



4th DNA Forensic Symposium: Challenges and future directions in Africa

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ABSTRACT

The 4th Forensic DNA Symposium in Africa underscored the critical role of regional collaboration in advancing forensic sciences, with a particular focus on forensic DNA examinations, databases, and humanitarian initiatives. The symposium aimed to assess the current forensic DNA capabilities across African countries and develop strategies to expand and better utilize DNA platforms. Key findings from the symposium highlight the necessity for enhanced cooperation among African nations to build robust forensic DNA databases and improve data-sharing mechanisms. The symposium also identified significant gaps in current capabilities and the need to develop legal frameworks, infrastructure, and expertise to support forensic initiatives. Moving forward, these findings suggest a strategic focus on capacity building, establishing standardized procedures, and implementing sustainable forensic practices across the continent. Champions were nominated by attending delegates to lead their respective countries in the implementation of these strategies, marking a critical step towards strengthening forensic science in Africa and addressing the pressing challenges related to crime and humanitarian efforts.

1. Introduction

DNA technology has significantly impacted science by providing tools for generating leads in investigations, aiding legal proceedings, and contributing to the resolution of humanitarian casework involving missing persons and unidentified bodies [1,2,3]. While advancements in DNA technology are crucial for enhancing the efficiency of the criminal justice system, it is equally essential to ensure that these technologies are implemented responsibly to safeguard individuals' rights and prevent any misuse or abuse of data [3,4]. Africa faces various financial, resource and political challenges to establishing forensic DNA profiling and forensic Databases [5–8]. Zambia has taken the lead on the African Continent by implementing a legal structure to regulate and impose standards and rules for forensic practice with the establishment of the National Forensic Authority [9,10]. South Africa has established the National Forensic Oversight & Ethics Board with oversight authority on implementing the legislation regarding performing forensic DNA analysis and the administration and management of the National Forensic

DNA database [8,11].

Many countries in this region, except for South Africa and Botswana, have not yet implemented the required DNA laws to ensure the responsible oversight and operation of forensic DNA databases [3,9]. Additionally, many African countries do not have the necessary resources, including infrastructure, funding, and specialist education, developed justice systems to support the implementation of forensic sciences. As a result, most African communities do not have access to the safety, security, and investigative benefits that forensic technologies can offer. This gap highlights the pressing need for action. DNA technology serves as a method for analysing biological evidence on a global scale and is integral to a multi-disciplinary approach to forensic identification [1]. Despite this shared foundation for analysis and data sharing, various factors limit the potential of supporting humanitarian investigations. These factors include differences in sample collection and preservation methods adopted by countries or organisations, DNA extraction processes, management of DNA databases and the statistical interpretation of information, and the absence of DNA policies or regulations [12].

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When family members across African regions report their loved ones missing, they are confronted by systematic limitations, sometimes transnationally, compounded by the absence of thorough investigations, including the collection of reference DNA samples, contribute to large numbers of deceased persons remaining unidentified [13–18].

The 4th DNA Forensic Symposium in Africa (#4FDNAS) occurred in Livingstone, Zambia, from May 21st to May 23rd, 2024,^{1,2,3} Livingstone is renowned for being home to the Mosi-oa Tunya/Victoria Falls. The sunsets over the Zambezi River and the rainbows and moonbows at Victoria Falls are stunning. In this setting, the #4FDNAS event promoted collaboration among experts and officials from various African nations, facilitating the exchange of knowledge, skills and policies while brainstorming ways to advance forensic DNA use in Africa. 117 delegates attended the symposium. The objective of the #4FDNAS was to augment the capacity and dependability of DNA examinations and associations, vital for criminal investigations and the identification of unidentified human remains and missing persons. The #4FDNAS has emerged as a forensic science gathering in Africa co-hosted this year by prominent organisations such as DNAforAFRICA, Interpol, the International Committee of the Red Cross, the United Nations Office on Drugs and Crime, the University of Cape Town and the Zambian Government. This event united African and global forensic specialists to promote the use of science to prevent and respond to crimes and to support humanitarian initiatives aimed at identifying missing and unknown individuals. Table 1 below provides information about the delegate attendance.

The main aim of the #4FDNAS symposium was to encourage regional cooperation in forensic DNA matters and establish sharing and exchange of DNA data to assist with the identification of missing persons and unidentified human remains. It explored the need to facilitate cross-border criminal investigations by adopting an approach to providing crucial services for survivors by enhancing the reporting and collection of forensic traces. Solid forensic DNA legislation can be developed by holding consultative workshops with various stakeholders, including persons with legislative drafting expertise, non-government organisations, academia, law advisers, and scientists, to draft legislation and implement forensic DNA databases [2,11,12]. This cooperative effort can help identify undocumented human remains and combat cross-border criminal activity in Africa [11,12,19–22]. The #4FDNAS recognised that upholding the rights of survivors and communities in-

Table 1
Delegate information.

African Delegates	Democratic Republic of the Congo, Ghana, Kenya, Mozambique, Nigeria, South Africa, Somalia, Zambia, Zimbabwe
Non-African Delegates	France, United Kingdom, United States of America
Agencies Represented	Angel Care Crises, DNAforAfrica, International Committee of the Red Cross (ICRC), African Centre for Migration & Society, International Committee of the Red Cross (ICRC), International Criminal Investigative Training Assistance Program, INTERPOL, Kenya National Commission on Human Rights, Forensic Practitioners from Law Enforcement Agencies and non-government agencies, National Forensic Regulator (Zambia), Non-Governmental Organisations, PANZU Foundation and Hospital, Prosecuting Authorities, United Nations Office on Drugs and Crime (UNODC), DNAforAfrica, ICRC, UNODC, UCT, Zambian Government
Hosts Sponsors	DNAforAfrica, ICRC, TFS, Qiagen, Separations, UNODC, University of Cape Town, Zambian Government (logistics).

