1-1-2003

Violent teeth: The validity and scientific basis for bite mark evidence

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VIOLENT TEETH: THE VALIDITY AND SCIENTIFIC BASIS FOR BITE MARK EVIDENCE

by

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Bachelor of Arts
University of Nevada, Las Vegas
2001

A thesis submitted in partial fulfillment
of the requirements for the

Master of Arts Degree in Criminal Justice
Department of Criminal Justice
Greenspun College of Urban Affairs

Graduate College
University of Nevada, Las Vegas
May 2003

UMI Number: 1414544

ProQuest Information and Learning Company
300 North Zeeb Road
P.O. Box 1346
Ann Arbor, MI 48106-1346

UNLV
UNIVERSITY OF NEVADA LAS VEGAS

Thesis Approval

The Graduate College
University of Nevada, Las Vegas

April 16, 2003 , 20

The Thesis prepared by

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Entitled

Violent Teeth: The Validity and Scientific Basis for Bite Mark Evidence

is approved in partial fulfillment of the requirements for the degree of

Masters of Arts in Criminal Justice

Examination Committee Chair

Dean of the Graduate College

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PR/1017-53/1-00

ABSTRACT

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Bite marks have become widely used in criminal cases in the last 10 years due to the fact that greater public attention to dental hygiene and professional dentistry record keeping has increased the number of dental x-rays used for comparison. Dental evidence is accepted in courts, but its validity and the scientific basis for its use as evidence, has been questioned. One problem is the wide variety of dental techniques described in the literature and the lack of direction from both European and American forensic dental organizations.

The paper explores the history of scientific evidence, addresses the evidence standards presented in court, and discusses its acceptance as scientific evidence. It also reviews bite mark evidence, describes the different techniques being used in collecting such evidence, and discusses the validity and reliability issues surrounding it. The paper ends with a critical review of the implications of scientific evidence for future use in general, the development of new standards for recovering such evidence, and its public acceptance.

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CHAPTER 1

STATEMENT OF PROBLEM

"Forensic odontology is the branch of odontology which deals with the proper handling and examination of dental evidence and with the proper evaluation and presentation of dental findings in the interest of justice"(Pederson, 1969).Human skulls come second only to the hands in providing the criminologist with a significant source of information.

The examination of teeth has three areas of use in forensic situation: (1) Formulation of a positive identification; (2) Analysis of bite marks on persons or associated evidence; (3) Interpretation of injuries or other changes in oral tissues (Levine, 1972). The soft tissues of the lips and cheeks serve as a cushion in trauma and as insulators in case of incineration, which makes dental characteristics highly individualistic and extremely stable (Luntz, 1966). Dental records of any work done on human teeth exist, and since teeth are one of the most indestructible parts of the body, " ...dental data, it is now realized has come to provide detail of any kind comparable with the infinitesimal detail that was previously thought likely to be provided only by fingerprints " (Smyth, 1980).

Bite marks have become widely used in criminal cases in the last 10 years due to the fact that greater public attention to dental hygiene and professional dentistry record keeping has increased the number of dental x-rays used for comparison (Morn, 2000). A

patient's dental record shows where teeth have been lost through an accident or extraction, where they have been drilled, filled, or crowned. The chart also includes details of discoloration, any missing fillings, cracks, or chips (Owen, 2001).

Dental radiography also reveals specific information such as root canal work, overbite, overlapping, or impacted teeth. The dentist's mold records also shows unique patterns of ridges in the patient's palate.

While fingerprint and DNA records can provide essential information regarding the identity of a victim or a suspect, dental records have one great advantage in that they exist for a far greater proportion of the general population than is ever subject to fingerprint or DNA testing (Owen, 2001). Therefore, if the bite mark evidence is collected and preserved properly and analyzed using acceptable scientific procedures, it can assist the courts in solving cases, which couldn't be solved using DNA or fingerprint evidence.

Dental evidence is accepted in courts, but its validity and the scientific basis for its use as evidence, has been questioned. One problem is the wide variety of dental techniques described in the literature and the lack of direction from both European and American forensic dental organizations.

