explosives analysis	3205	2799	Explosives AND analysis	25,407	1129
Explosives scene	2355	1990	Explosives AND scene	477	22
Toxicology challenge-advances	2014	1886	Toxicology AND (challenge AND advances)	4417	42
Toxicology surveillance	1162	1076	Toxicology AND surveillance	814	1
Digital evidence	479	281	forensic AND digital AND evidence	2819	47
Fingermarks composition	603	537	Fingerprint AND composition	5347	44
Fingermarks detection	2126	1840	Fingerprint AND (detection OR imaging)	11,308	434
Biological evidence–DNA	868	823	Forensic AND (DNA OR biology)	15,352	571
Questioned documents	1237	768	Questioned AND document	1397	201
Sum	18,085	14,718	–	82,273	3216

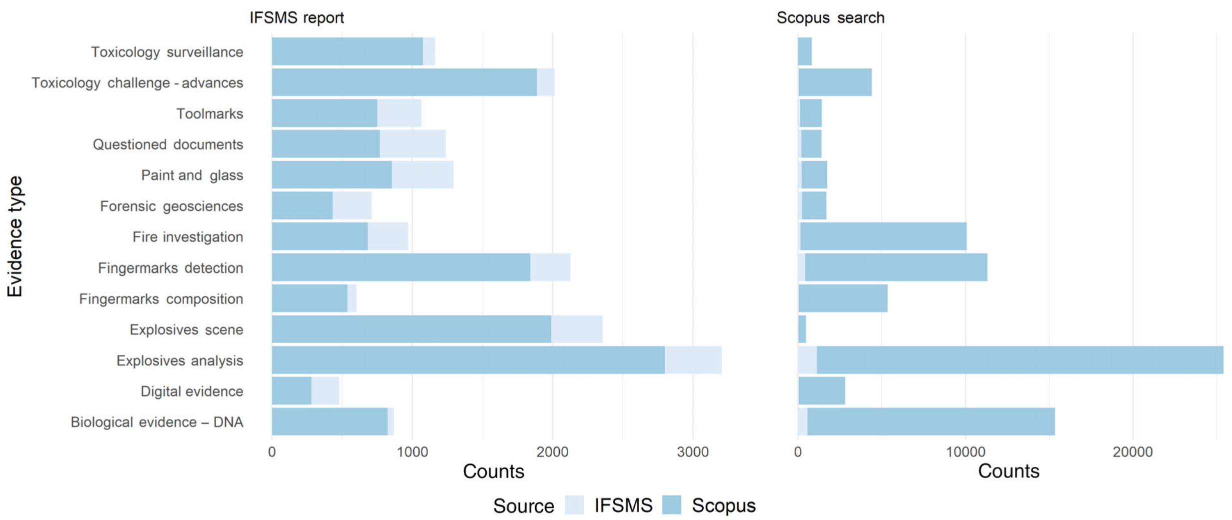

FIGURE 5 Graphic representation of Scopus search entries for the evidence types listed in the IFSMS reports. Figure on the left: IFSMS total (distinct) number of references and IFSMS references available in Scopus. Figure on the right: Scopus search—number of references and number of IFSMS references found in Scopus search

3.7% of the references within Scopus for this evidence type. This implies the IFSMS search for Biological Evidence–DNA only provides a shallow reflection of the wider research literature available. In contrast, only 1 document in the IFSMS reports for toxicology surveillance was found in the equivalent Scopus search. Even though the search entries included "toxicology" and "surveillance," it is reasonable to conclude the output for this Scopus search does not align with the type of references listed in the INTERPOL reviews.

The Scopus search criteria listed in Table 2 were intended to be simple and relevant to the evidence type and other searches could be performed that could have led to a greater coherence between the reference lists. It is important to remember the content generated from Scopus is based on text mining to assist in the identification of relevant work. No further processing or selection was applied to the content, which would have been necessary for any reviewers undertaking this task as part of a systematic review, or to generate a reference list of appropriate studies to produce a literature review. Without any screening process, documents not relevant to the topic or question of interest were likely to be listed.

The variations seen in Table 2 between the reference lists obtained from the IFSMS reports and Scopus indicated that it was not possible with simple searches in a bibliographic database to recreate the content of the IFSMS reports. It also illustrated the risk of an over reliance on searchable content made available in bibliographic databases. Finally, it demonstrated that the IFSMS reports were not limited to just reviewing specific evidence types by returning documents found in Scopus searches but also included a broader range of materials including non-published reports and literature.

An R-Shiny application was developed to create a means to search the IFSMS references by keywords.