¹ Full Programme: https://www.dnaforafrica.com/_files/ugd/7beeac_ac5ee0b39fd3470cb5bc1e121efd98c9.pdf.

² Highlight Reel: <https://www.instagram.com/p/C7oifw7qhr/>.

³ Photos: <https://www.dnaforafrica.com/4fdnas2024>.

volves partnering with government and non-government stakeholders who share goals of adopting a survivor-centred approach to resolving crimes and upholding human rights and humanitarian principles.

On the first day of the #4FDNAS event, a workshop was facilitated on court testimony, ethics, and bias issues in the sciences. The following two days of the symposium featured two tracks: one focused on DNA databases, while the other centred on gender-based violence and femicide. The main topics discussed in the DNA Database Track included:

- 1 Exploring Functionality, Differentiation and Software Solutions, for DNA Databases.
- 2 Understanding Population Allele Frequency Databases; Objectives, Current Status in Africa and Resource Needs.
- 3 Addressing Challenges in Resolving Unidentified Human Remains and Missing Person Cases; Existing Workflows, Regional Obstacles and Key Players in Human Identification.
- 4 Recognizing the Value of Regional Collaboration; the Importance of Regional Transnational Cooperation and Ongoing Initiatives.
- 5 Highlighting Key Legal and Policy Considerations for Regional DNA Data Sharing.
- 6 Overview of I-Familia; Technical Examination, Profile Submission Process and Expected Hurdles.

In the GBVF Track discussions, the key themes were:

1. Providing Essential Services for Survivors; Taking a Comprehensive Approach.
2. Enhancing Service Delivery; Reporting and Collection of Forensic Evidence.
- 3 Establishment of Regulated Forensic Nurse Training Programs in Africa to Address Demand.
- 4 Addressing GBVF Amidst Conflict Climate Disasters and Mobility Issues.
5. Strategies to Overcome DNA Court Challenges to Enhance Competency in Legal Proceedings.
6. Strengthening Justice in GBVF Cases through DNA Legislation and Databases.

Adopting an approach of encouraging teamwork and sharing information at the African regional and country levels is necessary given the mobile population in Africa today. It is necessary to tap into the expertise of professionals who actively support forensic sciences in an African and regional context. By collaborating in this way, the initiative gains access to perspectives and resources, leading to enhanced effectiveness and impact of forensic scientific practices across various settings in Africa [2,11,12]. Engaging and cooperating at all levels regarding forensic DNA examinations including the safe and secure exchange of biological information, enhances the implementation of the principles of the Sydney Declaration of Forensic Sciences by fostering ongoing collaborations and sharing of data within the Africa Region [19].

2. Symposium discussions

2.1. DNA databases

The DNA Database track opened with a discussion on the types of DNA databases used in forensic sciences. Delegates referenced law enforcement forensic (“intelligence”) DNA databases, population allele frequency databases and humanitarian databases. With few exceptions, developing and implementing forensic DNA databases in African countries are still in the early stages and require substantial investment in resources, infrastructure, and training to maximise capabilities and benefits [5–8,20].

A forensic DNA database used in law enforcement is a comprehensive and centralised storage facility for forensic DNA profiles obtained from

crime scenes and various individuals, including those who have been arrested, individuals who are not arrested but are needed for early investigative exclusion, convicted individuals, police and forensic personnel, contractors and suppliers of forensic equipment and consumables, and individuals who have visited the examination areas of the laboratory [23–25].

Humanitarian DNA databases are repositories of genetic information collected from relatives of missing individuals, antemortem reference samples, and unidentified human remains. These humanitarian databases are essential for associating unidentified human remains with their respective families [26–29]. By comparing forensic DNA profiles from these databases, practitioners can establish familial relationships which contribute to a multidisciplinary approach to forensic identification, provide resolution to families who have lost their loved ones, reduce uncertainty and trauma, and provide dignity and respect to those who have lost their lives [3].

Most delegates supported that forensic DNA databases also may include Indices for the profiles derived from missing individuals and unidentified human remains. Some, delegates, however, suggested that forensic DNA profiles collected from missing individuals and unidentified human remains rather should be stored in a distinct database specifically designed for humanitarian purposes, separate from law enforcement forensic DNA databases. These delegates acknowledged the potential challenges of such an endeavour, including the need for robust data management systems and international cooperation. Nevertheless, other delegates advocated that the omission of uploading these profiles to forensic DNA databases could impede the identification of individuals.

Furthermore, the symposium supported that African countries should be encouraged to submit forensic DNA profiles of antemortem and family reference samples to INTERPOL's i-Familia Kinship Matching Database [29]. Delegates suggested establishing appropriate data protection principles to allow the lawful and proportionate sharing of familial DNA profiles for humanitarian purposes. The importance of encouraging African countries to submit forensic DNA profiles of antemortem and family reference samples to INTERPOL's i-Familia Kinship Matching Database was emphasised. However, it was agreed that sharing these DNA profiles should not be automatic to uphold the principles of State sovereignty and non-interference in domestic affairs as dictated by international law. A good starting point for establishing a legal framework for sharing DNA profiles with INTERPOL i-Familia is reviewing existing agreements between INTERPOL and member states. The INTERPOL representative suggested that INTERPOL Resolution No. 6 of 2022 on the Identification of Missing Persons could be a suitable legal basis for developing domestic legislation or policies for such sharing. The symposium also discussed the need for governments, particularly those without robust data protection laws regarding forensic genetic data, to prioritize enacting such legislation.

