

The Dangers of Convictions Based on a Single Piece of Forensic Evidence

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Abstract

The overall goal of the criminal justice system is to ensure that perpetrators of crimes are duly punished and that victims of crimes are duly exonerated. As part of the effort to achieve this goal, the forensic disciplines have become very important in criminal investigations and prosecutions in identifying the guilty and in exonerating the innocent. There is a growing number of cases where people have been convicted based on a single piece of forensic evidence. However, some of the convictions have been found to be wrong, largely, due to the lack of adequate scientific validation of the forensic science methods. Some of these methods include latent fingerprint analysis, bite mark analysis, microscopic hair analysis and firearms identification. This article critically examines the application of forensic evidence in criminal prosecutions and highlights the dangers of convictions based on a single piece of forensic evidence. The findings of recent reports, such as, the National Academy of Sciences (NAS) 2009 Report and President's Council of Advisors on Science and Technology (PCAST) 2016 Report, confirm the critical role and broad scope of these forensic pattern-matching methods. The reports also indicate flaws that affect the accuracy of these methods, such as, inadequate scientific validation, coincidental results (erroneous match), human, laboratory and interpretive errors etc. Therefore, this article argues that the court should follow a cautionary approach when relying on a single piece of forensic evidence and that strong corroboration with other forms of evidence linking the accused to the crime should be required.

Keywords

Forensic evidence; wrongful conviction; expert witness; pattern-matching methods; criminal justice system.

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1 Introduction

Forensic¹ evidence refers to physical evidence that is obtained either at the scene of a crime or from the victim of a crime and analysed by using scientific methods and processes in a crime laboratory in order to produce scientifically based information that is then presented in court by an expert witness or as an expert's testimony² in order to link the accused to the crime.

In this way forensic evidence contributes immensely to the criminal justice system. Despite these contributions, there is a growing number of cases in different jurisdictions where people have been convicted based on a single piece of forensic evidence.³ Some of the convictions have been found to be wrong, largely, due to the lack of adequate scientific validation of the forensic evidence.⁴

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¹ The word "forensic" is derived from the Latin term *forensis* which means of the forum. This is a public place where the ancient Roman senate discussed and debated on political and policy issues. It was also used as a court to resolve legal issues. The term "forensic science" has been defined "as the application of scientific or technical practices to the recognition, collection, analysis, and interpretation of evidence for criminal and civil law or regulatory issues. See also Meintjes-van der Walt 2006 *SACJ* 152-154 and PCAST 2016 https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/PCAST/pcast_forensic_science_report_final.pdf 21.

² Kaplan and Puracal 2018 *Alb L Rev* 899-900; NAS *Strengthening Forensic Science* 5; Bell *et al* 2018 <http://www.pnas.org/content/pnas/115/18/4541.full.pdf> 4541-4544; Sangero and Halpert 2007 *Jurimetrics J* 43.

³ See, for example, *Regina v Adams* 1996 2 Cr App R 467. Also see Sangero and Halpert 2007 *Jurimetrics J* 46 and Griffin 2001 *Am U Int'l L Rev* 1241-1308.

⁴ See, for example, *Commonwealth v Cowans* 756 NE 2D 622 (Mass App Ct 2001) and *State v Krone* 897 P 2d 621 (Ariz 1995). See also the reports from the US National Registry of Exonerations (NRE) and the US Innocence Project which show a record of more than 2,270 wrongful convictions since 1989. The reports also confirmed that unvalidated or improper forensic methods have contributed to the conviction of innocent persons. US Innocence Project 2016 https://www.innocenceproject.org/wpcontent/uploads/2016/02/DNA_Exonerations_Forensic_Science.pdf; US Innocence Project date unknown <https://www.innocenceproject.org/causes/misapplication-forensic-science/>; Mnookin 2018 <https://ssrn.com/abstract=3300354> 99-118.

Forensic evidence is categorised as circumstantial evidence as it relies on inferences to connect it to a conclusion of fact.⁵ This involves a witness,⁶ in this case, a forensic expert witness (examiner) analysing and laying the scientific foundation for the forensic evidence when it is taken into consideration in court.⁷ The expert witness gives testimony in court based on his or her acquired skills and expertise on the application of forensic science methods/techniques to the evidence obtained at a crime scene.⁸

It is a general rule of law that a person can be convicted on the evidence of a single witness. For example, section 208 of *the South African Criminal Procedure Act 51 of 1977* provides that: "An accused may be convicted of any offence on the single evidence of any competent witness". However, it is trite that "...the evidence of a single witness should be approached with caution, and his or her merits being weighed against factors which militate against his or her credibility".⁹ It is also trite that "a court should not easily convict upon the evidence of a single witness unless it is substantially satisfactory in all material respects or unless it is corroborated".¹⁰ By corroboration is meant "other evidence which supports the evidence of the single witness and which detracts from the evidence of the accused and renders it less probable with regard to one or more of the issues in dispute".¹¹

The need for caution may also be increased by other factors such as the state's failure to adduce real evidence which should have been available.¹² This is pointed out in *S v Msane* where it was stated that:

The tendency of prosecutors to take short-cuts by not adducing all the available evidence should be discouraged by magistrates. The feckless presentation of the case for the prosecution is subversive of proper criminal justice. It creates alike the risk of the acquittal of guilty persons and the conviction of innocent ones.¹³

⁵ Zeffertt and Paizes *South African Law of Evidence* 101-102, 172.

⁶ A witness is a person who gives evidence in court either for the prosecution or the defence. See Hornby *Oxford Advanced Learner's Dictionary* 1729.

⁷ Kaplan and Puracal 2018 *Alb L Rev* 899-900.

⁸ Schwikkard and Van der Merwe *Principles of Evidence* 102, 594; Kaplan and Puracal 2018 *Alb L Rev* 899-900.

⁹ See *S v Stevens* 2005 1 All SA 1 (SCA) para 17. See also *S v Sauls* 1981 3 SA 172 (A) 180E-G where Diemont JA established the approach to the "cautionary rule".

¹⁰ See *S v Ganie* 1967 4 SA 203 (N) 206H and *S v Artman* 1968 3 SA 339 (A) 341 as quoted in *B v S* 2016 ZAFSHC 100 (12 May 2016) 55-58.

¹¹ *R v W* 1949 3 SA 773 (AD) 778/9 as quoted in *Cele v S* 2010 ZAKZPHC 26 (25 May 2010).

¹² See *S v Msane* 1977 4 SA 758 (N).

¹³ *S v Msane* 1977 4 SA 758 (N) 759C-E. See also *Nkuna v S* 2018 ZALMPPHC 21 (11 May 2018); *S v Sauls* 1981 3 SA 172 (A) 180 C-H.

The question of whether a single piece of forensic evidence is enough to convict an accused person, lies at the heart of this article. Forensic evidence implies the potential dangers of the wrongful conviction of an innocent person¹⁴ based on evidence that is probabilistic in nature and which has the possibility of coincidental results (random match), the possibility of laboratory errors and interpretive errors.¹⁵

The aim of this article is critically to examine the application of forensic evidence in criminal prosecutions and to pay particular attention to the dangers of convictions based on a single piece of forensic evidence. The article focuses on forensic pattern-matching methods, specifically latent fingerprint analysis, bite mark analysis, microscopic hair analysis and firearms identification. These methods are referred to as "forensic feature-comparison methods"¹⁶ by the President's Council of Advisors on Science and Technology (PCAST).¹⁷ The focus in this article on these methods is prompted by the fact that they are forensic tools commonly used during

¹⁴ According to *Oxford Advanced Learner's Dictionary* innocent means a person not guilty of a crime and "wrongful" is a term often used in a legal situation, it means for something to be mistaken, incorrect or inaccurate. Therefore, wrongful conviction is the wrongful act of finding a person guilty of a crime in court. Griffin also defines the terms "innocent" and "wrongful conviction" to mean "someone who is neither factually nor legally responsible for a charged crime" and "a conviction that is both factually and legally inaccurate". This definition of terms is intended for better understanding of the scope of the dangers of conviction based on a single piece of evidence. See Hornby *Oxford Advanced Learner's Dictionary* 327, 787, 1744 and Griffin 2001 *Am U Int'l L Rev* 1243 fn 2.

¹⁵ Sangero and Halpert 2007 *Jurimetrics* J 55.

¹⁶ Forensic feature-comparison methods refer to "the wide variety of methods that aim to determine whether an evidentiary sample (e.g. from a crime scene) is or is not associated with a potential source sample (e.g. from a suspect) based on the presence of similar patterns, impressions, features or characteristics in the sample and the source". See PCAST 2016 https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/PCAST/pcast_forensic_science_report_final.pdf 23 and Kaplan and Puracal 2018 *Alb L Rev* 898.

