Forensic hair morphology comparison – a dying art or junk science?

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There has been debate in both the judicial and forensic fields concerning the admissibility and reliability of the so-called forensic comparison sciences such as handwriting, tool mark analyses, and hair analysis. In particular, there has been increasing controversy over the use and interpretation of hair comparison evidence and it has been held partly responsible for miscarriages of justice. There has also been a perceived devaluation of the worth of microscopic human hair analysis particularly since the advent of DNA profiling. This article will attempt to initiate discussion on the past, current and future role of forensic human hair analysis and comparison.

Il y a eu un débat dans les milieux judiciaires et forensiques concernant l'admissibilité et la fiabilité des ainsi-dites sciences de la comparaison forensique dans les domaines tels que l'écriture, l'analyse des traces d'outils et l'analyse des cheveux. En particulier, il y a eu une controverse qui s'amplifiait sur l'utilisation et l'interprétation des indices basés sur la comparaison de cheveux et elle a été tenue partiellement comme responsable d'erreurs judiciaires. Il y a aussi eu une dévaluation perçue de la valeur de l'analyse du cheveu humain par microscopie, particulièrement depuis l'introduction du profil ADN. Cet article veut tenter de démarrer la discussion sur le passé, l'actuel et le futur rôle de l'analyse du cheveu humain forensique et de sa comparaison.

Sowohl in juristischen als auch forensischen Kreisen wurde über die Zulässigkeit und die Verlässlichkeit der sogenannten vergleichenden Forensik wie Handschriften-, Werkzeugspuren- oder Haaruntersuchungen debattiert. Insbesondere gab es eine wachsende Kontroverse über die Verwendung von Haarvergleichsuntersuchungen als Beweismittel und deren Interpretation; solche Gutachten wurden auch als mitverantwortlich für juristische Fehlurteile angesehen. Darüber hinaus ist es, besonders seit dem Aufkommen der DNA-Analyse, auch zu einer spürbaren Abwertung der Bedeutung der mikroskopischen Analyse von menschlichen Haaren gekommen. Mit diesem Artikel soll versucht werden, eine Diskussion über die frühere, jetzige und zukünftige Rolle der forensischen Analyse und vergleichenden Untersuchung von menschlichen Haaren zu initiieren.

Ha habido un debate en los medios judiciales y forenses en torno a la admisibilidad y fiabilidad de las llamadas ciencias forenses de comparación tales como escritura, huellas de utensilios y análisis de pelos. En particular ha habido una controversia creciente sobre el uso y la interpretación de la evidencia de comparación de pelos y se le ha achacado ser responsable en parte de errores en la justicia. También se ha percibido una devaluación del valor del análisis microscópico de pelos particularmente desde el advenimiento de los análisis de ADN. Este artículo intenta iniciar una discusión sobre el pasado, presente y futuro papel del análisis forense de pelo humano y comparaciones.

Key words Forensic science, criminalistics, hair, comparison, admissibility, justice

Introduction

The forensic 'comparison analyses', which incorporate such examinations as handwriting, tool marks and hairs, have recently preoccupied the legal and indeed scientific forensic community in some countries, particularly the United States. These are forensic examinations that generally do not incorporate associated statistical numbers as to their evidential value but depend on either 'individual' characteristics (such as fingerprints and tool marks) or 'class' characteristics (such as hairs and fibres). Evidence types that can be associated with a common source with a high degree of probability possess individual characteristics whereas evidence types that can only be associated with a group and never a single source possess class characteristics [1]. These evidence types have been questioned as to their admissibility in court, such as whether the examinations are scientific, subjective and/or reliable, particularly in United States courts. Even the 'ancient', long accepted analysis of fingerprinting has been called into question. A United States judge ruled in January 2002 that fingerprints did not meet the standards set for scientific testimony although he subsequently overturned his ruling [2]. In particular this judge originally ruled a fingerprint 'match' opinion as subjective. This was deemed likely to prompt challenges in other comparative techniques like ballistics [3].

This topic appears to have replaced the controversy over the interpretation of statistics in DNA profiling. Nuclear DNA profiling is an extremely powerful discrimination tool and is capable of providing statistical values with respect to the 'frequency' of the particular evidence. The court can thus have some guidance as to the value or worth of this evidence. The introduction of DNA profiling led to unprecedented challenges in the courts, not only to the new technology but also to the population genetics and statistics associated with frequencies of the profiles. Now the challenges appear to be diminishing and the focus is on the forensic disciplines that rely on class and individual characteristics. It has been stated [4] that the advent of forensic DNA analysis has produced significant changes in the perception of forensic science, particularly concerning the question of statistical evaluation of the evidence – the legal system now appears to want statistical values placed on evidence such as trace evidence of fibres, paint and glass.