Forensic DNA databases hold immense potential as beneficial instruments in criminal justice and human identification, inspiring hope, dignity, respect and progress in collective efforts when created and overseen with due regard for human rights and ethical considerations [24,30–32]. Important legal and policy factors to consider when sharing DNA data within a particular region based on genetic information in a particular geographical area require intricate legal and regulatory frameworks to safeguard individual rights [30–33].

Essential factors to consider include creating explicit procedures for accessing, obtaining consent for, and utilising data by authorised individuals, as well as supporting adherence to global human rights norms and universally accepted human rights protection standards [26]. Legal frameworks must balance the necessity for security and justice with an obligation to safeguard personal privacy and prohibit the unauthorised use of genetic information [8,30–32].

Ensuring sufficient human and physical resources is crucial for effectively supporting the whole value chain of employing DNA forensics [30]. It is necessary to employ competent crime scene examiners

who are adequately equipped to collect DNA trace. The presence of adequate and skilled forensic practitioners who examine DNA trace evidence in well-resourced forensic laboratories is crucial. Their role in avoiding delays in processing cases is significant, instilling confidence in the system's efficiency. It is vital to have an adequate number of forensic practitioners responsible for doing comparison searches and reporting the forensic investigative leads obtained from forensic databases. Additionally, having law enforcement personnel who are well resourced to follow-up the forensic investigative leads cannot be overemphasised to ensure the value obtained from forensic DNA databases is supported [3].

Integrating different information technology systems with the forensic DNA database should be an obligatory component of all operations to enhance value [3]. It is imperative to have a robust data management system that includes software capable of performing all necessary operations and tracking processes to achieve the goals of the investigation and effectively conduct thorough forensic investigations [6]. Procedures must be developed thoroughly and tested with a complete understanding of the potential for error in scientific analysis when performed in the absence of standard operating procedures and adequate leadership/supervision. Failures to implement robust policies and procedures are a recipe for miscarriages of justice and errors in humanitarian casework and identification, all culminating in further suffering for survivors, families and communities.

Forensic DNA databases have been integrated with sophisticated information systems (e.g., LIMS, CODIS, INTERPOL DNA Gateway Database, and INTERPOL i-Familial Database), improving the effectiveness of forensic investigations by offering powerful algorithms for DNA associations. South Africa has one of the most sophisticated forensic science capabilities in this region [8]. These advanced capabilities include maintaining the most extensive national forensic DNA database and state-of-the-art technologies in Africa, thus, playing a pivotal role in the international sharing of DNA data through INTERPOL which is a testament to a commitment to global collaboration [3,8,11,32–34].

The following 24 African countries have reported that they are performing forensic DNA analysis: Algeria, Botswana, Egypt, Eswatini, Ethiopia, Ghana, Kenya, Liberia, Libya, Mauritius, Morocco, Namibia, Nigeria, Rwanda, Senegal, Seychelles, South Africa, Somalia, Tanzania, Tunisia, Uganda, Zambia, and Zimbabwe. Eight of these countries administer a forensic DNA database to some extent: Algeria, Botswana, Egypt, Mauritius, Morocco, Namibia, South Africa and Tunisia [20,21,35–40]. Two countries, namely South Africa and Botswana are engaged in sharing forensic DNA data with the INTERPOL DNA Gateway Database, and INTERPOL's i-Familia Database [1,15,16]. Somalia has the intention of using the INTERPOL DNA Gateway Database to load their forensic DNA profiles for comparison searches.⁴ Fig. 1 illustrates the countries that are performing forensic DNA analysis, that are administering a forensic DNA database, that have allele frequency databases, are accredited, and have nominated champions to encourage collaboration between different African countries.

The Ampath National Reference Laboratory in South Africa has received accreditation for forensic genetic testing [41]. It is worth mentioning that although the Forensic Science Laboratory of the Government is not yet accredited, it has a quality management system that is based on ISO17025:2015 standard for competency of testing and calibration laboratories. This laboratory is responsible for forensic DNA profiling of criminal casework on DNA evidence [8,39,42]. The Egyptian Accreditation Council (EGAC), the second Accreditation Body in Africa to initiate the accreditation of forensic service providers, has granted accreditation to forensic service providers in Egypt [43]. The Forensic Science Laboratory in Mauritius has been accredited by the Mauritius Accreditation Service (MAURITAS) [44]. Morocco's police forensic

⁴ Personal discussion with the Interpol Administrator.