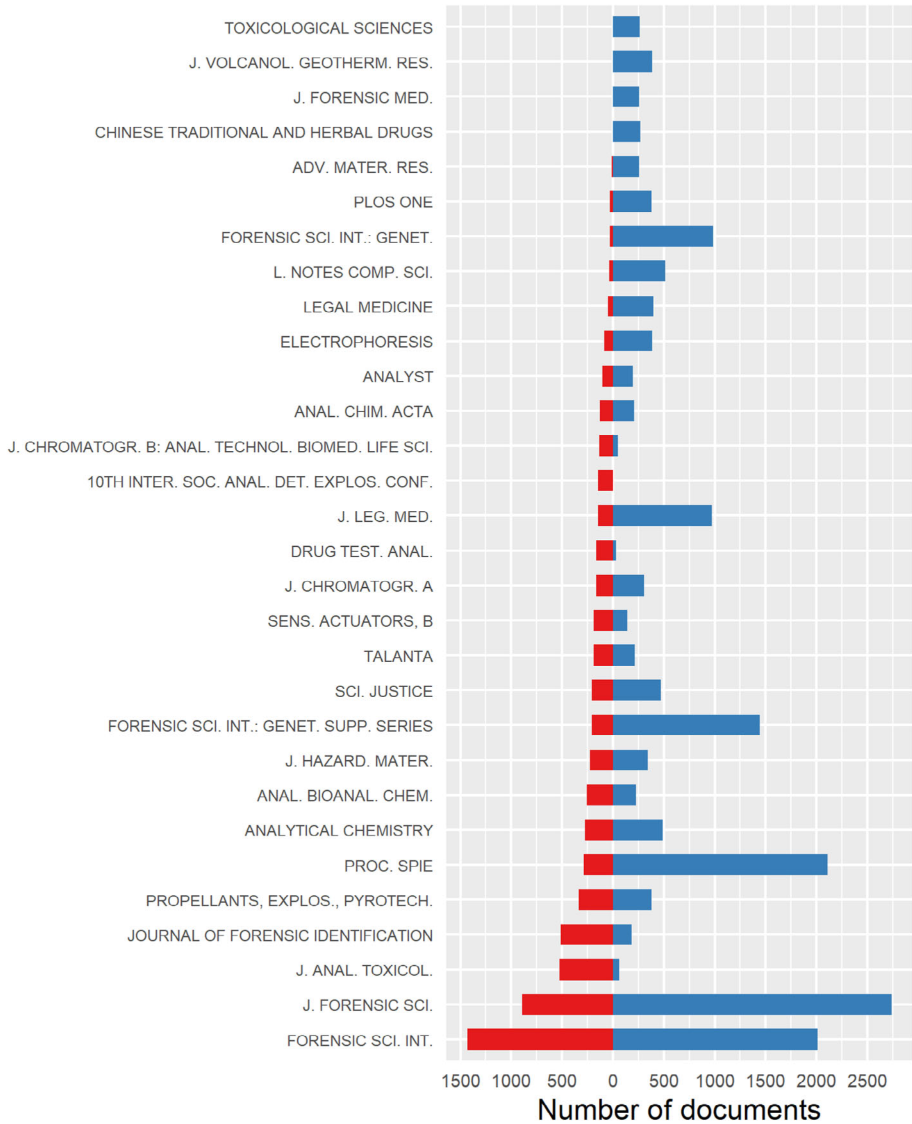

FIGURE 6 In red (left) the top (20) most listed source titles across all the evidence types identified in IFSMS reports, combined with in blue (right) the top (20) most listed source titles in the merged Scopus searches, making a total number of 30 source titles

3.5 | Source titles and open access

The 18,085 references within the IFSMS reports were published across 3042 journals and publications, with the most frequently listed shown in Figure 6. For comparison, the Scopus search produced 80,708 documents in 15,985 journals and publications. The 20 most frequently encountered journals in the INTERPOL reports accounted for 6508 documents (36.0% of the 18,085 documents) while for Scopus 15,346 out of 82,273 (18.7%) articles were published in the top 20 journals.

The journals *Forensic Science International* (1430 records) and *Journal of Forensic Science* (892 records) were the most frequently encountered in the INTERPOL reports. These two journals are also very frequently observed as a source of documents in the Scopus search (2736 entries for J. Forensic Sci. and 2012 for Forensic Sci. Int.), alongside "*Proceedings of SPIE*" with 2107 documents. There are only 285 records for "*Proceedings of SPIE*" in the INTERPOL reports, mainly relating to the analysis of explosives (238 documents). Other examples of note included 196 (out of 207 documents) in "*Forensic Sci. Int.: Genet. Supp. Series*" for biological evidence-DNA, the 524 (out of 525) in "*J. Anal. Toxicol*." for the toxicology publications and 333 outputs for explosives appearing in "*Propellants, Explos. Pyrotech*.". "*Journal of Forensic Identification*" was the most prevalent publication for fingermarks (377) and toolmarks (131), "*J. Forensic Sci*." for fire investigation (76), "*Forensic Sci. Inter*." for forensic geoscience and questioned documents, "*Digital Investigation*" for digital evidence, and "*Automotive News*" for paint and glass.