This paper addresses several issues. First, it explores the history of scientific evidence, addresses the evidence standards presented in court, and discusses its acceptance as scientific evidence. Second, it reviews bite mark evidence, describes the different techniques being used in collecting such evidence, and discusses the validity and reliability issues surrounding it. The paper ends with a critical review of the implications

of scientific evidence for future use in general, the development of new standards for recovering such evidence, and its public acceptance.

CHAPTER 2

LITERATURE REVIEW OF
SCIENTIFIC EVIDENCE

Forensic science is a field that incorporates all aspects of the application of scientific principles for purposes of the establishment of criminal guilt or innocence. It has assumed an increasingly important role in an effort to prevent, control, and detect crime (Redmayne, 2001). Scientists assist the criminal justice system in establishing if a crime has indeed been committed, reconstructing that crime, identifying suspects, and proving or disproving the involvement of a suspected offender with a particular crime.

Criminalistics is the subdivision of forensic science which involves the collection and laboratory examination of physical evidence from the scene of a crime or a suspicious occurrence (e.g., an unexplained death) and court testimony on the significance of that evidence in a particular case (Davis, 1975). There are three major steps in how criminalists evaluate physical evidence – (1) collection of the evidence, (2) laboratory evaluation of it, and (3) court presentation of the results and their significance. The crime scene has to be surveyed by a trained professional responsible for the collection and transmission of physical evidence. It is impossible to commit a crime without leaving a clue, and if all evidence is collected and

interpreted correctly, it will prove or disprove the truth of the allegation (Turner, 1975).

This chapter examines several issues about scientific evidence in criminal and civil disposition. It looks at the history of use of two types of scientific evidence –DNA and fingerprints. Second, it looks at reliability tests used in court such as the Frye and Dauber rules, since the strict scrutiny of scientific evidence is premised on the assumption that juries are not adequately suited to assess expert evidence when doubts about its reliability exist. Third, it assesses the validity and reliability issues involving scientific evidence and its admissibility in court.

History of Fingerprints

Forensic scientists have been able to establish the presence of individuals at crime scenes by analyzing fingerprints, made possible by the fact that everyone's fingerprints are thought to be unique (Easteal et al., 1991). When a match is present between the suspect's fingers and the prints found at the crime scene, there is virtually no possibility for the prints to belong to another person.

In the early days of police work, one of the great plagues of the professional judge was not being able to prove that a suspect was a repeat offender. Society wanted a way to be able to punish him/her accordingly, with a stiffer sentence. Different countries took different approaches to this problem: France took the method of branding their criminals with the fleur-di-lis symbol, as an indication that this person had offended the Crown before; Rome sometimes tattooed criminals; other countries went the route of removing the hand of a thief. Beginning in the

1850s, some areas began photographing criminals as they went into prison. This method became more popular in the 1880s, with the advent of the Kodak camera, which was quicker and easier to use. However, since people can drastically change their appearance, photographs could not be relied on. Nonetheless, police spent a great deal of time studying "Rogues Galleries"-thick books of photographs of known criminals in the hopes of being able to identify them in the case of similar crimes occurring near them (Skopitz, 2001).

Other methods included the Bertillon System, developed by a French anthropologist Alphonse Bertillon who posited that there were specific body measurements that would not change; an example would be the length of the femur. This was a very popular method, despite the obvious problems of obtaining measurements. In 1903 in Leavenworth, Kansas, while taking the measurements of one Will West, officials found that he was indeed a repeat offender. Mr. West mightily protested this charge, and upon further examination of the records, the jailers discovered that they already had one William West in their custody, with the same Bertillon measurements (Skopitz, 2001).

However, another system of identification was developing - fingerprinting. Fingerprints had been used as source of identification since the T'ang Dynasty in China, and in 8th century Japan- a thumbprint could suffice for a signature on legal documents (Skopitz, 2001). The first crime solved using fingerprints is sometimes stated to be a murder case that occurred in ancient Rome, where a bloody handprint was later found to be the match for the killer. Western awareness of the possibilities of fingerprinting first came to notice in 1684 with a lecture given by British doctor

Nehemiah Grew, who spoke on the ridge patterns of fingerprints. Two years later, Italian physician Marcello Malpighi wrote a treatise describing the ridged patterns. And there interest ended for over a hundred years; in 1823 Johannes Evangelist Purkinje wrote his doctoral thesis for the University of Breslaw that divided fingerprints into nine different types (Skopitz, 2001).