Africa

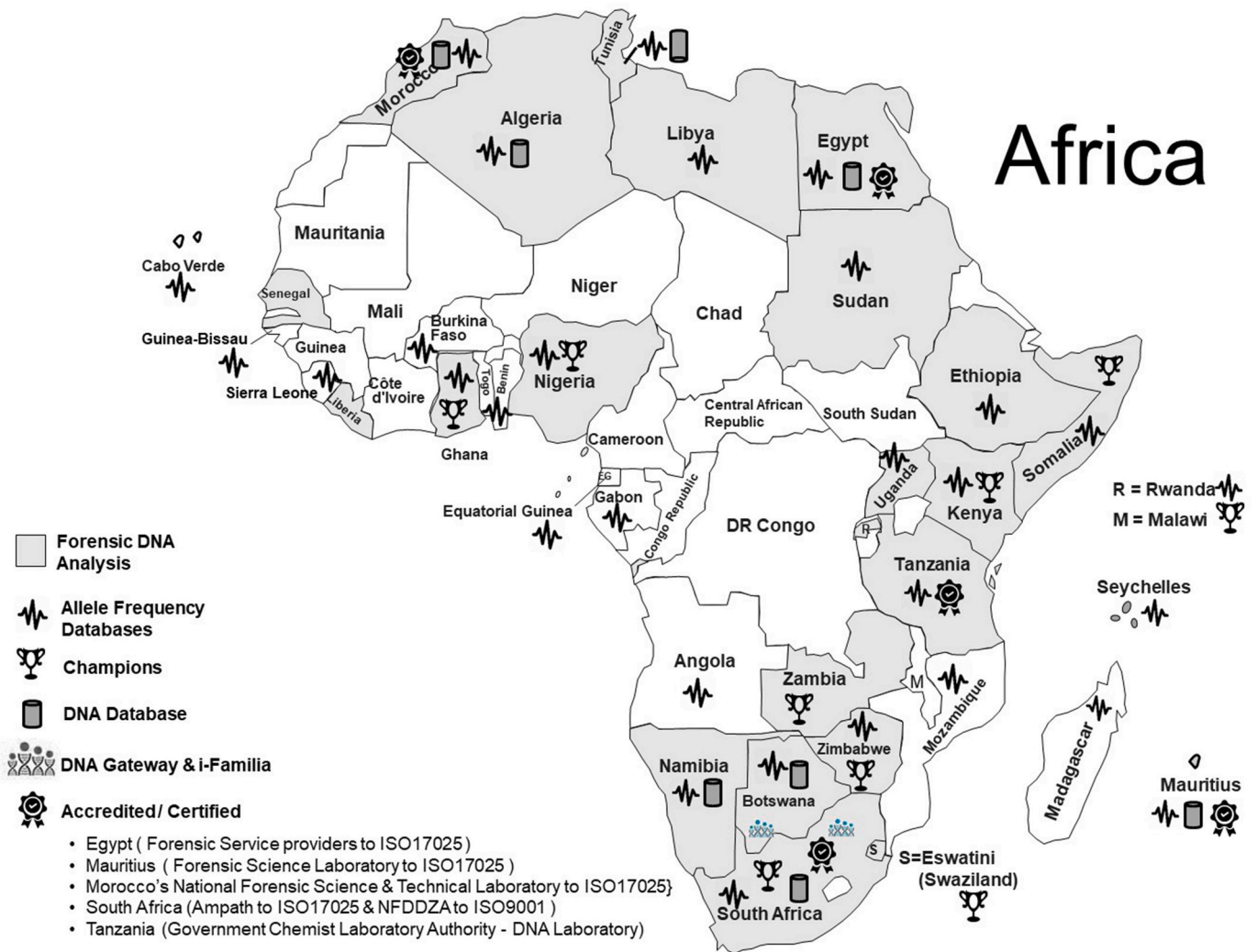


Fig. 1. Illustration of African Countries performing forensic DNA analysis, established or imminently establishing forensic DNA databases, accreditation of the testing laboratory and certification status of the forensic DNA database (The map lines delineate study areas and do not necessarily depict accepted national boundaries).

laboratory in Cassablanca is accredited with the American National Standards Institute National Accreditation Board (ANSINAB). The Government Chemist Laboratory Authority - DNA Laboratory in Tanzania has been accredited by the Southern African Development Community Accreditation Service (SADCAS) [45].

2.2. Allele frequency population databases

In forensic DNA analysis, allele frequencies are required to convey the strength of the evidence and not to overstate the strength by misapplying reference population datasets. The allele frequency population database selection may impact the weight of evidence [46–48]. Specifically, when an allele is rare, it provides more evidence supporting a questioned contributor to the evidence profile if it contains that allele. Ideally, the optimal population database aligns with the potential population(s) of contributors around or who had access to the crime scene – a complex requirement to meet without precise census data reflective of the crime scene area. The allele frequency population database must uphold the principles of justice and safeguard human society. It is crucial to consider the possible violation of individual human rights and research ethics standards when gathering, storing, and sharing individual genetic information [49].

The conversation during the symposium addressed the essentiality of

the purpose and current status in Africa, resource requirements for population allele frequency databases, and measures that countries should undertake to build them. Many African countries presently have an allele frequency database for their country⁵ (see Fig. 1). For countries without allele frequency databases, such as Zambia, Afro-American allele frequencies have been used to indicate the strength of their DNA results. Delegates shared their approaches to generating allele frequency databases. A focus on representing common alleles and estimating rare allele frequencies using a minimum threshold for forensic purposes may be considered. Given the constraints of a small sample size, a conservative statistical methodology was discussed to account for the potential occurrence of sampling errors and variations within population and cultural subgroups. The following countries have allele frequency population databases (some countries may have data or some sub-population groups only): Algeria, Angola, Botswana, Cape Verde, Egypt, Equatorial Guinea, Ethiopia, Ghana, Kenya, Libya, Morocco, Mozambique, Namibia, Nigeria, Rwanda, Somalia, South Africa, Sudan, Tanzania, Tunisia, Uganda, and Zimbabwe [50–73].