The large numbers of variable factors which must be considered in evaluating trace evidence such as hairs and fibres often require inductive (based on experience or experimental evidence) rather than the deductive (mathematical) logic which generally appeals to jurors and lay-people [5]; as such, statistical weighting may be inappropriate. However in many fibre cases, for example, an estimate of fibre frequency is often attempted and the future holds promise for the further application of statistics [5].

The increased scrutiny described above has also arisen because of the large numbers of acquittals obtained in the United States of convicted offenders, many on death row. The highly discriminating technique of DNA profiling has been performed on 'cold' cases (mostly from the 1980s) where originally far less discriminatory genetic tests were performed; typically these original tests involved blood enzyme typing. In a number of cases, microscopic hair comparisons were originally performed. One project based in New York (the Innocence Project) has helped secure exonerations for people, using DNA analyses [6,7]. Allegedly 21 out of the first 70 DNA exonerations had microscopic hair comparison 'matches' that led, in part, to a wrongful conviction [6,7]. Whilst there may also be non-scientific based reasons for the false convictions such as poor eyewitness evidence, incompetent defence attorneys and other deficiencies in the legal system, the number of cases where hair evidence was considered a factor is a real concern.

There have been other high profile cases concerning microscopic hair comparison evidence in the United States and also Canada. A Royal Commission in Canada [8] heavily criticised hair comparison evidence. One of the first legal cases drawing attention to forensic hair analysis evidence was Williamson v. Reynolds [9]. This court had ruled that the state of hair analysis had not reached the level of certainty to permit testimony that a defendant's hair was microscopically consistent with samples from a murder scene. One legal article has also argued that hair comparison analysis should be excluded altogether from criminal trials [10].

This article will attempt to initiate discussion on the various factors that today have dented the credibility of hair comparison evidence, particularly in the United States. It will also discuss the value of hair examination in general and the possible future of forensic hair examinations.

Human hair as evidence

The morphology of human hair has been well described in the literature for over the past century [11]. Potentially human hair is especially useful as evidence as it originates directly from an individual and is readily transferred during interactions among people and other surfaces, although the possibility of secondary transfer should be considered. The prevalence of hair (human as well as domestic animal) at crime scenes and on items examined in the crime laboratory again should make it potentially one of the most valuable sources of evidence available. It is not easily destroyed and may remain intact even after extensive fluid and tissue decomposition. It can be seen on Egyptian mummies, and wall hangings from the Second World War, reputedly from Auschwitz deportees, have been found to be woven from human hair [12]. However, until the advent of DNA profiling, little genetic information could be obtained from hairs, and it was the observation of morphological characteristics in the hair that provided evidential value. These morphological characteristics are 'class characteristics' and do not, in general, have accompanying statistical values.

These physical characteristics, without comparative analysis, may be the crucial evidence in violent crimes. For example, the appearance of the root of the hair (or the presence of 'clumps' of hair) may indicate the forcible removal of that hair. This may be important in cases of rape where 'consent' is the defence, or in allegations of assault. Root morphology may also assist with

establishing the time of death [13,14]. There are other cases where the appearance of the hair, not its origin, may be more important such as the application of dye to a suspect's hair in order to alter their appearance. These factors illustrate the fact that forensic science is not solely concerned with 'individualisation' and 'who did the crime?' but also with 'what was the crime and the circumstances surrounding it?'

With the advent of nuclear and mitochondrial DNA profiling in the 1980s and 1990s a most valuable discriminating tool for human material, including human hair, was introduced [15–17]. Accompanied by associated statistical evaluations this tool is now the one of choice, if available. Even today, nuclear DNA profiling results can only be confidently predicted on hair roots in an appropriate growth cycle (anagen or catagen) or with attached sheath material [18]. Most hair found at crime scenes has roots that are in the telogen or resting phase [18,19]. These telogen hairs were previously considered unsuitable for nuclear DNA profiling [18]. This is because it is thought that nuclear DNA degrades dramatically in keratinised cells in not only the hair shaft but also in the hair root [19]. The future holds promise for obtaining nuclear DNA from these telogen hairs using different analytical techniques, such as shorter primer pairs [19].