In 1858, however, fingerprinting found a firm believer in William James Herschel. Herschel wanted a good way to seal a contract with a Bengali firm, and settled on using a handprint on the contract. Two years later, Herschel became a magistrate at Nuddea. One of his official duties was to prevent as much fraud as possible. High illiteracy rates, and therefore the inability to get a signature, drastically raised the potential for fraud. Remembering the success of the handprint, Herschel began requiring pensioners to use their fingerprint as a form of signature in order to receive the money due them. In 1877, Herschel requested permission to try his system in a small prison in Bengal, but was refused. Meanwhile, Dr. Henry Faulds a Scottish physician working as the Surgeon Superintendent of a hospital in Japan, was also studying fingerprints, having become interested after seeing some in some ancient pottery work. In October 1880, he wrote a letter to a journal describing his work with fingerprints. William Herschel wrote a letter in response for the next issue of the journal, and a feud ensued between these two pioneers.

While Dr. Faulds continued his work, a noted anthropologist Sir Francis Galton, began work on the problem of fingerprints as a means of identification, and of classification. In 1892 he published “Fingerprints”, the first book on the subject. In it he stated his belief that fingerprints were unique and unchanging, making them

ideal for identification. He warned however, that they would not provide heredity or racial clues. His basic method of classification is still in use. The use of fingerprints during this time was inactive. In 1893 the British Home Office set up a committee to determine the best criminal identification system for Scotland Yard to use. After consideration, they recommended the Bertillon system, but to also use fingerprinting as a complementary means of identification (Skopitz, 2001). In the United States, interest was growing. Gilbert Thompson, a geologist in New Mexico used his fingerprints on documents in 1882 to prevent forgery and became the first person to use fingerprinting in the United States. Argentine detective Juan Vucetich began his own work on fingerprinting and classification. By 1892, he solved the first criminal case to depend on the matching of fingerprints-the case of a mother who murdered her two sons. By 1912, Vucetich's method became the standard in South America. Great Britain and most of Europe accepted the Galton-Henry system, with the exception of France, Belgium, and Egypt, who used an amalgam of the two systems. Edward Henry finished his system of identification and retrieval of fingerprints in 1896, to great success. The following year the Indian government made fingerprinting the official means of keeping track of criminals.

In 1901, Henry becomes the head of Scotland Yard's Criminal Investigation Division. The four basic divisions that Henry creates are: Arches, Loops, Whorls, and Composites. Every fingerprint will fall into one of these four groups, narrowing down potential matches. The New York Civil Service began testing fingerprinting in 1902. In March, 1903 the New York State Prison system began fingerprinting criminals and in 1904 the federal prison at Leavenworth began to do so. The US

Army began using them in 1905, and the Navy in 1906. The Marines began fingerprinting in 1907 (Skopitz, 2001). The International Association for Chiefs of Police began keeping extensive fingerprint files, which, in 1924 they sent to the newly created federal Identification Division of the Bureau of Investigation of the Justice Department. Nine years later they had 5 million cards, and by 1946, 10 million (Skopitz, 2001). After eight years of testing, the FBI created a computerized Criminal Fingerprint File in 1980. In 1983 the FBI created the National Crime Information Center, to allow for the dissemination of information about criminals between the federal and local governments. As part of this, the FBI standardized the methods of fingerprint classification, eradicating local differences in classification, and making national retrieval easier. By 1989, all fingerprints match requests were done on the computer, and the response time cut from 14 to 1 day.

Fingerprinting identification are still key to solving criminal cases, despite the technological advances that are making DNA testing more reliable and easy to obtain (Skopitz, 2001). It is possible that they may one day become obsolete, as new methods supersede them, but for the future, the ends of the fingers will continue to point the way.

Fingerprint identification does not rest, as does DNA analysis, on class characteristics, but on individual ridge detail. The DNA of identical twins is identical according to methods of analysis now available, but by contrast, it has been empirically established that the fingerprints of identical twins are different in their individual ridge characteristics. Jurors also believe fingerprint evidence is true. Illsley (1987) showed that jurors place great weight on the testimony of fingerprint

experts, and rank fingerprint evidence as the most important scientific reason why they vote for conviction. However, that does not provide any scientific evidence whatsoever that the fingerprint testimony is correct. Consensus judgments of fingerprint comparisons show either undetermined or quite large error rates; the proficiency and certification procedures in current use lack validity, and cannot serve to specify the accuracy or skill level of individual fingerprint examiners; and there is no published research evidence on error rates, so it is impossible to determine whether true error rates are miniscule or substantial (Meagher, 2002).