⁵ Personal discussion with the Regional Director for DNAforAfrica.

2.3. Unidentified human remains

Considering the high prevalence of unidentified and unclaimed deceased persons reported each year in Africa, it is evident that the present methods used to determine their identities are insufficient [15-18,74-78]. Frequent cross-border movements in this region exacerbate this problem because many unidentified human remains belong to undocumented individuals who have crossed borders [79,80]. Professional, ethical, and moral standards and regulations require forensic pathology specialists to collect information on unidentified human remains entering forensic pathology services or medicolegal mortuaries [79-81].

Establishing their identities remains the responsibility of the State authorities [74-81]. However, collaboration between government agencies and non-government organisations (NGOs), including the International Committee of the Red Cross, can improve systems that successfully collect missing persons' information and samples from families needed to confirm the identification [82-84]. However, many unidentified human remains remain unidentified because most families have yet to report their loved ones missing for myriad factors compounded by the fact that there are no regional databases or standard protocols in place to facilitate transnational communication between authorities to investigate and confirm the identification of unknown persons [17,85].

Resolving cases involving unidentified human remains and missing persons requires skilled practitioners and investigation that considers various evidence (primary and secondary identifiers, circumstances, temporal and spatial information, etc.) and the associated weight of each in a multidisciplinary approach to forensic identification that considers various evidence (primary and secondary identifiers, circumstances, temporal and spatial information, etc.) and the associated weight of each in a multidisciplinary approach to forensic identification [85-89]. Experts should avoid being swayed by analysing only evidence that supports a hypothesis. On the contrary, forensic identification is a process that must deliberately seek to include explainable and unexplainable discrepancies before confirming any identification, reaching an inconclusive finding, or making an exclusion [85-89]. In cases involving missing persons, trained practitioners must undertake family interviews on their missing person's disappearance and carry out data and sample collection for further comparison. From a forensic DNA perspective, unidentified human remains and missing persons are matched or associated through intricate workflows encompassing DNA collection, analysis, and comparison within and among databases [85-89]. Regional problems include restricted technological access, inadequate financial resources, and a lack of validated and standard protocols [84, 85,90-92].

Key players encompass law enforcement authorities, forensic experts, and humanitarian organisations, all of which must collaborate effectively to address these gaps [85-92]. The delegates selected champions in eight African countries (Fig. 1) to develop a standard approach to build on best practices and ensure a fit for purpose in the African region, including the strengthening of national capabilities and engagement with the INTERPOL I-Familia programme. Presently South Africa and Botswana are contributing forensic DNA profiles to the INTERPOL I-Familia repository.

2.4. Privacy concerns and ethical data collection

Delegates deliberated on balancing the purpose and privacy protections of forensic DNA databases. Ethical considerations in data collection, management, and sharing are vital to protecting individuals' privacy while leveraging the power of DNA technology to solve crimes and identify unidentified human remains and missing persons [93-99]. Privacy safeguards are paramount because of collecting, processing, and sharing personal and sensitive data. Individuals are increasingly worried about how their data are used, who has access to the data, and the potential for misuse, which can lead to abuse. Achieving the right balance

between criminal investigative purposes and identifying unidentified human remains and missing persons, and privacy is a moral obligation and a legal requirement in most jurisdictions. Delegates emphasised the need for criminal justice practitioners and relevant stakeholders to consider the international data protection principles for the processing and use of DNA data for policing and humanitarian purposes, including⁶ [100-104]:

1. **Accountability and Transparency in Data Collection and Usage:** Ensuring that individuals are fully aware of how their DNA is used and the benefits, limitations, and risks are vital. Therefore, clear privacy policies and informed consent mechanisms are essential as well as the establishment of oversight bodies.
2. **Purpose Limitation and Data Minimisation:** Collecting only the necessary data for specific purposes and retaining reference data and samples for the shortest possible time reduces the risk of privacy invasion.
3. **Ethical Handling of Sensitive Data:** Special care must be taken when dealing with sensitive genetic information, ensuring lawful processing, robust security measures, strict access controls, data fairness and accuracy, and data retention.

2.5. Gender-based violence and femicide (GBVF)

The delegates of the GBVF stream of the 4#FDNAS held fruitful discussions on the challenges and successes in dealing with GBVF, a grave violation of human rights that leads to both immediate and long-term health issues for survivors. Internationally, women encounter a wide range of mistreatment, including stigmatisation, harassment and exploitation. The prevalence of rape is on the rise, presenting a substantial societal issue and public health priority due to its profound consequences [105-120]. An essential aspect of tackling sexual violence entails comprehending the impediments to survivors' disclosure [112, 119].

Numerous scholars indicate that sexual offences and GBVF are increasingly prevalent in communities, especially during conflict, in Africa [107-109]. Perpetrators often employ collective public rape, torture, and sexual violence to accomplish their goals. Instances of sexual violence frequently occur in women residing in rural areas, resulting in both primary (women themselves) and secondary survivors (the wider community). The utilisation of rape as a strategic tool in warfare is non-selective, deliberately victimising individuals regardless of their gender, age, or population affinity [107,108,121].

A primary goal of interventions to prevent GBVF should be to reshape the socialisation of boys and young men towards more gender-equitable ideals of masculinity [115]. Addressing the structural factors of poverty and childhood trauma, which have significant influences on men who commit rape, is crucial [114]. This approach helps prevent the development of harmful masculinities. While reducing social marginalisation is essential, it alone will not decrease the likelihood of men committing rape; changing notions of masculinity is essential [111,114].