Mitochondrial DNA profiling can be performed on the hair shaft but the accompanying statistics are far less powerful than nuclear DNA because it is inherited maternally. Many laboratories do not have the facility to perform mitochondrial DNA profiling. Thus forensic scientists have continued to observe and interpret the morphological characteristics of hair, and subsequently use them in 'comparisons' to gain evidential value. Previously, their use had been accepted both scientifically and legally for decades [20]. But it has now become the subject of controversy.

Subjectivity

The general consensus since 1934 [11] is that it is not possible to definitively identify a sample of hair as coming from a particular person's head. The major difference with hair morphology evidence from other physical evidence lies in the variety of characteristics that exists among the hairs from a single body region of any one person. What has been accepted is that samples can be unequivocally excluded from a common origin if they are found to be significantly different (assuming representative sampling). This method of hair comparison utilises a macroscopic and microscopic examination of the hair morphology encompassing various hair 'characteristics'. This process is not objective in the numerical sense; there is currently no direct association between the number of different properties that correspond in a comparison and the probability that the samples did or did not have a common origin.

Hair examiners have been searching for more 'objective' criteria upon which to base their microscopic hair comparisons since at least 1976 [21]. However, there are no frequency data for the measurement of a particular hair characteristic, such as degree of pigmentation, in the relevant population [22–25]. The frequency of some hair microtypes (microscopic hair characteristics) may also be higher than others, just as for STRs in DNA profiling. Most experienced hair examiners would be pressed to describe 'objectively' the criteria that they use in the comparison of hair [21]. Objectivity in this sense means those criteria that can be expressed numerically and thus compared numerically [21]. Other statistical evaluations have been attempted, such as the probability of a false or a coincidental 'match'. There was considerable debate surrounding the statistical evaluation by Gaudette and Keeping [26] and Gaudette [27]. Barnett and Ogle [28] criticised the experimental design as it dealt solely with the ability to distinguish two hairs, rather than also matching with the correct exemplar as encountered in crime cases. One study, whilst demonstrating that the frequency of coincidental hair matches in comparisons was low, also demonstrated that routine hair classification was not feasible because of inconsistency in examiner discrimination [29]. This study agreed with a previous one that not only showed that examiners described characteristics of the same hairs differently, but that their descriptions of the same hairs varied over time [30].

The concept of similarity or even 'match' becomes fraught with difficulty in hair comparisons. This is because there is no accepted number of characteristics in which two samples are considered similar. The fact that hairs are similar in appearance may simply be a reflection of the lack of discrimination and in any case would change according to the hairs in question. It is important to remember that an evidentiary hair may be found to have 'similar' characteristics to an individual when it actually originated from another. This is no more of an error than the finding that several persons share a particular STR allele at a locus.

It is thus a subjective opinion that decides whether a hair could have come from a particular sample when comparing morphological characteristics and whether that hair is 'similar' in appearance. But is this opinion science? The demonstration of similarity among samples is a general principle of evidence and may also be known by the terms pattern comparison or comparative micrography [31]. This principle can be applied to the reconstruction of stature or estimation of age from skeletons. Just because statistical probabilities cannot be applied to a particular branch of science does not make this evidence 'unscientific'. But is hair comparison unscientific on other grounds?

Validity and reliability

Scientific methodology is based on generating hypotheses and testing them to see if they can be falsified. The falsifiable hypothesis distinguishes science from other professional endeavours. The reproducible experiment affirming the hypothesis completes the methodology. Objectivity is achieved by constructing a replicable set of procedures and establishing the criteria by which results will be evaluated [32]. The use of the scientific method, an objective protocol, a competent examiner and established quality assurance procedures establish credibility [32].

'Validity' and 'reliability' are terms used in the evaluation of

scientific evidence in the courtroom. Yet these terms may have different meanings to the scientist and to the lawyer. It has been accepted for many years in the literature that hair comparisons are valid and reliable, although subjective, providing credibility as defined above is established. The courts have recently used the Daubert ruling [33], which is gradually superseding the Frye standard in the United States courts and has similarities to admissibility rules in Australia. This considers whether the reasoning or methodology underlying the testimony is scientifically valid and whether that reasoning or methodology can be applied to the facts in issue. This ruling was the result of two product liability suits in the United States where it was deemed that the 'reliability' of the expert evidence must be determined before admitting it [33,34]. The courts held that an expert could not testify about the scientific certainty of a technique unless its accuracy had been tested and its rate of error was known.