There is also challenge to the validity of fingerprints under the Daubert criteria, and that challenge is limited to how fingerprints may be admitted in federal courts. Even the states which continue to use the Frye criteria would likely see an increased number of challenges to finger print identifications in the event of an adverse rule, and such a ruling would undoubtedly diminish the certainty of fingerprint identification for some prospective jurors. Therefore, the goal of a Daubert hearing in the US v. Mitchell case was to create the definitive legal precedent in support of fingerprint individuality as a means to prevent future perfunctory actions. A subsequent clarification of Daubert application by the US Supreme Court in Kumho v. Carmichael weakened the challenge somewhat, but of greater concern is the potential domino effect that if the court determines that fingerprints analysis is not a science, other types of forensic examinations might follow (Meagher, 2002).

There have always been challenges to practitioners and expert reliability regarding fingerprint evidence. But a good example of the continued faith in forensic

fingerprint applications was the October 2000 ruling for the Daubert hearing in U.S. v. Havvard. The court ruled that under Daubert criteria, finger print identification is "...the very archetype of reliable expert testimony..."

Forensic DNA in the Trial Court: A Brief History

Scientists have long been interested in linking biological forms of evidence to perpetrators or victims, the way fingerprints do. In some cases, mostly with violent crimes such as assault, murder, or rape, the perpetrator leaves behind a part of him/herself in the form of hair, blood, or semen. On the other hand, he/she might take a part of the victim- usually the blood or hair. During the last decade, techniques for analyzing certain kinds of DNA variation have been acclaimed as providing a means of doing this, and the application of these techniques has been called DNA fingerprinting.

Deoxyribonucleic acid, or DNA, is an organic polymer, which is found within every cell of every organism. The polymer is composed of three specific parts: (1) the phosphate backbone, (2) the deoxyribose sugar, and (3) the nitrogenous base. The first two components remain constant across all individuals, while the third is what distinguishes each constituent of the polymer and thus aids in distinguishing between individuals (Inman & Rudin, 1997).

DNA is composed of a string of nucleotides. Within each human cell, this string is approximately three billion bases long. A fortunate consequence of such a long string is that variation arises and small changes, which may not affect the function of the DNA or the proteins for which it codes, can allow for distinction

between samples. Thus, very small differences in human DNA sequences can be detected and used to differentiate between individuals. This observation led to the first forensic DNA testing in 1984 by Alec Jeffreys, who exploited genetic differences among individuals. Initially, his technique used for this analysis was based on Restriction Fragment Length Polymorphisms (RFLP). This technique was the standard in DNA forensics for a long time because it offered a high degree of discrimination and in some circumstances it is still used. However, it usually requires large amounts of non-degraded DNA, which is difficult to find outside of the human body (McKenna et al., 1994).

In 1986, Kary Mullis developed a technique called the Polymerase Chain Reaction (PCR). This technique revolutionized not only forensic DNA science, but also all of molecular biology. PCR is a method, which allows the cell's normal machinery for replicating DNA to amplify DNA within a sample, which may contain as little as one nanogram of DNA. However, the use of the polymerase chain reaction (PCR) method made DNA analyses more sensitive, simpler, faster, and more amenable to analyzing degraded samples. PCR is a sample preparation technique in which relatively large amounts of specific DNA sequences of DNA can be generated from relatively small quantities of DNA. Improved extraction procedures, quality assurance guidelines and standards, proficiency testing, interpretation guidelines, and statistical analyses also have been developed (Inman & Rudin, 1998).

A new forensic DNA approach that is being more broadly applied is mitochondrial DNA sequencing. Mitochondria are structures within cells that

contain DNA that is distinct from the DNA in the nucleus. Mitochondrial sequencing is used extensively in FBI labs, as well as state and private crime labs. This technique, which takes into account small differences between people's mitochondrial DNA is very useful for minute samples or ancient or degraded samples (Hammond & Caskey, 1997).