The experience of GBVF frequently leads to significant repercussions on the physical, psychological, and social well-being of survivors, their families, and their communities, highlighting the need for efficient support and safeguarding justice [119]. There are notable deficiencies in the support systems of survivors, which can cause additional detriments [111]. Survivors of sexual abuse require comprehensive care that addresses the multifaceted repercussions of violence, encompassing physical, psychological, legal, and socioeconomic aspects. Therefore, it is crucial to treat them with dignity and compassion [111-113].

⁶ United Nations Trade and Development, <https://unctad.org/page/data-protection-and-privacy-legislation-worldwide> (accessed 22 August 2024). Of 194 countries, 137 have implemented legislation to secure data protection and privacy. Only 61 % of the African countries have adopted such legislation.

During the #4FDNAS discussions, the delegates highlighted several critical aspects of their experiences with the examination of rape survivors and rape crisis counselling. These experiences include the significance of having trained professionals and a secure environment, establishing a solid rapport with a counsellor, recognizing the benefits of open communication and active listening, engaging in collaborative efforts for self-exploration, and the therapeutic value of sharing collective narratives of suffering [119,120,122]. The delegates highlighted the necessity for increased efforts to reach out to and educate people about rape and other sexual offences as well as the significance of providing professional medico = legal care, compassionate psychological and other health-related assistance.

A significant concern highlighted in the #4FDNAS is the necessity for more assistance within the criminal justice system to provide an environment in which survivors of GBV feel at ease when reporting crimes. Survivors may experience considerable distress throughout legal proceedings, even when perpetrators are apprehended [119,120,122]. This anguish can hinder their capacity to effectively articulate their experiences when interrogated by law enforcement, prosecutors, magistrates, and defence counsel. An important challenge many survivors face difficulties in articulating their stories and how they are understood when reported for court proceedings [119,120,122]. Additionally, survivors fear social stigma, retribution by perpetrators, and a lack of confidence in the investigative and legal systems [119,120,123].

The inadequate education provided to individuals who engage in meaningful activities when addressing sexual violent cases poses substantial obstacles to realistically tackling this widespread problem [119,120,123]. Inadequate training and lack of understanding among healthcare practitioners, law enforcement officials, legal professionals, and community workers frequently lead to insufficient support for survivors, mishandling of cases, and ultimately high rates of attrition and low rates of conviction. In the absence of thorough education, these influential individuals may continue to propagate misconceptions, prejudices, and negative perceptions about sexual assault, which exacerbates the distress experienced by survivors and discourages them from seeking assistance. Improving education and training for all individuals involved is essential to employing an empathetic, knowledgeable, and efficient response to sexual assaults [124,125]. A more supportive atmosphere for survivors is essential and will help to prevent and reduce such crimes [119,124,125]. These challenges significantly contribute to the low rates of court enrolment, conviction, and sentencing for rape cases in many African countries [119,120]. The efficient transmission of GBVF survivor encounters is vital for legal procedures.

In South Africa, the government enacted progressive laws to promote gender equity and specifically address gender-based and domestic violence [126–128]. Despite these efforts, the incidence rates of GBVF crimes remains high. Civil society has played a crucial role in advocating for these laws and initiatives to combat sexual and gender-based violence [116,129]. Delegates acknowledged that African government agencies recognise the need for improvements in the system.

The delegates agreed that healthcare, counsellors, legal professionals, judges, lawyers, law enforcement personnel, policymakers, and stakeholders with economic support are all crucial in addressing GBVF cases and deliberated on several interventions to enhance proficiency in court proceedings. The complexity of GBVF cases and forensic evidence can pose issues in court, as legal professionals may have different levels of comprehension [117,119]. Measures to enhance proficiency involve providing specialised instructions to these critical individuals regarding the scientific principles and interpretation of forensic trace evidence. Implementing explicit protocols for collecting, processing, and presenting forensic trace evidence can improve its utilisation in legal proceedings, supporting fair and equitable results in the African Region [117].

Effective legislation and well-managed DNA databases are pivotal for strengthening the legal system's response to GBVF and other crimes. Legislation should provide clear guidelines on how to deal with rape

survivors and ensure the ethical and transparent collection, storage, and analysis of DNA, focusing on safeguarding the rights of both survivors and suspects. Regulatory frameworks ensure the viability of forensic science practices and processes to improve fairness and justice, reduce wrongful convictions, and maintain confidence [120]. The use of robust DNA databases is instrumental in facilitating efficient and sound investigations and prosecutions in GBVF cases, enabling the swift identification of culprits and exoneration of the innocent. Additionally, the use of sexual assault evidence kits is encouraged as they enhance the quality of DNA collection and help maintain the integrity of the trace evidence during the entire process from sample collection through judicial litigation.

2.6. Models for addressing sexual violence

2.6.1. The panzi one care stop centre model

The delegates of #4FDNAS were introduced to the Panzi One-Stop Centre model (OSC), which surpasses its structural elements by embracing a culture of care centred on survivors and guided by an understanding of trauma [130]. Drawing from this empathetic approach, the Mukwege Foundation disseminates and applies this framework to other vulnerable and war-torn regions, such as the Democratic Republic of Congo and the Central African Republic. OSC is a novel and comprehensive care model that focuses on women and girls who have experienced violence. At Panzi Hospital in the Eastern Democratic Republic of Congo, the OSC continues its efforts by providing medical care to girls and women who have suffered rape and severe physical injury. OSC encompasses four critical areas of care: medical, psychosocial, legal, and socioeconomic. These areas work together cohesively to address the needs of the survivors.