¹⁷ The terms "matching" and "comparison" are two words often used interchangeably especially in the context of the identification and individualisation of a particular individual and a piece of forensic evidence. Also, important to note that in forensic science identification involves comparing "a questioned item of evidence to an exemplar from a known source and judge whether they appear so alike that they can be said to match". It also involves assessing "the meaning of that reported match: What is the probability that the questioned and the known originated from the same source?" Individualisation on the other hand "implies uniqueness". It "refers to absolute specificity and absolute identification". The uniqueness of a particular sample simply shows that the characteristics of the sample is distinct from others. For further discussion, see Saks and Koehler 2008 *Vand L Rev* 199, 205; Meintjes-van der Walt 2006 *SACJ* 152-153; and Kaye 2010 *Brook L Rev* 1165.

criminal investigations and prosecutions.¹⁸ These forensic methods belong to the "same broad scientific discipline" which involves forensic experts "measuring and comparing features" to identify the accused person.¹⁹ In addition to this, some of the forensic experts' testimony based on using these forensic science methods, have been linked to cases of wrongful conviction of innocent persons.²⁰ Furthermore, there is an increased concern regarding the lack of adequate standard(s) for the scientific validity and reliability²¹ of pattern-matching methods, as this can result in the problem of a high possibility of error in the interpretation of evidence, threat of bias and absence of reliable operational procedures.²² By scientific validity and reliability, is meant that each forensic pattern-matching method must have been subjected to empirical testing that provides valid estimates of the error rate of each method as well as of the possibility of an accurate match.²³

This article does not consider DNA analysis which is recognised as the "gold standard" for forensic feature-comparison methods.²⁴ DNA analysis is recognised for having a higher capacity to support conclusions about individualisation²⁵ which refers to matching forensic evidence to a particular

¹⁸ PCAST 2016 https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/PCAST/pcast_forensic_science_report_final.pdf 23; Mnookin 2018 <https://ssrn.com/abstract=3300354> 102.

¹⁹ PCAST 2016 https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/PCAST/pcast_forensic_science_report_final.pdf 21, 23.

²⁰ See, for example, *Commonwealth v Cowans* 756 NE 2D 622 (Mass App Ct 2001) where fingerprint identification evidence contributed to the wrongful conviction of the accused person, but he was later exonerated by DNA evidence and *State v Krone* 897 P 2d 621 (Ariz 1995) where bitemark analysis led to the wrongful conviction of the accused person, but DNA analysis exonerated the accused after ten years. Also see Garrett and Neufeld 2009 *Va L Rev* 1-97. (The study found that there was a large number of cases where forensic experts provided invalid testimony at trial this is regarding testimony with conclusions misstating empirical data or wholly unsupported by empirical data).

²¹ The term validity refers "to the ability of a test procedure to measure what it is supposed to measure [that is] its accuracy", while reliability refers "to whether the same results are obtained in each instance in which the test is performed [that is] its consistency". See Giannelli 1980 *Colum L Rev* 1201 fn 20.

²² PCAST 2016 https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/PCAST/pcast_forensic_science_report_final.pdf 23; NAS *Strengthening Forensic Science* 87; Kaplan and Puracal 2018 *Alb L Rev* 904-905.

²³ PCAST 2016 https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/PCAST/pcast_forensic_science_report_final.pdf 46.

²⁴ PCAST 2016 https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/PCAST/pcast_forensic_science_report_final.pdf 26; Kaplan and Puracal 2018 *Alb L Rev* 904-905.

²⁵ The National Academy of Sciences notes that: "With the exception of nuclear DNA analysis, however, no forensic method has been rigorously shown to have the capacity to consistently, and with a high degree of certainty, demonstrate a connection between evidence and a specific individual or source". See NAS

accused person or exonerating persons that were wrongfully convicted of a crime.²⁶ It is important to note that this is not to state that DNA analysis is error-free,²⁷ but rather to state that when compared to the other forensic feature-comparison methods, DNA analysis has a higher standard for the validity and reliability of evidence.

This article considers the development and interpretation of the courts regarding the admissibility of forensic evidence in jurisdictions such as the United States, England and Wales²⁸ and South Africa. The interest in these jurisdictions is because they operate an adversarial system which involves the prosecution and the defence conducting vigorous cross-examination, presenting contrary evidence, and careful instruction regarding the burden of proof in criminal cases.²⁹ The United States offers a broad picture of forensic science with a large number of cases that have used different forensic pattern-comparison methods. For example, the case of *Frye v United States*³⁰ and *Daubert v Merrell Dow Pharmaceuticals, Inc*³¹ provide landmark decisions on the development and interpretation of standards pertaining to the admissibility of scientific evidence.³² Some of the judicial decisions have influenced the law and standards for scientific evidence in other jurisdictions, such as England and South Africa.³³ Also, the interest in England is mainly because South African law draws much of its history from the English law.³⁴ South African law of evidence is based broadly on the English system and therefore expert evidence is admissible whenever it is relevant.³⁵ This is different from the United States approach where the

Strengthening Forensic Science 7. Also, some of the reports that have highlighted the significance of DNA analysis include: PCAST 2016 https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/PCAST/pcast_forensic_science_report_final.pdf 26; Connors *et al* 1996 <https://www.ncjrs.gov/pdffiles/dnaevid.pdf>; NAS *Strengthening Forensic Science 7*, 87.

²⁶ NAS *Strengthening Forensic Science 7* and Connors *et al* 1996 <https://www.ncjrs.gov/pdffiles/dnaevid.pdf>.

²⁷ Elster 2017 <https://daily.jstor.org/forensic-dna-evidence-can-lead-wrongful-convictions/> (points out that DNA evidence sometimes can be misused or misunderstood which can lead to a miscarriage of justice).

²⁸ When the rest of the text refers to England it implies England and Wales.

²⁹ NAS *Strengthening Forensic Science 10*; Griffin 2001 *Am U Int'l L Rev* 1244; Langbein *Origin of Adversary Criminal Trial* 1-3.

³⁰ *Frye v United States* 293 F 1013 (DC Cir 1923).

³¹ *Daubert v Merrell Dow Pharmaceuticals, Inc* 1993 509 US 579 (hereafter *Daubert v Merrell Dow Pharmaceuticals, Inc*).

³² NAS *Strengthening Forensic Science 88*.

³³ Bernstein 1996 *Yale J Int'l L* 125-126.

³⁴ Zeffertt and Paizes *South African Law of Evidence* 3-14.

³⁵ *Nduna v S* 2010 ZASCA 120 (30 September 2010), the court stated that evidence is only admissible if relevant to an issue in a case; *S v Gokool* 1965 3 SA 461 (N) 457G.

expert evidence must not only be relevant, but also reliable.³⁶ However, as the United States also falls within the Anglo-American family of jurisdictions, worthwhile comparative lessons can be learnt from its jurisprudence regarding the validity and reliability of forensic feature comparison evidence.

This article proceeds as follows: part II provides the legal justification surrounding the burden of proof, the admissibility of forensic expert evidence and the evaluation of such evidence in determining the weight that should be attached to it. Part III provides a general overview of the forensic feature-comparison methods: latent fingerprint analysis, bite mark analysis, hair analysis and firearm identification and highlights areas of shortcomings when using the method. In part IV the dangers of conviction based on a single piece of forensic evidence is briefly considered.

2 The admissibility of forensic expert evidence in criminal cases

The law of evidence and the adversarial criminal procedure system regulate criminal proceedings in common law jurisdictions.³⁷ In criminal cases, the general procedural rule of law is that the burden of proof rests on the prosecution and the standard of proof of the guilt of the accused must be "beyond reasonable doubt" (using all available evidence including forensic evidence).³⁸ This is confirmed by Sachs J in the case of *S v Baloyi* in stating that:

The requirement that the state [prosecution] must prove guilt beyond a reasonable doubt has been called the golden thread running through the criminal law, and a prime instrument for reducing the risk of convictions based on factual error.³⁹

The success or failure of proving the guilt of the accused beyond reasonable doubt largely depends on the evidence, including the expert testimony, presented in court and the admissibility thereof. The standard for the admissibility of expert testimony derived from scientific methods or techniques, originated in *Frye v United States* where the court established

See also s 210 of the *Criminal Procedure Act* 51 of 1977 which provides that irrelevant evidence is inadmissible.

³⁶ See Part 2: Admissibility of Forensic Expert Evidence in Criminal Cases for more discussion. *Daubert v Merrell Dow Pharmaceuticals, Inc*, where the court ruled that trial judges are to make sure that expert testimony is not only relevant but reliable.

³⁷ Griffin 2001 *Am U Int'l L Rev* 1241.

³⁸ Schwikkard and Van der Merwe *Principles of Evidence* 17.

³⁹ *S v Baloyi* 2000 2 SA 425 (CC) para 15. Also see *Green v R* 1971 126 CLR 28 32-33 cited in *The Queen v Dookheea* 2017 HCA 36; 91 ALJR 960 para 20.

the general acceptance test.⁴⁰ The test implies that an expert witness must show that his or her testimony is generally accepted in the relevant scientific community.⁴¹ This test became the dominant standard⁴² and precedent for the admissibility of scientific testimony.⁴³ Although the general acceptance test was embraced by some courts,⁴⁴ it, however, had a number of shortcomings, especially relating to the vagueness of the scope of the test and its limited scientific scrutiny.⁴⁵

In 1975, the *Federal Rule of Evidence* was enacted to guide criminal and civil litigations in Federal courts.⁴⁶ Rule 702 provides that:

If scientific, technical, or other specialized knowledge will assist the trier of fact to understand the evidence or to determine a fact in issue, a witness qualified as an expert by knowledge, skill, experience, training, or education, may testify thereto in the form of an opinion or otherwise.⁴⁷

⁴⁰ *Frye v United States* 293 F 1013 (DC Cir 1923) cited in NAS *Strengthening Forensic Science* 88; PCAST 2016 https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/PCAST/pcast_forensic_science_report_final.pdf 40. The court considered the admissibility of a deception test that measured systolic blood pressure which an expert witness sought to introduce as evidence on behalf of the defendant to establish his innocence in the murder trial. The court rejected the evidence, stating that: "...while courts will go a long way in admitting expert testimony deduced from a well-recognized scientific principle or discovery, the thing from which the deduction is made must be sufficiently established to have gained general acceptance in the particular field in which it belongs". The court ruled that the deception test had "not yet gained such standing and scientific recognition among physiological and psychological authorities".