In 1989, the Technical Working Group on DNA Analysis Methods, cognizant of the large number of sexual assaults in the United States and the tendency for sex offenders to repeat crimes, proposed the concept of combining forensic DNA technology with computer science capabilities to aid in resolving violent crimes.

Forensic DNA profiling techniques cannot typically prove that a person committed a particular crime, but they can prove whether he/she was there and left DNA evidence. Also, DNA evidence can be used to overturn previous serologically based guilty verdicts because of its higher discriminatory power. Based on statistical results from allele frequency databases, a DNA investigator can generate likelihood that a suspect's DNA profile will randomly match an evidentiary sample (Inman et al., 1997).

The realization of the full use of DNA typing technology has come to fruition by the development by the FBI of a national DNA data bank called CODIS (Combined DNA Index System). The two main objectives for CODIS operations are: 1) assist investigators in the identification of suspects of violent crimes, and 2) increase the efficacy of forensic laboratories by providing software to conduct DNA casework and perform statistical calculations. Using the CODIS loci, one can

typically obtain a frequency on the order of one-in-a-billion to one-in-a-trillion that the profiles will match at random, given non-related subjects (Weedn et al., 1998).

As techniques for manipulating and analyzing DNA become more efficient and more durable, forensic DNA testing will improve. Currently, DNA can be used to very specifically discriminate between individuals, using a wide variety of techniques. Depending on the amount of sample and the level of degradation, several techniques can be applied to narrow the likelihood that a particular individual was present at a crime scene. An additional advantage of DNA testing is the ability to review previous cases that were decided primarily based on older technology. In these instances, DNA techniques can be used to reanalyze material that may allow for previously convicted individuals to be acquitted. It is clear that DNA technology will advance as will the database technology for analyzing forensics data. Thus, the power of DNA technology should be incredibly useful to lawyers in the years to come. However, the limitations of these technologies should always be kept in mind (Connors et al., 1996).

After a decade of courtroom battles and heated academic debate, the United States has entered an age where the scientific validity of DNA evidence is not subject to serious dispute. The problem with DNA evidence is no longer one of validity, but one of proficiency. The admissibility of forensic DNA evidence must be conditioned on its examination by a crime lab governed by uniform national standards to avoid cross-contamination and other lab errors. Such governing national standards must encompass every aspect of the forensic process, from chain of custody to DNA testing procedures, in order to ensure the reliability of DNA evidence. For the

maintenance of DNA reliability, it is important that judges strictly apply and enforce the national guidelines governing chain of custody and lab procedures when making decisions regarding DNA. If any of these standards are not followed, judges must find the evidence inadmissible. If compliance with the standards is established, the judge must determine and admit evidence of either a positive or negative DNA match (McDonald, 1998).

Courts have successfully objected improper application of DNA scientific techniques to particular cases, especially when used to declare a DNA match based on frequency estimates. However, DNA testing properly applied is generally accepted as admissible under Frye or Daubert standards. As stated in the National Research Council's 1996 report on DNA evidence, "The state of the profiling technology and the methods for estimating frequencies and related statistics have progressed to the point where the admissibility of properly collected and analyzed DNA data should not be in doubt." At this time, 46 States admit DNA evidence in criminal proceedings. In 43 States, courts have ruled on the technology, and in 3 States, statutes require admission (Thompson, 1994).

Standards for Evaluating Scientific Evidence

During its early stages, DNA profiling gained a reputation of an enormous and infallible power (Easteal et al., 1991). The interests of the private companies providing DNA profiling as a service encouraged this trend. Evidence presented in criminal cases was unchallenged, and there were little existing procedures to control it.

The first serious challenge to the validity and admissibility of such evidence was in a case, where the testimony presented suggested that there were serious irregularities in the laboratory procedures used to obtain the evidence. The evidence was ruled inadmissible because DNA profiling had not been performed correctly in the case. Within a short time, there were numerous articles published, suggesting the establishment of procedural standards and quality control measures (Conner, 1988).

Judges still employ the criteria used in Frye vs. United States 293 F. 1013 (D.C. Cir. 1923), to determine whether a new scientific test or procedure should be admissible in court. This test required that new tests must gain general scientific acceptance before they can be used in court. In some instances when a scientist or an expert presents information to a single judge or court, the decision of the court is influenced by the preparation and delivery of the expert, the competence of the prosecutor and defense attorney, and the ability of the judge making the ruling, apart from the test itself (Peterson, 1975).