The OSC customises care plans to facilitate survivors' health and societal reintegration by attentively listening to their narratives. In addition to offering extensive individual care, the OSC is a platform for promoting healthy lifestyles at individual and community levels. If rigorously applied to all healthcare systems, this method could help achieve a universal right to health [130]. The OSC represents a holistic, person-centred care model that empowers women affected by sexual, physical, and mental harm to participate actively in their healing journey. Recognised for its success, various countries in the Great Lakes Region have adopted the OSC model following endorsement by regional leaders [131]. Despite challenges, such as integrating mental health into primary care and political barriers to replication, its systematic implementation across healthcare facilities could substantially advance universal healthcare access.

2.6.2. Thuthuzela care centre (TCC)

During the #4FDNAS, reference was made to the one-stop care centre, the Thuthuzela Care Centres (TCC), established in South Africa [132,133]. The TCC service delivery model was established as a multi-disciplinary one-stop centre for survivors of sexual offences and domestic violence. This model addresses the comprehensive management of services for sexual violence survivors and emphasises the importance of placing them at the forefront of service delivery. A survivor-centred approach aims to empower and guide survivors through the criminal justice system, leading to the development of the current TCC model [132,133]. This initiative, a prime example of a transdisciplinary approach to national challenges, is driven by a shared commitment to its goals if fully supported and implemented. Each centre, integrated within a healthcare institution such as a hospital or clinic and connected to one or more police stations, is a result of the collaborative effort between the National Prosecuting Authority (Department of Justice), Department of Health, Department of Social Development, Treasury Department, and NGOs. In close collaboration with social workers, these entities provide essential counselling and support services, furthering the initiative's mission and inspiring commitment and motivation [122,133,134].

Nevertheless, there are doubts about the government's dedication to

fulfilling this pledge. Delegates emphasised that currently there are insufficient TCC in certain regions of South Africa and some are often under-resourced. The success of the TCC Blueprint depends on having sufficiently trained personnel at every stage. Additionally, some TCCs are not available 24/7, necessitating survivors to return for certain services during office hours. Transportation to access the TCCs also poses a significant challenge, impacting court visits and follow-up psychosocial support, particularly for low-income or unemployed survivors [132–135].

A sustainable and consistent funding environment is essential to deliver the necessary services at all TCC-like facilities, with funding for NGOs and after hour medical personnel being another critical issue [135]. Coordination among departments needs to be improved to enhance the efficiency of comprehensive service delivery. The enforcement of progressive laws within the criminal justice system is inconsistent, which hinders the timely resolution of cases [135]. To tackle and reduce the occurrence of rape and other sexual offences in a country, it is crucial to have efficient legal procedures and training thereon, (e.g. including, but not limited to, better conviction rates and impose stricter sentences), and strong support networks for survivors [135].

3. Forensic nursing

Forensic nursing is a specialised field that integrates the concepts and principles of law and nursing sciences to provide trauma-based, empathetic services for GBV survivors [136–138]. Forensic nurses are specifically skilled at assisting with the examination of GBV survivors. The delegates emphasised that one of the difficulties faced in Africa with sexual violence examinations was the scarcity of adequately trained medical professionals in terms of both education and experience. Medical practitioners, some of whom possess a Diploma in Clinical Forensic Medicine (Dip Fr Med) administered by the Colleges of Medicine of South Africa (CMSA), perform these examinations; however, this certification is not obligatory [138]. The inadequate trained number of medical practitioners available lead to untrained doctors being relied on to offer care and examination of these survivors during after- hours periods. Furthermore, the compensation for these professionals is inadequate and inappropriately structured, exacerbating disparities and comprising in healthcare and forensic evidence collection [136–139].

The lack of quality assurance and clinical governance structure is evident in the few forensic nursing personnel available in South Africa. Some nurses possess more experience than doctors but are not accredited nor adequately appropriately recognised or compensated for their forensic expertise. A forensic nursing course is neither registered nor accredited across the African region, and lengthy administrative processes, a lack of political will, and no updates to the system hinder its formalisation [136–139]. Delegates discussed minimum standards and agreed that a forensic nurse training program must include the completion of an approved postgraduate forensic nursing course with topics to be included but not limited to the following modules:

1. Medico-legal law, statutory obligations, and ethics – specific to the region.
2. Traumatology in Clinical forensic practice – identification and documentation of wounds, pelvic and anal exams, and determining intoxication.
3. Sexual violence medical forensic examinations, age assessment, and identification of abuse (vulnerable groups such as the mentally ill, women, children, and the elderly).
4. Medical care after sexual violence/rape and follow-up procedures.
5. Forensic evidence collection and documentation, including forensic photography.
6. Forensic evidence handling and chain of custody.
7. Role of investigative and legal processes in sexual violence cases.
8. Expert opinion training for courtroom testimony.
9. Psychosocial counselling and support.

4. DNA track recommendations

Through the focus group discussions at the symposium, several recommendations were made by delegates to enhance collaboration and sharing of DNA and forensic data within and between African countries to support criminal investigations and humanitarian efforts to identify unidentified human remains and missing persons. A collective vision, dubbed the “African Forensic Science Vision”, was suggested to advance forensic sciences in the region. The proposed vision aims to facilitate capacity building in the region to meet Africa’s modern security and humanitarian needs. Further, the initiative will promote equivalence in the core operational framework of forensic science practice at the national and local levels and consistency across the region. Delegates recognised that such a unified vision would ensure the validity and reliability of forensic results across different African states.