⁴¹ Cooley and Oberfield 2013 *Tulsa L Rev* 285, 287.

⁴² Giannelli 1980 *Colum L Rev* 1207.

⁴³ NAS *Strengthening Forensic Science* 88-89. See also *United States v Scheffer* 1998 523 US 303, No 96-1133 cited in Newton *DNA Evidence and Forensic Science* 75, where the defendant sought to present evidence from a polygraph testing, but the court ruled that "polygraph evidence is not relevant because polygraph testing had still not attained the necessary level of [general] acceptance in the scientific community".

⁴⁴ The support for the general acceptance test was mainly because the test assures of the opinion of well-qualified experts within the particular field of the scientific method; it promotes a degree of uniformity in judicial decision and eliminates possible time-consuming hearings on the validity of scientific methods. See Giannelli 1980 *Colum L Rev* 1207.

⁴⁵ Giannelli notes that the courts discovered that there was a need to determine the parameters of the *Frye* test in terms of "who must find the procedure acceptable, they [the courts] must define exactly what must be accepted, and they [the courts] must determine what methods will be used to establish general acceptance". See Giannelli 1980 *Colum L Rev* 1208; Meintjes-van der Walt 2006 *SACJ* 154. Also see *United States v William* 1978 583 F 2d 1194 para 28.

⁴⁶ PCAST 2016 https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/PCAST/pcast_forensic_science_report_final.pdf 40; NAS *Strengthening Forensic Science* 89.

⁴⁷ NAS *Strengthening Forensic Science* 89.

The standard in Rule 702 contrasts with *Frye's* general acceptance test and this raised questions regarding the acceptable standard for admissibility of forensic expert evidence derived from scientific methods or techniques. Questions in this regard were clarified in *Daubert v Merrell Dow Pharmaceuticals, Inc* when the Supreme Court overruled *Frye's* general acceptance test and ruled that under Rule 702 "a trial judge must ensure that any and all scientific testimony or evidence admitted is not only relevant but reliable".⁴⁸ The court must make "a preliminary assessment of whether the reasoning or methodology underlying the testimony ... properly can be applied to the facts in issue" and whether that reasoning or methodology "rests on a reliable foundation".⁴⁹ This means that "the subject of an expert's testimony should be 'scientific knowledge', so that evidentiary reliability will be based upon scientific validity".⁵⁰ Also, the trial judges must act as "gatekeepers" and confirm the expert's testimony to ensure that it rests on a reliable foundation.⁵¹ In doing so, the judges must consider five factors in evaluating the validity of an underlying scientific method.⁵² The factors include:

- (i) whether a theory or technique can be (and has been) tested;
- (ii) whether the theory or technique has been subjected to peer review and publication;
- (iii) the known or potential rate of error of a particular scientific technique;

⁴⁸ *Daubert v Merrell Dow Pharmaceuticals, Inc* is a civil case brought to court by two children born with birth defects and their parents against Merrell Dow Pharmaceuticals alleging that the children had birth defects as a result of their mothers' prenatal ingestion of Bendectin a drug marketed by Merrell Dow. At the trial, Merrell Dow called an expert witness who testified that Bendectin has been subjected to intensive trials with human and that no evidence existed for teratogenic effects of the in humans. The plaintiffs (Daubert) called eight witnesses who testified on animal studies and comparisons of the chemical structure of Bendectin. They concluded that the drug could cause birth defects. The trial court held that the plaintiff's expert testimony was inadmissible because the scientific evidence was not sufficiently established to be generally accepted in the field to which it belonged. The Court of Appeal affirmed the decision of the trial court citing the *Frye* case. At the Supreme Court, the trial court's decision was reversed. The Supreme Court held that the trial court had applied the wrong standard to assess the admissibility of the plaintiff's expert testimony. The court ruled that the *Federal Rules of Evidence* applied and supersedes the *Frye* test as the standard for admissibility. See NAS *Strengthening Forensic Science* 90.

⁴⁹ Chandler 2013-2014 *Buff Pub Int LJ* 44.

⁵⁰ NAS *Strengthening Forensic Science* 90.

⁵¹ PCAST 2016 https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/PCAST/pcast_forensic_science_report_final.pdf 41.

⁵² PCAST 2016 https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/PCAST/pcast_forensic_science_report_final.pdf 41.

- (iv) the existence and maintenance of standards controlling the technique's operation; and
- (v) a scientific technique's degree of acceptance within a relevant scientific community.⁵³

In *Kumho Tire Co v Carmichael* the court noted that these *Daubert* factors do not constitute a definitive checklist or test and the law grants the court broad latitude to determine whether or not they are "reasonable measures of reliability".⁵⁴ Following the decision in the *Daubert* case, in 2000, the *Federal Rule of Evidence 702* was amended and provides that:

If scientific, technical, or other specialised knowledge will assist the trier of fact to understand the evidence or to determine a fact in issue, a witness who is qualified as an expert by knowledge, skill, experience, training, or education may testify in the form of an opinion or otherwise if:

- (1) the testimony is based on sufficient facts or data;
- (2) the testimony is the product of reliable principles and methods; and
- (3) the expert has reliably applied the principles and methods to the facts of the case.⁵⁵

By this amendment, courts are compelled to question the empirical research foundation of all expert testimony presented in court and to "exclude opinions which are connected to existing data only by the *ipse dixit* of the expert".⁵⁶

The standards for the admissibility of forensic evidence specifically in the *Daubert* case and the *Federal Rule of Evidence 702* have influenced the reasoning of the courts in the United States and other jurisdictions. The South African approach to the admissibility of an expert witness's testimony is different. The South African law of evidence, which governs expert testimony, is broadly based on the English system and therefore expert evidence (including evidence based on pattern-matching forensic methods) will be admissible whenever it is relevant and if it can be of assistance to the court.⁵⁷ Section 210 of the *South African Criminal Procedure Act 51* of

⁵³ PCAST 2016 https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/PCAST/pcast_forensic_science_report_final.pdf 41.

⁵⁴ *Kumho Tire Co v Carmichael* 1999 526 US 137; NAS *Strengthening Forensic Science* 10-11.

⁵⁵ Cooley and Oberfield 2013 *Tulsa L Rev* 288-289.

⁵⁶ Cooley and Oberfield 2013 *Tulsa L Rev* 288-289. The term "*ipse dixit*" simply means an assertion made by an expert without any proof.

⁵⁷ See *Nduna v S* 2010 ZASCA 120 (30 September 2010), the court stated that evidence is only admissible if relevant to an issue in a case; *S v Gokool* 1965 3 SA 461 (N) 457G.

1977 also provides that: "No evidence as to any fact, matter or thing shall be admissible which is irrelevant or immaterial and which cannot conduce to prove or disprove any point or fact at issue in criminal proceedings". Therefore, reliability is not considered as a prerequisite for the admissibility of forensic evidence in South Africa.⁵⁸ However, Edmond and Meintjes-van der Walt point out that the reliability of evidence "will be explored effectively during trial, through cross-examination and/or by contrary (ie rebuttal) expert evidence that may be adduced by another party".⁵⁹ In addition to this, Schwikkard and Van der Merwe explain that the court must be satisfied that:

(a) the [expert] witness not only has specialist knowledge, training, skill or experience but can furthermore, on account of these attributes or qualities, assist the court in deciding the issues; (b) that the witness is indeed an expert for the purpose for which he is called upon to express an opinion; (c) that the witness does not or will not express an opinion on hypothetical facts, that is facts which have no bearing on the case or which cannot be reconciled with all the other evidence in the case.⁶⁰

The lack of a reliability test in South Africa, contrasts with the standards in the *Daubert* case which are designed to ensure greater caution.⁶¹ Despite the fact that the standards are guidelines subject to the discretion of the courts, regarding the weight (reliability) that should be attached to the forensic evidence, specifically as far as forensic pattern-matching methods are concerned, the South African legal system has much to learn from the admissibility criteria set out in *Daubert*.

2.1 The scientific validity and reliability of forensic evidence

The use of forensic science, specifically in criminal prosecutions, according to the PCAST Report, require that a high standard be satisfied.⁶² The established standard in the *Daubert* case and Rule 702 of the *Federal Rules of Evidence* is that expert testimony should be based, among other things on the application of reliable principles and methods that are scientifically valid.⁶³

According to Giannelli, the reliability of forensic (scientific) evidence depends on three factors:

⁵⁸ Edmond and Meintjes-van der Walt 2014 *SALJ* 113.

⁵⁹ Edmond and Meintjes-van der Walt 2014 *SALJ* 113.

⁶⁰ Schwikkard and Van der Merwe *Principles of Evidence* 102.

⁶¹ Sangero 2018 *Ga St UL Rev* 1203.

⁶² PCAST 2016 https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/PCAST/pcast_forensic_science_report_final.pdf 4, 21.

⁶³ PCAST 2016 https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/PCAST/pcast_forensic_science_report_final.pdf 4, 21.