Whilst testability, peer review and general acceptance can be satisfied with hair comparison evidence, there is little historical information on error rates for hair comparison cases, just like some other forensic disciplines [24]. A review of external proficiency test results from laboratories in the years 1978 to 1991 was conducted in the United States [35,36]. The Forensic Science Foundation and Collaborative Testing Services issued the tests, with some 390 laboratories participating including 65 laboratories in 21 foreign countries. The results showed that animal hair and human body hair identifications/classifications were the most troublesome of all categories tested (ranging from drugs to glass and fibres). Although the tests could be considered as not ideal (animal hairs were provided without roots) 'success' rates were only about 50%. Microscopic human hair comparisons (where hairs from a crime scenario were to be compared with known standards from the victim and one or more suspects) had rates of 'correct' identification of 80 to 90% and had higher rates of inconclusive responses than some other tests due to limitations in the data and/or examination techniques [36].

A recent paper [20] has compared mitochondrial DNA analyses with hair comparison morphology and found that these two techniques are complementary and valuable. However there is still no documented data in which PCR based typing of hair roots has been compared with microscopic associations to determine which hair microtypes and case circumstances repeatedly cause difficulty in association [24]. It is the limitations of the examination and the particular circumstances of the case that ultimately determine the 'reliability' of the examination.

The concept of error rates in DNA analysis has recently created some interest. A paper has asked why it is considered essential to have valid scientific data on the random match probability of a DNA match between a suspect and a crime stain but unnecessary to have valid data on the false positive probability [37]. There have been reports of DNA matches between samples that have actually originated from different people due to human error such as mishandling of samples [37]. With the focus on other forensic disciplines and their error rates, such as hairs, perhaps the DNA error rate will become a subject of debate. Indeed this may already have arrived. An investigation into a laboratory in Houston, Texas concluded that sloppy standards and contamination in DNA testing might have contributed to wrongful convictions [38].

The courtroom

There has been an interest and awareness of problems associated with hair comparison evidence in the United States. Some legal commentators have argued that hair comparison evidence should be excluded altogether from criminal trials [10]. This controversy has not arisen as yet in British or Australian courts. This may be due to the lesser emphasis placed on hair analysis in British and Australian forensic laboratories and a perceived lower evidential value compared with the United States.

The Innocence Project [6,7] uncovered many wrongful convictions in which microscopic hair comparison evidence was used by the prosecution. These cases typically involved a hair 'match' between a suspect and a crime scene sample. Jimmy Ray Bromgard became the 111th person to be freed by the Innocence Project when DNA evidence showed that he was not responsible for the rape of an 8-year-old girl in her Montana home [7,39]. A forensic scientist testified that the chances of hair found at the crime scene belonging to someone other than Bromgard were one in 10,000. A peer review report has criticised these findings as showing no statistical basis [7]. During May 2003 Paul Kordonowy was exonerated through DNA evidence of a rape 13 years ago where again it was alleged the same scientist had given questionable statistical testimony [40].

Mark Reid was convicted of sexual assault and kidnapping in 1977 in Hartford, United States where three pubic hairs found on the victim were microscopically similar to those from Reid [41]. Mitochondrial DNA tests subsequently excluded the hairs as coming from Reid. Allegedly the disclaimer that microscopic hair analysis did not identify an individual was omitted from the scientific report [41].

Joyce Gilchrist from an Oklahoman laboratory is probably the most highly publicised forensic scientist in recent years. She received notoriety due to her presentation of hair evidence (and other forensic evidence) in the courtroom and some thousands of cases she examined between 1980 and 1993 were to be reviewed [42].

A forensic review committee was established in Manitoba Canada during April 2003 to examine homicide cases in which the accused was found guilty during the last 15 years and in which the Crown relied upon microscopic hair comparison evidence [43]. This review was initiated after recent DNA tests excluded the accused in two high profile murder cases in which hair comparison evidence was used [44].

The misrepresentation of microscopic hair comparison evidence appears to be shared by both the legal professions and forensic science. Forensic scientists may overstate the value in their testimony when challenged in the stage-like atmosphere of the

courtroom. Aggressive prosecutors may characterise microscopic similarities as absolute matches; defence attorneys may also lack the expertise to challenge [45]. A notorious case from New York, the rape and beating of a jogger in Central Park, illustrates the problems sometimes encountered when law and science mingle [46]. The forensic scientist's evidence was that the hairs found on the clothing of two of the suspects were 'similar' to the victim; however, allegedly one of the prosecutors translated this as 'matching' for one of the defendant's. DNA tests subsequently excluded the hairs as coming from the jogger [46].