The proposed elements of the forensic science vision for Africa encompassed five key areas:

1. Infrastructure: Delegates called for setting minimum infrastructure requirements for all forensic science activities by relevant stakeholders, including national and regional law enforcement agencies, forensic science institutes, the justice systems, government bodies, accreditation bodies, professional forensic science societies, and criminal justice practitioners. The prioritised infrastructural needs noted included improved systematic unidentified human remains and missing person’s investigations (including routine data and sample collection), crime scene support, laboratory analysis, creation of intelligence databases, allele frequency databases, interpretation/evaluation, communication of scientific evidence, and research support.
2. Expertise: Delegates proposed defining a minimum level of expertise for providers/practitioners to ensure respect for expertise from all countries. Given the multidisciplinary nature of forensic science, it was suggested that minimum expertise should include a combination of formal education in the sciences or relevant discipline, general and specialist training in forensic science, competency/proficiency testing, and relevant continuous professional development.
3. Quality Standards: It was noted that very few forensic science laboratories have achieved formal accreditation in the region. Delegates called for minimum quality standards and accreditation requirements based on the ILAC G19 and the ISO standards (ILAC G19 ISO17020, ISO17025, ISO18385, ISO21043) [140–144] to be defined by national and regional accreditation bodies and relevant forensic science authorities. Although formal accreditation may be absent, delegates recognised that all forensic activities must be consistent with the requirements of international standards, and a robust quality management system must be in place to ensure the reliability of scientific evidence and safeguard against the use of misleading evidence.
4. Laws and Policies: The DNA database policy panel and delegates noted the limited transnational exchange of DNA data in the region, partly due to the absence of dedicated legislative frameworks or inconsistent policies. It was proposed that to harmonise laws and policies to facilitate regional cooperation, a) Laboratories in Africa should adopt research-informed core STR/SNP markers; b) African Union (AU) member states should establish a legislative instrument on transnational exchange of forensic data, similar to the European Union (EU) Prüm Framework [145]; and c) National laws and policies on the use of forensic evidence should be future proof, covering data collection, retention, sharing, and protection, criminal procedures, substance control and emerging technologies, such as forensic investigative genetic genealogy (FIGG) [146–148]. The principles to underpin the regulation and use of forensic science and national legislative frameworks, especially the use of DNA, was referenced by experts.

5. Oversight/Operational Framework: In line with the principles of the effective regulation of the use of forensic evidence (specifically DNA evidence), delegates noted the need to safeguard independent forensic practices to ensure transparency, fairness, and accountability as forensic services in Africa are mainly managed or funded by the police. It was emphasised that such a framework may minimise the risk of miscarriage of justice and protect the integrity of forensic science. Irrespective of the party that has instructed the scientist, it is important that the scientist is impartial and recognise his/her over-riding duty to justice.

5. GBVF recommendations

Concerning GBVF interventions in the region, the symposium delegates emphasised coordinated efforts in all African countries for the immediate establishment of extensive reforms in the criminal justice system to provide more robust support for survivors of GBV and victims of femicide. Conducting comprehensive investigations, offering sufficient assistance during initial healthcare and evidence collection and legal proceedings, and honouring governmental commitments are essential measures to enhance conviction rates and, ultimately, decrease the occurrence of rape and other sexual offences. Additionally, accountability from all stakeholders throughout a case process is crucial for improving outcomes and moving closer to eradicating GBVF. More partnerships and transdisciplinary and multiagency approaches are needed to address these national challenges effectively. With their transdisciplinary approach, the Panzi One Care Stop Model and the TCC model could positively impact the GBVF crisis in Africa if implemented more widely and well-resourced. Success requires leadership, collaboration and accountability from all parties involved.

6. Conclusions

African governments must use forensic DNA analysis effectively and efficiently to examine DNA trace and create networks for sharing of forensic data. Initiatives promoting collaboration among African countries are beneficial and essential, especially in fighting cross-border crime and addressing humanitarian challenges [149]. Collaboration enhances the effectiveness of forensic investigations and the identification of unidentified human remains and missing persons improves criminal justice and humanitarian outcomes, emphasising our shared responsibility in this endeavour. Improvements are required in regulating forensic sciences in Africa, focusing on setting minimum standards and conducting peer reviews. The #4FDNAS provided a unique platform for forensic stakeholders across Africa to discuss existing capabilities, critical challenges and identify collective solutions to enhance regional capacity building.

An African forensic science vision supported by key action plans, spearheaded by the African Union agencies, regional economic development communities, government organisations, professional associations, and NGOs, is proposed to foster and bolster the growth of forensic science expertise in Africa. Such a unified programme will enhance, and support investigations and humanitarian endeavours aimed at addressing a range of crimes and challenges, including GBVF, sexual violence associated with armed conflicts, large-scale migration, drug and human trafficking, terrorism, and natural disasters.

CRedit authorship contribution statement

J.H. Smith: Writing – review & editing, Writing – original draft, Conceptualization. **V. Lynch:** Writing – review & editing. **A.O. Amankwaa:** Writing – review & editing. **B. Budowle:** Writing – review & editing. **S.A. Fonseca:** Writing – review & editing. **S.K. Shako:** Writing – review & editing. **I. Molefe:** Writing – original draft.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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