- (i) the validity of the underlying principle
- (ii) the validity of the technique applying that principle
- (iii) the proper application of the technique on a particular occasion (this is regarding an examination of the functioning of any instrument employed in the technique to ensure the accuracy of results; adherence to the correct procedures; qualification of experts conducting the procedure and/or interpreting the results).⁶⁴

Giannelli rightly notes that the first two factors are critical considerations for the admissibility of evidence derived from a novel scientific principle and technique.⁶⁵ This is because once forensic or scientific evidence is established as reliable, the court thereafter may take judicial notice of the validity of the principles and techniques.⁶⁶

The PCAST Report, which is a more recent study, provides a broader context of the standards for scientific validity and reliability, including the three factors for the reliability of scientific evidence discussed above.⁶⁷ Scientific validity is described as a method [principle or technique] which "has shown, based on empirical studies, to be reliable with levels of repeatability, reproducibility, and accuracy that are appropriate to the intended application."⁶⁸ In other words, a method (such as fingerprint identification or bitemark analysis) is valid if it can, by means of empirical testing distinguish between a guilty person and an innocent person.⁶⁹ Scientific reliability, on the other hand, means consistency of a method, in terms of different experts obtaining the same result each time a method is performed in a different case.⁷⁰

Most importantly, the accuracy of a forensic method has to be measured based on appropriate empirical testing. Therefore, an expert's conclusions that two samples are similar or dissimilar without valid estimates of accuracy, is scientifically meaningless.⁷¹ Such conclusions have "no

⁶⁴ Giannelli 1980 *Colum L Rev* 1197-1250; Sangero 2018 *Ga St UL Rev* 1134; Cooley and Oberfield 2013 *Tulsa L Rev* 288-289; Mnookin 2018 <https://ssrn.com/abstract=3300354> 99-118.

⁶⁵ Giannelli 1980 *Colum L Rev* 1201; Chandler 2013-2014 *Buff Pub Int LJ* 46.

⁶⁶ Giannelli 1980 *Colum L Rev* 1202; Chandler 2013-2014 *Buff Pub Int LJ* 46.

⁶⁷ PCAST 2016 https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/PCAST/pcast_forensic_science_report_final.pdf 4, 47-48.

⁶⁸ PCAST 2016 https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/PCAST/pcast_forensic_science_report_final.pdf 48.

⁶⁹ Sangero 2018 *Ga St UL Rev* 1134.

⁷⁰ Sangero 2018 *Ga St UL Rev* 1134.

⁷¹ PCAST 2016 https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/PCAST/pcast_forensic_science_report_final.pdf 46.

probative value and considerable potential for prejudicial impact.⁷² Also, the appropriate empirical testing employed by an expert cannot be substituted with training, personal experiences, professional practices or inference from casework.⁷³

3 A brief overview of some forensic pattern-matching methods

3.1 Latent fingerprint analysis

Latent fingerprints are said to be "unique patterns" made from "a complete or partial friction-ridge impression" on the fingers and thumbs of a person.⁷⁴ During criminal investigations, "a residue of oily secretions that corresponds to the ridges on the fingers..." are usually found on surfaces, such as, a doorknob, a drinking glass or a computer keyboard etc at the crime scene.⁷⁵

A latent print examiner often uses the "conventional procedure" known as the ACE-V (Analysis, Comparison, Evaluation and Verification) to examine the impression of friction ridge of the unknown latent print obtained at the crime scene and the fingerprint of the accused.⁷⁶ The conclusions with regard to whether or not a similarity exists between the prints are presented in court as the examiner's testimony.

⁷² PCAST 2016 https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/PCAST/pcast_forensic_science_report_final.pdf 46.

⁷³ PCAST 2016 https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/PCAST/pcast_forensic_science_report_final.pdf 46, 53.

⁷⁴ Newton *DNA Evidence and Forensic Science* 16-19; Champod and Chamberlain "Fingerprints" 57-58; PCAST 2016 https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/PCAST/pcast_forensic_science_report_final.pdf 87-103; National Forensic Science Technology Center date unknown <http://www.forensicssciencesimplified.org/prints/Fingerprints.pdf>.

⁷⁵ Newton *DNA Evidence and Forensic Science* 16. According to the National Forensic Science Technology Center, a common method for "discovering and collecting latent prints is by dusting a smooth or nonporous surface with fingerprint powder (black granular, aluminium flake, black magnet etc). If any prints appear, they are photographed... and then lifted from the surface with clear adhesive tape. The lifting tape is then placed in a latent lift card to preserve the print". See National Forensic Science Technology Center date unknown <http://www.forensicssciencesimplified.org/prints/Fingerprints.pdf> 1-6.

⁷⁶ The fingerprints are usually taken by an enforcement officer ie police officer using an ink pad and a white identification card or Automated Fingerprint Identification System (IAFIS). See Kaye *et al* 2012 <https://commons.erau.edu/publication/1222/> 1-8 and Budowle, Buscaglia and Swartz Perlman 2006 https://archives.fbi.gov/archives/about-us/lab/forensic-science-communications/fsc/jan2006/research/2006_01_research02.htm.

The latent print identification method is based on the premise that no two people, including identical twins, have the same fingerprint patterns.⁷⁷ This implies that the friction ridge pattern of a latent print left at a crime scene should match to the fingerprint of the person who committed the crime.⁷⁸ The friction ridge on the fingers are said to be unique and permanent.⁷⁹ By the assumption of uniqueness and permanence, latent print identification is argued to be a relatively reliable forensic pattern-matching method.⁸⁰

The latent print method is well- established in the United States and it has been admitted by the courts for many years.⁸¹ It is a well-recognised forensic method and is also used in criminal cases in South Africa. The court in *S v Mbatha* notes that the latent fingerprint testimony must be presented by an expert witness in criminal proceedings.⁸² The court in *S v Gumede* specified the duty of courts when assessing evidence of fingerprint experts as follows:

The courts must, first be satisfied that the witness is competent to give evidence, that he is properly trained and has sufficient experience. Secondly, it must be satisfied as to the origin of the sets of fingerprints that are being compared, meaning the set that was found at the scene of the crime and the set of the accused. Thirdly, it must be satisfied that the expert conducted a proper enquiry in comparing the two sets and that he is capable of referring to sufficient points of similarity.⁸³

In order to establish the guilt of the accused and for the courts to be sufficiently satisfied with the identification of the accused, it is common practice for the South African courts to accept at least seven points of similarity as sufficient evidence.⁸⁴ It should be noted that there is no general consensus or standard with regard to matching points of similarities. While

⁷⁷ Newton *DNA Evidence and Forensic Science* 16; PCAST 2016 https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/PCAST/pcast_forensic_science_report_final.pdf 88; Kaplan and Puracal 2018 *Alb L Rev* 911 and National Forensic Science Technology Center date unknown <http://www.forensicsciencesimplified.org/prints/Fingerprints.pdf> 1-6.

⁷⁸ Kaplan and Puracal 2018 *Alb L Rev* 911.

⁷⁹ Budowle, Buscaglia and Swartz Perlman 2006 https://archives.fbi.gov/archives/about-us/lab/forensic-science-communications/fsc/jan2006/research/2006_01_research02.htm.

⁸⁰ Cole 2006 *Golden Gate UL Rev* 39-41. Also see NAS *Strengthening Forensic Science* 43, 140-142 and Kaplan and Puracal 2018 *Alb L Rev* 911.

⁸¹ Mnookin 2003 <https://issues.org/mnookin/> 1 and Koehler 2008 *Hastings LJ* 1086.

⁸² See *S v Mbatha* 2018 ZAGPJHC 502 (13 August 2018) para 64.

⁸³ See *S v Gumede* 1982 4 SA 561 (T) cited in *S v Mbatha* 2018 ZAGPJHC 502 (13 August 2018) para 64.

⁸⁴ See *S v Nala* 1965 4 SA 360 (A) cited in *S v Mbatha* 2018 ZAGPJHC 502 (13 August 2018) para 64. Also see *S v Gumede* 1982 4 SA 561 (T); *S v Nyathe* 1988 2 SA 211 (O) (where the court in both cases accepted that seven points of similarity is sufficient to prove identity).

some countries adopt a point-counting method, some others have rejected this method for a more holistic approach.⁸⁵

Although latent fingerprint analysis has been recognised as a relatively reliable forensic method, it, however, has a number of shortcomings. Firstly, there is a lack of sufficient empirical studies conclusively to establish the uniqueness of the fingerprints.⁸⁶ According to the NAS Report:

Uniqueness does not guarantee that prints from two different people are always sufficiently different that they cannot be confused, or that two impressions made by the same finger will also be sufficiently similar to be discerned as coming from the same source.⁸⁷

Meintjes-van der Walt equally notes that with fingerprint evidence there is no testing conducted that shows the statistical significance of a match (like DNA testing) to establish the probability of two fingerprints being identical.⁸⁸ The PCAST Report found that although fingerprint comparison evidence has a foundationally valid subjective methodology, its false positive rate is substantial and likely to be higher than expected by judicial fact-finders.⁸⁹ It recommended that conclusions need to be accompanied by accurate information about reliability and false positive rates.⁹⁰ Several steps should be taken to further strengthen latent fingerprint analysis, including blind proficiency testing incorporated into regular casework, limiting an

⁸⁵ Epstein also points out that: "[t]here is considerable disagreement among fingerprint examiners as to how many common ridge characteristics should be found before an identification is made. Examiners historically have employed identification standards ranging from between eight and sixteen matching characteristics, or 'points of similarity.' Many examiners, however, including those at the FBI, currently believe that there should be no minimum standard whatsoever and that the determination of whether there is sufficient basis for identification should be left to the subjective judgement of the individual examiner". For example, England and Wales had 16-point fingerprint standards, however, this was abolished in 2000 and identifications are now subject to examiner's judgment. See Epstein date unknown http://www-bcf.usc.edu/~usclrev/html_articles/075302/075302.htm; Meintjes-van der Walt 2006 SACJ 159; Mnookin 2003 <https://issues.org/mnookin/> 1.