While many of these journals have the option of open access publishing, none comes by default, leaving the forensic practitioners or researchers to decide whether or not to make the payment of Author Processing Charges (APCs) (i.e., cover the publishing costs), which are not insubstantial. There are 1404 distinct documents listed as open access (across all evaluated evidence types, considering only document title, source title, year, and access type information) in the overall INTERPOL reference list although some may be missing or not mentioned but available in other (academic and peer reviewed) resources such as magazines or standards for example. Open access articles are clearly a benefit to readers of research outputs, especially those who do not have access to desired publications via their institution or employer or who are unable to cover the access costs.

Open access removes barriers to access, but high visibility does not necessarily translate into a citation advantage, with several studies reporting that open access articles do not generally experience a citation advantage in many subject areas (Archambault et al., 2014; Basson, 2019; Basson et al., 2020; van Leeuwen et al., 2018). Combined with high publishing costs, this observation only gives a poor incentive for open access publishing, particularly by academic based researchers for whom citation indicators are often used, for example, and not without controversy, to evaluate scientific performance (Kostoff, 1998; Moed, 2009), research proposals (Allen et al., 2009; Cabezas-Clavijo et al., 2013), the allocation of funding (Carlsson, 2009; Kalachikhin, 2018), or for recruitment (Gorraiz & Gumpenberger, 2015; Holden et al., 2005). Despite this, in forensic science, it is reasonable to ask if any unwillingness to publishing open access does not have an implication for the larger concepts of justice and equality of arms. To help expert witnesses present evidence in court with transparency, this information should be accessible to all. Furthermore, open access publishing should also publish the data that underpins any research. Compared with many research disciplines, the forensic community is relatively small and concerted effort is needed to assert, justify and lead the community to embrace open access with full disclosure of research data.

4 | CONCLUSION

The present study demonstrated the effectiveness of scientometric analysis as a tool for identifying trends in different fields of research. It provided a comprehensible output displaying trends in keywords and journals for 10 of the evidence types reviewed in the IFSMS reports. It also presents an R-shiny application developed for this study and available at https://uod.ac.uk/lrcfsinterpolreportsexplorer, which enables a full keyword search the INTERPOL IFSMS review articles.

A comparison between the IFSMS and Scopus reference lists revealed that only a limited number of documents were found in both, possibly suggesting gathered data is dependent on the utilized source. The results suggest that the INTERPOL review articles contain publications which are outside of the mainstream scientific literature and that they also do not include much of the literature now available within this literature base, indicating that the IFSMS reports should be seen as complementary to the information available in other citation databases. Other citation databases such

Web of Science, PubMed or Google Scholar should also be considered when searching for forensic science based literature.

Compared with many research disciplines, the forensic community is relatively small and concerted effort is needed to assert, justify and lead the community to embrace open access with full disclosure of research data.

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CONFLICT OF INTEREST

Niamh Nic Daeid is an Editor of the journal and was excluded from the peer-review process and all editorial decisions related to the publication of this article.

AUTHOR CONTRIBUTIONS

Herve Menard: Conceptualization (equal); methodology (lead); software (equal); supervision (equal); writing – original draft (equal). **Oyewumi Akinpelu:** Investigation (equal); software (equal); writing – original draft (equal). **Nana Fiakpui:** Investigation (equal); software (equal); writing – original draft (equal). **Rong (Lily) He:** Investigation (equal); software (equal); writing – original draft (equal). **Sarah Huxter:** Investigation (equal); software (equal); writing – original draft (equal). **Caitlin Jordan:** Investigation (equal); software (equal); writing – original draft (equal). **Lucy Judge:** Investigation (equal); software (equal); writing – original draft (equal). **Aoife King:** Investigation (equal); software (equal); writing – original draft (equal). **Brianna Miller:** Investigation (equal); software (equal); writing – original draft (equal). **Sophie Moggs:** Investigation (equal); software (equal); writing – original draft (equal). **Carmen-Teodora Patrascu:** Investigation (equal); software (equal); writing – original draft (equal). **Teri Pearson:** Investigation (equal); software (equal); writing – original draft (equal). **M.E.J. Seneviratne:** Investigation (equal); software (equal); writing – original draft (equal). **Lotte Timmerman:** Investigation (equal); software (equal); writing – original draft (equal). **Penelope Haddrill:** Supervision (equal); writing – original draft (equal). **Joyce Klu:** Software (equal); supervision (equal); writing – original draft (equal). **Christian Cole:** Software (equal); supervision (equal); writing – original draft (equal). **Niamh Nic Daeid:** Conceptualization (equal); funding acquisition (lead); supervision (equal); writing – original draft (equal).

DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

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