Whilst it could be argued that rogue professionals exist in any discipline, the consequences are serious when not only is an individual's liberty at stake but also his or her very life. Problems such as poor supervision, overconfidence in one's ability and limitations not stated or realised, can be encountered in many professions but in the criminal justice system this cannot be tolerated. This applies not only to forensic scientists but also to those in the legal field. Forensic reviews such as the one in Manitoba Canada may assist in determining how the courts use hair comparison evidence. They may assist in determining whether the original hair comparison was 'wrong' in these cases (such as incorrectly including a particular hair as potentially coming from a known source), whether both the forensic scientist and the lawyer have conveyed limitations of the technique, or whether there were indeed no deficiencies in the hair evidence.

Utility

There is a perceived 'devaluation' of the worth of microscopic human hair analysis particularly since the advent of DNA profiling. Many British and Australian laboratories only perform DNA profiling on the hair roots without microscopic examination and comparison. This situation is also prevalent in the United States where the focus of forensic biology on DNA typing methods has led to a gradual decline in hair microscopy practice and training [18]. The general practice of most forensic laboratories is to assess hair roots prior to nuclear DNA typing, without a complete microscopic comparison. The use of morphological hair comparison evidence as associative, incriminating evidence on its own today is rare. Considering recent high profile cases where DNA evidence has overturned convictions which utilised hair comparison evidence, this could be considered by some to be only of benefit.

Depending on the case, however, the morphology of the hair may have more probative value than DNA profiling. Where hair comparisons are required to support identity, the reliability of the method can be demonstrated as long as procedures and protocols are followed. These are necessary today in the delivery of any expert scientific opinion.

A value of microscopic hair comparison is that it is a non–destructive test. Consequently the samples are available for testing in the future, or by other scientists if required. Indiscriminate DNA analyses without benefit of a meaningful microscopic assessment of the hair may not only incur financial waste but also the equally critical waste of analytical time [18]. It has been recommended that microscopic hair evaluation and comparison should always precede DNA testing [18]. This would mean that the hair examination would be used as a 'screening' tool, a tool that is timely and cost effective. Samples may be quickly eliminated and important morphological features noted. Exceptions to this are 'intelligence' type cases where no reference hair samples are available and successful DNA profiling may enable searching on DNA databases to locate a potential offender.

Progress can also be made on making the probative value of hair evidence more objective. The best approach to developing frequency data for microscopical human hair variates is for researchers to use a standard atlas of these variates so that workers in different geographical areas can investigate hair characteristic variate frequencies using the same archetypes [25]. The feasibility of the automation of forensic hair analysis and comparison tasks using new techniques in computer science such as neural network explanation systems has also been recently proposed [47].

External laboratory audits and external blind proficiency testing are the best sources of determination of laboratory error rates [36]; the error rates for hair analysis in various laboratories could then be estimated in an attempt to satisfy the Daubert criteria. Standard external hair proficiency tests incorporating case scenarios, guidelines such as those promulgated through SWGMAT (Scientific Working Group for Materials Analysis), and the accreditation of forensic laboratories will help to ensure that those practising hair examination will have confidence in their results, and that the public and legal system will have confidence in them. Advances in DNA technology may improve the success of obtaining nuclear DNA from hair in the future.

Conclusion

Initial controversy over hair comparison evidence arose because legal commentators confused probabilities with reliability. Just because a statistical probability of the evidence cannot be stated does not inherently make that evidence unreliable. Hair evidence may be unreliable for the very same reasons that make other forensic evidence unreliable. Limitations of the examination should be measured and acknowledged, and quality assurance procedures followed. Those scientists practising hair examination will then be able to properly evaluate and report their results. Due to recent publicity a prosecution will rarely use microscopic hair analysis as the only scientific evidence, and hopefully lawyers will understand the limitations involved when using this type of evidence.

DNA analysis is not always successful on hairs, and there are many cases where identity is not an issue but the morphology of the hair and the case circumstances may be more important. There is a danger that general hair examination will become a lost art, and research in this area abandoned, because it is subsumed by the glamour (and success) of DNA analysis. Finally, rogue scientists and poor quality control should not be allowed to discredit an entire discipline that still has the ability to provide valuable evidence in criminal cases.

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