⁸⁶ For example, Chandler notes that: "the uniqueness of fingerprints cannot be proven since not everyone's fingerprints are recorded and there is no method to compare the fingerprints that are on record". Chandler 2013-2014 *Buff Pub Int LJ* 50.

⁸⁷ See NAS *Strengthening Forensic Science* 137; Meintjes-van der Walt 2006 SACJ 157-161 and the *United States v Bryon Mitchell* 2004 365 F 3d 215 (3rd Cir) (inconclusive findings to establish the probability of two fingerprints being identical).

⁸⁸ Meintjes-van der Walt 2006 SACJ 162 and PCAST 2016 https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/PCAST/pcast_forensic_science_report_final.pdf 90. Also see Chiwara *Review of Five International Forensic Reports*.

⁸⁹ PCAST 2016 https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/PCAST/pcast_forensic_science_report_final.pdf 101.

⁹⁰ PCAST 2016 https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/PCAST/pcast_forensic_science_report_final.pdf 102-103.

examiner's access to potentially biasing information and examining and documenting the features of the unknown sample before comparing them to a known sample.⁹¹ All of these factors should be considered when determining whether the techniques were validly applied in the case at hand.

The lack of a validated scientific standard is a major issue often raised. This is regarding whether the expert witness provided conclusive empirical testing with a determined error rate and whether the expert's findings are credible given that there can be distortion, or smudging or problems regarding the size and clarity of the latent print.⁹² The ACE-V method provides a broad framework for examining the latent prints in order to prove or disprove a similarity.⁹³ However, it "does not guard against bias; is too broad to ensure repeatability and transparency; and does not guarantee that two analysts following it will obtain the same results".⁹⁴ In addition, the ACE-V method does not stipulate specific measurements, standards or statistical models (like in DNA analysis) and much reliance is on the subjective judgement of the examiner.⁹⁵ For these reasons, when an expert uses the ACE-V method, it does not mean the expert is proceeding in a scientific manner or producing reliable results.⁹⁶

These shortcomings have contributed either in part or in total to the wrongful identification and conviction of innocent persons and this is evident in a number of cases. Perhaps the most publicised is the Brandon Mayfield's case, which concerns the misidentification of Mayfield as the source of an unknown print by the Federal Bureau of Investigations (FBI) Laboratory following the investigation into multiple terrorist attacks on commuter trains in Madrid, Spain.⁹⁷ The Spanish National Police, unable to identify the source of an unknown fingerprint on a bag of detonators found at the crime

⁹¹ PCAST 2016 https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/PCAST/pcast_forensic_science_report_final.pdf 57-58, 102-103.

⁹² NAS *Strengthening Forensic Science* 137; Meintjes-van der Walt 2006 *SACJ* 157; Mnookin 2003 <https://issues.org/mnookin/> 1.

⁹³ NAS *Strengthening Forensic Science* 142.

⁹⁴ It should be noted that bias often occurs during the final stage of verification where the outcome of first examiner's assessment influences the conclusions of other examiners. However, it is recommended that blind verification be conducted to avoid bias. NAS *Strengthening Forensic Science* 142 and Chandler 2013-2014 *Buff Pub Int LJ* 52.

⁹⁵ "The statistical models in existence only account for matching points of minutiae and do not take the clarity of the latent print into consideration." See Chandler 2013-2014 *Buff Pub Int LJ* 51-52; NAS *Strengthening Forensic Science* 137-141.

⁹⁶ NAS *Strengthening Forensic Science* 142.

⁹⁷ US Department of Justice 2006 <https://www.hsdl.org/?abstract&did=458960> 1; Cole 2004-2005 *J Crim L & Criminology* 985-986; Chandler 2013-2014 *Buff Pub Int LJ* 42.

scene, contacted other police agencies including the FBI.⁹⁸ The FBI examiners withdrew their identification of Mayfield after this was discovered it was an error.⁹⁹ Another example is *Mckie v Scottish Ministers*¹⁰⁰ which highlight the systemic problems associated with establishing a conclusive fingerprint matching. In this case, despite the use of different highly experienced experts, the outcome of their findings produced widely divergent opinions on the similarities or dissimilarities of the fingerprints obtained at the crime scene and from the suspect. This is largely due to the lack of a scientific basis for analysing the fingerprint evidence.

Furthermore, latent print experts have traditionally used the words "identification" and "individualisation" to show a positive match of an unknown latent print to a specific known source. However, in November 2015, the US Army's Defence Forensic Science Centre (DFSC) gave notice of a change in the use of these terms and directed that experts should refer to the "the concept of likelihood" in their technical reports and expert witness testimony.¹⁰¹ The reason for this change is mainly because the words imply "absolute certainty" or "100 percent" or that the method boasts a "zero error rate".¹⁰² However, neither of these has been conclusively demonstrated through the purported scientific method (latent print).¹⁰³ The DFSC recognised the need to ensure that expert's testimony on forensic science findings is reported in a manner that "appropriately conveys the strength of the evidence...".¹⁰⁴ The DFSC'S decision further confirms the uncertainty that exists with the expert's testimony on latent print identification.

⁹⁸ US Department of Justice 2006 <https://www.hsdl.org/?abstract&did=458960> 1.

⁹⁹ US Department of Justice 2006 <https://www.hsdl.org/?abstract&did=458960> 1. See also *United States v Bryon Mitchell* 2004 365 F 3d 215 (3rd Cir) where the very foundation of fingerprint identification was challenged in terms of the standards set in *Daubert v Merrell Dow Pharmaceuticals, Inc.* Also see Cole 2004-2005 *J Crim L & Criminology* 985-986.

¹⁰⁰ See *Mckie v Scottish Ministers* 2006 SC 528. Also see Cromwell 2011 <https://www.scottishlawreports.org.uk/publications/macfadyen-2011.html#71>.

¹⁰¹ The change in language clearly reads as follows: "The latent print on Exhibit ## and the record finger/palm prints bearing the name XXXX have corresponding ridge detail. The likelihood of observing this amount of correspondence when two impressions are made by different sources is considered extremely low". See Kaye 2015 <http://for-sci-law.blogspot.com/2015/11/marching-toward-improved-latent.html> and Dawson 2016 *Natl Inst Justice J* 1-6.

¹⁰² Mnookin 2018 <https://ssrn.com/abstract=3300354> 111.

¹⁰³ Kaye 2015 <http://for-sci-law.blogspot.com/2015/11/marching-toward-improved-latent.html> 1 and Dawson 2016 *Natl Inst Justice J* 1-6.

¹⁰⁴ Kaye 2015 <http://for-sci-law.blogspot.com/2015/11/marching-toward-improved-latent.html> 1 and Dawson 2016 *Natl Inst Justice J* 1-6.

Kadane states that:

... the finding of similarities between the mark found at a crime scene and a fingerprint on file does not permit estimation of the number of persons in a given population who share those characteristics. Consequently, there is no scientific basis for a source attribution; whether phrased as a 'match' as 'individualization' or otherwise.¹⁰⁵

He sees it as circumstantial evidence and not direct evidence¹⁰⁶ and as such it allows for more than one explanation.

3.2 *Bite mark analysis*

Bite marks are patterned marks (injury) made by human teeth on the skin of a victim of a crime or on an object at a crime scene.¹⁰⁷ Bite mark analysis is an important area of forensic odontology which is the application of the science of dentistry to law.¹⁰⁸ This article does not attempt to discuss the broad scope of forensic odontology but focuses on bite mark analysis which involves examining and comparing the marks made on the skin of the victim or an object and the dental impressions obtained from an accused person.¹⁰⁹ The expert known as forensic odontologist collects bite mark evidence during investigations of crimes, such as homicide, sexual assault and child abuse.¹¹⁰ The methods of collection of evidence which are generally recognised as "relatively noncontroversial" include "various forms of photography, dental casts, clear overlays, computer enhancement, electron microscopy, and swabbing for serology...".¹¹¹

¹⁰⁵ Kadane date unknown <https://pdfs.semanticscholar.org/7925/4e4ec0ecc46ab24e14da0788dab8028107b1.pdf>.

¹⁰⁶ Kadane date unknown <https://pdfs.semanticscholar.org/7925/4e4ec0ecc46ab24e14da0788dab8028107b1.pdf> and Rea 2017 <https://www.cmu.edu/dietrich/news/news-stories/2017/february/fingerprint-science.html>.

¹⁰⁷ NAS *Strengthening Forensic Science* 173; PCAST 2016 https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/PCAST/pcast_forensic_science_report_final.pdf 8, 83; Saks *et al* 2016 *JLB* 538-575.

¹⁰⁸ NAS *Strengthening Forensic Science* 173.

¹⁰⁹ PCAST 2016 https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/PCAST/pcast_forensic_science_report_final.pdf 8, 83.

¹¹⁰ NAS *Strengthening Forensic Science* 173-174.