The current criteria for admissibility of evidence originate from a case known as Frye v. United States in 1923. The case gave rise to the "Frye rule," which states that expert witnesses should be allowed to give evidence provided that their conclusions derive from a principle that is "sufficiently established to have gained general acceptance in the particular field to which it belongs." This means that a judge, in a pretrial hearing, can determine whether expert witnesses and their testimony meet a reasonable scientific standard (Foster & Huber, 1999).

In 1975, Congress enacted a revised set of federal rules of evidence, which were similar to those in the "Frye rule" but omitted any mention about the "general

acceptance" of the science being presented. Some courts have followed the "Frye rule" and others have used the revised rule. Consequently, there is a considerable amount of questionable science in the courtroom. The very broad latitude in the procedure of different courts was probably the reason that the Supreme Court decided to hear the criteria for admission of scientific evidence in court (Foster & Huber, 1999).

The Supreme Court in June 1993 issued a verdict on the *Daubert v. Merrell Dow Pharmaceuticals* case. It essentially ruled that judges should exclude testimony based on evidence not generally accepted by the scientific community. The following five Daubert criteria were to be considered when determining the reliability of a method or principle:

Table 1: Daubert criteria

CRITERIA	DESCRIPTION
TESTING	the extent to which the principle or methodology has been tested.
RESEARCH METHODS	– the adequacy of research methods employed in testing the principle or methodology
PEER REVIEW	– the extent to which the principle or methodology has been published and subjected to peer review
RATE OF ERROR	– the rate of error in the application of the principle or methodology
ACCEPTANCE WITHIN THE FIELD	– the extent to which the field or knowledge has substantial acceptance within the relevant scientific, technical, or specialized community

In the first year, four cases were dismissed based on the "junk science" concept: (1) dismissal by the Texas Supreme Court of a claim against the Dupont Co. that alleged the fungicide Benlate had damaged a pecan grove, (2) banning by a federal judge of two doctors' testimony claiming that use of a Unisys computer keyboard was linked to carpal tunnel syndrome, (3) dismissal by a federal judge of a case against NEC that cellular phone use caused brain cancer, (4) dismissal by a U.S. District Court of a claim that birth defects were caused by Primatene (for asthma) taken during pregnancy. In 1996, the much publicized claims that electromagnetic fields (EMF) caused cancer were dismissed by the California Supreme Court (Weil, 2001).

Courts have also successfully challenged improper application of DNA scientific techniques to some cases. As stated in the National Research Council's 1996 report on DNA evidence, "The state of the profiling technology and the methods for estimating frequencies and related statistics have progressed to the point where the admissibility of properly collected and analyzed DNA data should not be in doubt." (Thompson, 1994).

There also have been Daubert challenges filed in federal courts seeking to prohibit fingerprint examiners from testifying, but there has not been a comprehensive treatment of this issue in the academic literature (Epstein, 2002).

CHAPTER 3

LITERATURE REVIEW OF BITE MARKS

Bite mark analysis can play a key role in the identification of assailants in variety of cases (De La Cruz, 1987). One of its most frequent uses in actual crime is in cases of sexual attack and murder, also child and elderly abuse, where bite marks are present on the victim (Smyth, 1980). Bite marks are sometimes left in foodstuffs or other material found on scenes of murder and burglaries. If the bite mark evidence is collected and preserved properly and analyzed using acceptable scientific procedures, it can yield valuable and defendable opinions that will assist the courts in the resolution of criminal cases (B., E. &, D., 1994). The historical background of dental evidence, description of techniques to collect bite marks, and issues of validity and reliability of such evidence are all summarized below.

Historical Background of Dental Evidence

Tooth impressions were utilized for personal identification as far back as 900 years ago (Danielson, 1973). One of the first intriguing cases occurred in a.d. 66, when Sabina, Nero's mistress, requested the head of his wife on a silver platter, and positively identified the head by a discolored anterior tooth (Vale, 1969).

The first formal case of dental identification was that of John Talbot who was killed in a battle in 1453 (Swanson, 1967). The next such case was reported in 1477,

where a disfigured body was positively identified by a missing lower tooth (Humble, 1933).