¹¹¹ NAS *Strengthening Forensic Science* 173-174.

Bite mark analysis is based on the premise that:

(1) dental characteristics, particularly the arrangement of the front teeth, differ substantially among people and (2) skin (or some other marked surface at a crime scene) can reliably capture these distinctive features.¹¹²

This implies that each person's dentition is unique and that the human skin can reliably record a person's bite marks. On the basis of this assumption, many courts have accepted the admissibility of an expert's testimony for the purpose of identification.¹¹³ However, several reports have cast serious doubt on the accuracy of these premises.¹¹⁴ For example, the NAS Report notes that the "uniqueness of the human dentition" and the ability "to transfer a unique pattern to human skin and the ability of the skin to maintain that uniqueness has not been scientifically established".¹¹⁵ Also, the "ability to analyse and interpret the scope or extent of distortion of bite mark on human skin is yet to be demonstrated".¹¹⁶

The PCAST Report, a more recent study, also states that "bite mark analysis does not meet the scientific standards for foundational validity" and the current standards to determine a degree of similarity is not well defined.¹¹⁷ The conclusions drawn from the bite marks comparison method is based mainly on human (subjective) judgement which may result in a high probability of error, inconsistency and cognitive bias.¹¹⁸ In *State v Krone*¹¹⁹ the accused was convicted by two juries for murder based on bite marks

¹¹² PCAST 2016 https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/PCAST/pcast_forensic_science_report_final.pdf 8, 83.

¹¹³ See, for example, in *Brooks v State* 748 So 2d 736 (Miss 1999) the court held that bite mark testimony is admissible in Mississippi without much focus on the scientific basis of the evidence; *Carter v State* 766 NE 2d 377 (Ind 2002) 380 where the court accepted a bite mark testimony because there was no reason why the evidence should be considered as unreliable. Also see Beecher-Monas *Evaluating Scientific Evidence* 96 fn 7; Saks *et al* 2016 *JLB* 542 fn 8.

¹¹⁴ See, for example, NAS *Strengthening Forensic Science* 175 and PCAST 2016 https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/PCAST/pcast_forensic_science_report_final.pdf 87.

¹¹⁵ See NAS *Strengthening Forensic Science* 175.

¹¹⁶ See NAS *Strengthening Forensic Science* 175-176.

¹¹⁷ PCAST 2016 https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/PCAST/pcast_forensic_science_report_final.pdf 8-9, 87.

¹¹⁸ PCAST 2016 https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/PCAST/pcast_forensic_science_report_final.pdf 5, 83. See also *People v Brown* 618 NYS 2d 188, 188 (NY Co Ct 1994), *aff'd*, 600 NYS 2d 593 (NY App Div 4th Dept 1993) cited in Cooley and Oberfield 2013 *Tulsa L Rev* 297 fn 99. In this case, Brown was convicted of murder based on bite mark comparison with obvious discrepancies between Brown's teeth and the bite mark, concluded that Brown could have left the bite mark. However, a DNA testing exonerated Brown.

¹¹⁹ *State v Krone* 897 P 2d 621 (Ariz 1995). Also see Cooley and Oberfield 2013 *Tulsa L Rev* 295-296

evidence. The Styrofoam (casts) impression of Krone's dentition compared with the bite marks on the victim's body, suggested a pattern match.¹²⁰ However, Krone's conviction was overturned after DNA testing of saliva found on the victim's top excluded Krone from the murder.¹²¹

The problems associated with bite mark analysis affect the validity and reliability of the method. Therefore, as concluded in both NAS and PCAST Reports, much more research is needed to establish the scientific validity of this method so that expert testimony can be readily accepted in court and that wrongful convictions can be avoided.¹²²

3.3 *Microscopic hair analysis*

Space restrictions do not allow for a detailed discussion of microscopic hair analysis (or comparison) which involves examining and comparing features of hair found at the crime scene and hair taken from an accused to establish whether or not the accused is the source of the questioned hair.¹²³ The basis for this method stems "from the fact that human and animal hairs routinely are shed and thus are capable of being transferred from an individual to the crime scene, and from the crime scene to an individual".¹²⁴ Therefore, in an attempt to find out whether or not the suspect is the source of the questioned hair obtained from the crime scene, an examiner's first step is to determine the following:¹²⁵

- (1) whether the hair is of human or animal origin, (2) the part of the body that the hair came from (scalp, pubic, or limb hair), (3) racial origin, (4) whether the hair has been dyed, (5) whether the hair was pulled or fell out as a result of natural causes or disease, and (6) whether the hair was cut or crushed.

The next step is to examine the hair macroscopically to identify certain features like hair colour (eg black, brown or grey) or hair structure (eg straight, wavy, and curved).¹²⁶ The third step is to examine the hair

¹²⁰ *State v Krone* 897 P 2d 621 (Ariz 1995).

¹²¹ See Cooley and Oberfield 2013 *Tulsa L Rev* 295-300. Also see *Burke v Town of Walpole* 405 F 3d 66 (1st Cir 2005). In this case, bite mark analysis led to the wrongful arrest for 41 days for murder. However, DNA testing of the suspect's saliva excluded him.

¹²² PCAST 2016 https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/PCAST/pcast_forensic_science_report_final.pdf 87 and NAS *Strengthening Forensic Science* 175-176.

¹²³ PCAST 2016 https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/PCAST/pcast_forensic_science_report_final.pdf 13; Sangero 2018 *Ga St UL Rev* 1203.

¹²⁴ NAS *Strengthening Forensic Science* 155-156.

¹²⁵ Giannelli 2010 *Case Research Paper Series in Legal Studies* 2; NAS *Strengthening Forensic Science* 156-157.

¹²⁶ NAS *Strengthening Forensic Science* 156-157.

microscopically to determine more features of the hair (eg, pigment size or shaft diameter).¹²⁷ Sangero points out that the characteristics to be determined in this process are not "consistent for even one individual's hair" due to variations.¹²⁸ Therefore "this type of comparison between pieces of hair from two different people often points to an alleged match".¹²⁹

There is an assumption that microscopic hair analysis "can yield reliable information about class characteristics of hair strands" which can help to narrow down a possible source of unknown hair.¹³⁰ Based on this assumption, microscopic hair analysis has been admitted by many courts and in *State v West* the court explicitly stated that "microscopic comparison of morphological characteristics of human hairs has been accepted both scientifically and legally for decades".¹³¹

However, microscopic hair comparison has been recognised as "highly unreliable"¹³² as "no scientifically accepted statistics exist about the frequency with which particular characteristics of hair are distributed in the population".¹³³ Furthermore, there are "no uniform standards on the number of features on which hairs must agree before an examiner may declare a 'match'".¹³⁴ The conclusions drawn from hair comparison is mainly based on human judgement.¹³⁵

Flaws identified with this method are linked to several cases of wrongful convictions.¹³⁶ In *Williamson v State*, the court held that the microscopic hair analysis presented in court was "irrelevant, imprecise and speculative and its probative value was outweighed by its prejudicial effect".¹³⁷

The extent of the unreliability of microscopic hair comparison is pointed out by Sangero:¹³⁸

¹²⁷ NAS *Strengthening Forensic Science* 156-157; Giannelli 2010 *Case Research Paper Series in Legal Studies* 2.

¹²⁸ Sangero 2018 *Ga St UL Rev* 1203.

¹²⁹ Sangero 2018 *Ga St UL Rev* 1203.

¹³⁰ Giannelli 2010 *Case Research Paper Series in Legal Studies* 3.

¹³¹ *State v West* 877 A 2d 787 (Conn 2005). Also see NAS *Strengthening Forensic Science* 161.

¹³² NAS *Strengthening Forensic Science* 161; Giannelli 2010 *Case Research Paper Series in Legal Studies* 1.

¹³³ NAS *Strengthening Forensic Science* 160.

¹³⁴ NAS *Strengthening Forensic Science* 160.

¹³⁵ Giannelli 2010 *Case Research Paper Series in Legal Studies* 3-4.

¹³⁶ Sangero 2018 *Ga St UL Rev* 1201-1205.

¹³⁷ *Williamson v State* 812 P 2d 384 (Okla Crim App 1991). Also see Cooley and Oberfield 2013 *Tulsa L Rev* 301-303.

¹³⁸ Sangero 2018 *Ga St UL Rev* 1202.

In twenty-one of the first seventy exonerations in which the Innocence Project was involved, experts gave erroneous testimony on the microscopical comparison of hair. In a later study, it emerged that in seventy-five of the Project's first 250 exonerations, the convictions had also been based on microscopical comparisons of hair, and in twenty-nine of these cases experts gave erroneous testimony. In eighteen of the cases, moreover, the experts had grounded their testimony on an individualization claim; that is to say, that the hair found at the scene of the crime was unique to the defendant. In six of the exoneration cases, mitochondrial DNA testing ruled out the expert's assessment of a match between the hair at the scene of the crime and the defendant's hair.

Mnookin notes that the recent reports from the FBI and the Innocence Project found that "...microscopic hair identification experts regularly overstated their conclusions when testifying, frequently going well beyond what the field ostensibly permitted".¹³⁹ The flaws in this method cast serious doubt on the validity and reliability of microscopic hair analysis.

3.4 Firearm identification

In firearms identification, examiners generally "attempt to determine whether ammunition is or is not associated with a specific firearm based on 'tool marks' produced by guns on the ammunition".¹⁴⁰ Examiners establish that a specific firearm is the source (or not) of a particular bullet, cartridge case, shotshell casing or slug etc found at the crime scene.¹⁴¹

The basis of firearms identification is the principle of uniqueness, in which each tool mark produced by different firearms are presumed to be unique and is considered to vary substantially from one another.¹⁴² This is because each tool mark has individual characteristics (resulting from variations in manufacture and use) that may be uniquely associated with a specific tool or firearm and are reproduced by the same specific tool or firearm.¹⁴³ According to the PCAST Report, firearm examination "begins with an

¹³⁹ See reports: Hsu 2015 https://www.washingtonpost.com/local/crime/fbi-overstated-forensic-hair-matches-in-nearly-all-criminal-trials-for-decades/2015/04/18/39c8d8c6-e515-11e4-b510-962fcfab310_story.html?noredirect=on&utm_term=.c22d03885a0e; FBI 2015 <https://www.fbi.gov/news/pressrel/press-releases/fbi-testimony-on-microscopic-hair-analysis-contained-errors-in-at-least-90-percent-of-cases-in-ongoing-review>; Mnookin 2018 <https://ssrn.com/abstract=3300354> 103 fn 7.

¹⁴⁰ PCAST 2016 https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/PCAST/pcast_forensic_science_report_final.pdf 11.

¹⁴¹ PCAST 2016 https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/PCAST/pcast_forensic_science_report_final.pdf 11. See also the National Forensic Science Technology Center date unknown <http://www.forensicsciencesimplified.org/prints/Fingerprints.pdf> 1.

¹⁴² NAS *Strengthening Forensic Science* 150.

¹⁴³ NAS *Strengthening Forensic Science* 150.

evaluation of class characteristics of the bullets and casings, which are features that are permanent and predetermined before manufacture".¹⁴⁴ In a case where the:

... class characteristics are different, an elimination conclusion is rendered. If the class characteristics are similar, the examination proceeds to identify and compare individual characteristics, such as the markings that arise during firing from a particular gun.¹⁴⁵

According to the PCAST Report, the "most widely accepted method used in conducting a toolmark examination is a side-by-side, microscopic comparison of the markings on a questioned material item to known source marks imparted by the tool".¹⁴⁶ The conclusions drawn from the examination is based on the subjective judgments of the examiner and the accuracy of the assessments is highly dependent on the examiner's acquired skill and training.¹⁴⁷

While this method of identification is commonly used in criminal cases and accepted by the courts, some fundamental problems have been identified. The assumption of the uniqueness of tool marks has been criticised by both the NAS and the PCAST Reports which note that "the validity of the fundamental assumptions of uniqueness and reproducibility of firearms-related tool marks has not yet been fully demonstrated".¹⁴⁸ The NAS Report further asserts that in making a comparison between firearms-related tool marks, there is the possibility of similarity on bullets and cartridge cases from the same gun, but there is the need for caution and for scientific-based research that can determine the degree to which firearm-related tool marks are unique.¹⁴⁹

It should be noted that some courts have ruled on the admissibility of an expert's testimony based on the argument that a bullet or cartridge case is produced from the same gun. For example, in *United States v Monteiro*¹⁵⁰

¹⁴⁴ PCAST 2016 https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/PCAST/pcast_forensic_science_report_final.pdf 11; Kaplan and Puracal 2018 *Alb L Rev* 2018 904-905.

¹⁴⁵ National Forensic Science Technology Center date unknown <http://www.forensicssciencesimplified.org/prints/Fingerprints.pdf> 1; Kaplan and Puracal 2018 *Alb L Rev* 904-905.

¹⁴⁶ PCAST 2016 https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/PCAST/pcast_forensic_science_report_final.pdf 104.

¹⁴⁷ NAS *Strengthening Forensic Science* 153.

¹⁴⁸ See NAS *Strengthening Forensic Science* 154 and PCAST 2016 https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/PCAST/pcast_forensic_science_report_final.pdf 105.

¹⁴⁹ NAS *Strengthening Forensic Science* 154.

¹⁵⁰ *United States v Monteiro* 407 F Supp 2d 351 (D Mass 2006).

the motion brought before the court by the accused, was for the court to exclude expert testimony that cartridge cases found at several crime scenes matched the firearms linked to the defendant. The expert testimony was based on the assumption of the uniqueness of toolmarks and the accused wanted the court to declare the method unreliable under the standards set in the *Daubert* case. However, the court held that "the underlying scientific principle behind firearm identification that firearms transfer unique toolmarks to spent cartridge cases, is valid under *Daubert*".¹⁵¹

Nevertheless, Judge Saris, in the *Monteiro* case, stated that:¹⁵²

Because an examiner's bottom line opinion as to identification is largely a *subjective one*, there is no reliable statistical or scientific methodology which will currently permit the expert to testify that it is a 'match' to an absolute certainty, or to an arbitrary degree of statistical certainty.¹⁵³

The Supreme Court in *Ramirez v State of Florida*¹⁵⁴ cautioned firearm and toolmark examiners regarding relying on:

"... nothing more than their own subjective criteria for '*striae* identification' and those who are unable to put forth "a convincing, logical, scientifically based explanation for the basis of their identifications".¹⁵⁵

In *United States v Green*¹⁵⁶ the expert testified that a match could be made between two casings and that the casings came from a specific firearm "to the exclusion of every other firearms in the world". The testimony lacked empirical testing and the court allowed the expert only to explain the ways in which the casings were similar but not that they came from a specific weapon "to the exclusion of every other firearms in the world".¹⁵⁷ The court cautioned that:¹⁵⁸

¹⁵¹ *United States v Monteiro* 407 F Supp 2d 351 (D Mass 2006).

¹⁵² *United States v Monteiro* 407 F Supp 2d 351 (D Mass 2006) 372.

¹⁵³ Emphasis added. Instead of articulating criteria, most examiners rely solely on subjective, mind's eye judgments of when the resemblances between tool marks are sufficient to justify identity conclusions. See Schwartz 2008 <https://www.wisped.org/images/practice-groups/homicide/ChallengingFirearmsIdentificationpart2.pdf> 49-50.

¹⁵⁴ *Ramirez v State of Florida* SC92975 (20 December 2001).

¹⁵⁵ Grzybowski *et al* 2003 *AFTE Journal* 2.

¹⁵⁶ *United States v Green* 405 F Supp 2d 104 (D Mass 2005). See also Giannelli 2010 *Faculty Publications* 1143-1144.

¹⁵⁷ *United States v Green* 405 F Supp 2d 104 (D Mass 2005). See also Giannelli 2010 *Faculty Publications* 1143-1144.

¹⁵⁸ *United States v Green* 405 F Supp 2d 104 (D Mass 2005). See also Giannelli 2010 *Faculty Publications* 1143-1144.

The more courts admit this type of tool mark evidence without requiring documentation, proficiency testing, or evidence of reliability, the more sloppy practices will endure; we should require more.

Furthermore, the subjective judgements of the examiners have been criticised as problematic because it lacks scientific and statistical proof to corroborate an examiner's conclusions.¹⁵⁹ According to the PCAST Report, neither an examiner's skill, experience nor judgement can be used to establish the scientific validity or reliability of firearms identification.¹⁶⁰ The report further notes that:¹⁶¹

The frequency with which a particular pattern or set of features will be observed in different samples, which is an essential element in drawing conclusions, is not a matter of 'judgment.' It is an empirical matter for which only empirical evidence is relevant.

The lack of an objective standards for examining firearms is a major flaw that raises fundamental questions on the reliability of firearms identification and the possibility of human error in judgment. Therefore, as recommended in the PCAST Report, there is the need for the development of objective methods similar to those used in DNA analysis.¹⁶²

4 Dangers of convictions based on a single piece of forensic evidence and some recommendations on the way forward

The wrongful conviction of an innocent person, especially on a single piece of evidence, poses serious risks for the victim and the society at large.¹⁶³ Wrongful conviction is a clear miscarriage of justice that affects the fundamental rights of the convicted person. Such rights include the right to life, the right to liberty and security, as well as the right to human dignity.¹⁶⁴

¹⁵⁹ PCAST 2016 https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/PCAST/pcast_forensic_science_report_final.pdf 55-60; NAS *Strengthening Forensic Science* 153-154.

¹⁶⁰ PCAST 2016 https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/PCAST/pcast_forensic_science_report_final.pdf 55.

¹⁶¹ PCAST 2016 https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/PCAST/pcast_forensic_science_report_final.pdf 55.

¹⁶² PCAST 2016 https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/PCAST/pcast_forensic_science_report_final.pdf 125, 129.

¹⁶³ Sangero and Halpert 2007 *Jurimetrics* J 46.

¹⁶⁴ These rights are well established in international and regional human rights instruments. See, for example, the *Universal Declaration of Human Rights* (1948) (art 3: Everyone has the right to life, liberty and security of person); the *International Covenant on Civil and Political Rights* (1966) (ICCPR) (art 9(1): Everyone has the right to liberty and security of person); *African Charter on Human and Peoples Rights* (1981) (ACHPR) (art 4: right to life, art 5: prohibition of torture and cruel, inhuman

Furthermore, convicted persons are faced with the challenges (i.e. delay regarding court processes) and the cost of appealing their conviction as well as the cost of pursuing legal remedies from the court as compensation for wrongful conviction, when exonerated and released.

The danger for society is that the real perpetrator of the crime remains within the society and there is a high possibility of a reoccurrence of the crime.¹⁶⁵ Also, the state is faced with the high cost of complying with the order of the court regarding legal remedies for the convicted person.

As explained above, serious flaws are associated with forensic pattern-matching methods and are linked to the wrongful conviction of an innocent person based on a single piece of forensic evidence. Despite the flaws, some courts still admit forensic expert testimony based on pattern-matching methods as scientific evidence.¹⁶⁶ This is confirmed by Mnookin:¹⁶⁷

Judges today are tremendously reluctant to exclude from trials long familiar forms of forensic science evidence even when... the scientific foundation is weak and the evidence has played an established role in numerous proven wrongful convictions.

However, detailed recommendations addressing the flaws in order to ensure a more scientifically valid and reliable foundation for forensic evidence, are provided in both the NAS and PCAST reports, some of which are highlighted above. The findings and recommendations in these detailed reports as well as in other scholarly articles in the field of the forensic disciplines and criminal law, provide a strong foundation for continuous education, training and awareness regarding pattern-matching methods.¹⁶⁸ Mnookin rightly observes that since the release of the NAS Report, and the subsequent PCAST Report, there has been a change in the conversation on pattern-matching methods.¹⁶⁹ However, there is a need for an increased conscious effort with regard to educating and training relevant stakeholders, such as judges, prosecutors, defence attorneys, forensic experts and examiners etc.¹⁷⁰ Furthermore, there is a need to raise awareness in order

and degrading treatment, art 6: right to liberty and security of person). These rights are also enshrined in the South African Bill of Rights, specifically, ss 10-12 of the *Constitution of the Republic of South Africa*, 1996.

¹⁶⁵ Sangero and Halpert 2007 *Jurimetrics J* 46.

¹⁶⁶ Sangero 2018 *Ga St UL Rev* 1130.

¹⁶⁷ Mnookin 2018 <https://ssrn.com/abstract=3300354> 102-105.

¹⁶⁸ See, for example, Sangero 2018 *Ga St UL Rev* 1129-1220; Sangero and Halpert 2007 *Jurimetrics J* 43-94; Mnookin 2018 <https://ssrn.com/abstract=3300354> 102-105.

¹⁶⁹ Mnookin 2018 <https://ssrn.com/abstract=3300354> 110.

¹⁷⁰ Mnookin 2018 <https://ssrn.com/abstract=3300354> 105.

to generate more focus and more research both at national and international levels on the scope of pattern-matching methods; the gaps in knowledge regarding the validity and reliability of the methods; establishing error rates and ensuring the accuracy of examiners findings.¹⁷¹ These suggestions are important because at present attempts at effective implementation of the recommendations in the reports are slow and greater progress is needed.¹⁷²

While an effort is being made to implement these recommendations and create awareness, this article contends that courts should follow a cautionary approach when relying on forensic evidence which is scientifically unvalidated and that strong corroboration with other forms of evidence linking the accused to the crime, should be required.¹⁷³ The need for caution, especially in the South African courts, is important for the following reasons: Firstly, forensic pattern-matching methods are not error-free and there is the reality of high occurrence of wrongful conviction of innocent persons.¹⁷⁴ Secondly, reliability is not a prerequisite for the admissibility of forensic evidence in South Africa.¹⁷⁵ As explained above, the *Daubert* case requires high standards for considering when to admit expert testimony. Thirdly, there is a need to prevent the misuse of the legal principle which provides that an accused can be convicted on any offence based on the evidence of any single competent witness.¹⁷⁶ Fourthly, the need for caution is also prompted by the state's failure, at times, to adduce real evidence which should have been available.¹⁷⁷ Therefore, the court must encourage the state to provide additional material evidence, if available, to corroborate the circumstantial evidence (ie forensic evidence) in order to reinforce their argument(s).

Sangero asserts that "the aura of science can be expected [or has a possibility] to blind judges and jurors and lead them to overestimate the real

¹⁷¹ Mnookin 2018 <https://ssrn.com/abstract=3300354> 102-105.

¹⁷² Mnookin 2018 <https://ssrn.com/abstract=3300354> 100-102 and PCAST 2016 https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/PCAST/pcast_forensic_science_report_final.pdf 9.

¹⁷³ See *S v Msane* 1977 4 SA 758 (N).

¹⁷⁴ Sangero 2018 *Ga St UL Rev* 1129-1132

¹⁷⁵ But recently there seems to be a tendency to require expert evidence to be not only relevant but also reliable. This is pointed out in *Twine v Naidoo* 2018 1 All SA 297 (GJ), where Vally J notes that the learning over the years has established principles regarding expert witnesses including that "...expert testimony should only be introduced if it is relevant and reliable. Otherwise it is inadmissible". Also see *AR v Road Accident Fund* 2018 ZAGPJHC 637 (29 November 2018) para 37 and Edmond and Meintjes-van der Walt 2014 *SALJ* 113.

¹⁷⁶ See s 208 of the South African *Criminal Procedure Act* 51 of 1977.

¹⁷⁷ See *S v Msane* 1977 4 SA 758 (N).

probative strength of scientific evidence".¹⁷⁸ Although science is generally held in high esteem,¹⁷⁹ the court in *Holtzhauzen v Roodt* notes that:¹⁸⁰

The expertise of the witness should not be elevated to such an extent that the court loses sight of its own capabilities and responsibilities in drawing inferences from the evidence.

However, the reality is that judges often have to rely heavily on the specialised knowledge and skill of expert witnesses in order to draw inferences and to reach conclusions, while the expert's testimony, purported to be based on science, may be erroneous.¹⁸¹ Brandon Mayfield's case is a popular example of this argument that well-qualified experts with years of experience and knowledge can and do make mistakes in findings and judgement.

Lastly, the high crime rate and violence in South Africa could support an assumption (often public opinion judgement which can dissuade an expert to make an inconclusive finding / judgement) that a suspect is guilty of a crime (even before proving his or her guilt beyond reasonable doubt in court).¹⁸² The high crime rate contributes to why wrongful convictions remain "mostly unacknowledged, usually ignored and often denied" in South Africa.¹⁸³

5 Conclusion

The article above examines the dangers of conviction based on a single piece of forensic evidence. There can be no doubt that forensic evidence contributes immensely to criminal investigations and prosecutions. Traditionally, expert testimony, especially on pattern-matching methods (fingerprint analysis, bite mark identification, microscopic hair analysis and firearms identification) has been generally accepted in South African courts but, in the light of the above, for any forensic evidence meaningfully to contribute to the successful outcome of a trial, it must be accurate, relevant,

¹⁷⁸ Sangero 2018 *Ga St UL Rev* 1135.

¹⁷⁹ This is because it is believed to entail objective methods which will ensure greater accuracy, lower risks of human error or cognitive bias and establish foundational validity and reliability. Sangero 2018 *Ga St UL Rev* 1136-137.

¹⁸⁰ *Holtzhauzen v Roodt* 1997 4 SA 766 (W) 772E-G. Also see Edmond and Meintjes-van der Walt 2014 *SALJ* 112.

¹⁸¹ Sangero 2018 *Ga St UL Rev* 1136-137; Cromwell 2011 <https://www.scottishlawreports.org.uk/publications/macfadyen-2011.html#f71>.

¹⁸² Raphaely 2018 <https://www.dailymaverick.co.za/article/2018-10-02-getting-it-wrong-guilty-until-proven-innocent/> (the recent acquittal of a South African man wrongfully convicted of rape at the Pietermaritzburg High Court).

¹⁸³ Raphaely 2018 <https://www.dailymaverick.co.za/article/2018-10-02-getting-it-wrong-guilty-until-proven-innocent/>.

scientifically valid and reliable. The lack of scientific validity is the main problem affecting pattern-matching methods. Different proposals and recommendations for reforms that will ensure a more scientific method, have been proffered in detailed reports and studies, some of which are mentioned above. However, at present, implementation is slow and therefore there is the need for the courts to exercise caution especially when the conviction is based on a single piece of forensic evidence.

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List of Abbreviations

ACE-V	Analysis, Comparison, Evaluation and Verification
ACHPR	African Charter on Human and Peoples' Rights
AFTE Journal	Association of Firearm and Tool Mark Examiners Journal
Alb L Rev	Albany Law Review
Am U Int'l L Rev	American University International Review
Brook L Rev	Brooklyn Law Review
Buff Pub Int LJ	Buffalo Public Interest Law Journal
Colum L Rev	Columbia Law Review
DFSC	Defence Forensic Science Centre
DNA	Deoxyribonucleic acid
FBI	Federal Bureau of Investigation
Ga St UL Rev	Georgia State University Law Review
Golden Gate UL Rev	Golden Gate University Law Review
Hastings LJ	Hastings Law Journal

IAFIS	Automated Fingerprint Identification System
ICCPR	International Covenant on Civil and Political Rights
J Crim L & Criminology	Journal of Criminal Law and Criminology
JLB	Journal of Law and the Biosciences
Jurimetrics J	Jurimetrics Journal
NAS	National Academy of Sciences
Natl Inst Justice J	National Institute of Justice Journal
NRE	National Registry of Exonerations
PCAST	President's Council of Advisors on Science and Technology
SACJ	South African Journal of Criminal Justice
SALJ	South African Law Journal
Tulsa L Rev	Tulsa Law Review
US	United States
Va L Rev	Virginia Law Review
Vand L Rev	Vanderbilt Law Review
Yale J Int'l L	Yale Journal of International Law