The first forensic odontologist in the United States was Dr. Paul Revere, who in 1775 was able to identify the body of one of his patients through a bridge of silver and ivory he had constructed 2 years previously. In 1814, in Glasgow, England, a body-snatching case was dismissed after the dentist for the defense couldn't prove that a denture belonged to the corpse in question. Another famous case occurred in 1835, where the burned body of the Countess of Salisbury was identified by a gold denture (Harvey, 1966). The Webster-Parkman case in 1849 marked the first time in which dental evidence was accepted in the United States courts (Suzuki, 1970).

The first treatise on forensic odontology as a subject in its own right was written in 1898 by Dr. Amoedo, who is recognized as the father of forensic odontology (Furahata, 1967). His publication entitled *L'Art Dentaire an Medicine Legale* acquired worldwide recognition.

In 1953 dental evidence played a vital role in the internationally famous Christie case in London (Keiser-Nielsen, 1968). A concept of utilizing the cracks and wrinkles of the lips was introduced in the 1950's by a forensic expert in California. His idea of lip prints in combination with bite marks was to be analyzed in future use in criminology.

The 1970's have found an increasing interest in the field of forensic odontology in the United States. Several organizations such as the American Society of Forensic Odontology and the American Academy of Forensic Sciences have been an outstanding addition to the field. The value of the forensic odontologist has been

increasingly recognized by the legal, medical, and law enforcement professions. However, the forensic odontologists are dependent upon these professions for the case material, and the encouragement to attain the confidence of the lay public and its acceptance of dental science (Levine, 1972). For it is private citizens who make up the juries which need to be convinced of the validity of dental scientific conclusions.

Techniques for Conducting Bite Mark Analysis on Human Skin

The use of bite imprints or bite marks made by the human dentition on skin for identification has been well accepted by the scientific, law enforcement, and legal communities (McCabe, 1995). Properly preserved and analyzed, bite mark evidence on skin can link the assailant to the victim of the crime. Such bite marks are most commonly found on the victim's skin - either deceased or alive. In some occasions, the victim may have also inflicted a bite on the assailant or even on her/him self. Bite marks inflicted in human skin are very transient in nature; therefore proper preservation of the evidence is a necessity (Pretty & Sweet, 2001).

The considerable variation of bite mark presentations on human skin brings the accuracy of skin as a registration material into doubt. Skin is a poor registration material, since it is highly variable in terms of anatomical location, underlying musculature, or fat, curvature, and looseness or adherence to underlying tissues (Sopher, 1976). Skin is also highly visco-elastic, which allows stretching to occur during either the biting process or when evidence is collected.

In 1971, DeVore issued a preliminary report describing studies performed on the variability of bite marks found on skin. The experiment involved the inking of

human skin of living volunteers using a stamp with two concentrically placed circles with intersecting lines. Following the analysis of the photographs, it was found that in all cases there was an expansion or shrinkage of the stamp, with a maximum linear expansion of 60% at one location. The design of the stamp permitted the investigators to examine the distortion in both size and direction. DeVore concluded that, due to the level of distortion found, photographic images of a bite mark in comparative analysis should be used only if the exact position of the body can be replicated. The placement of a body in the exact position is usually impossible, as such a position of the body during an attack is rarely known. DeVore stated that further research to investigate the effect of postmortem changes on skin distortion was required (DeVore, 1971).

In 1974, researchers from the Bioengineering Unit of the University of Strathclyde examined the features of the biting process likely to impact upon the appearance of bite marks on human skin. They described the differing characteristics of skin from a variety of anatomical locations. Like DeVore, they emphasized the importance of body location during biting as the directional variations or tension lines will change with movement. The report also described distortion that can occur in skin after biting. The response of skin to trauma is likely to stiffen the area, thus rendering it more stable, while the resumption of fluid will cause a large amount of distortion. They concluded that the changes in bite mark appearance are likely to be greater as the injury grows older (Barbenel & Evans, 1974). This was found equally applicable to both living and dead victims. The article concluded that forensic

odontologists where “still ignorant... of the conditions during normal biting...and considerable research is required [to address this]” (Barbenel & Evans, 1974).

One of the most difficult things in forensic dentistry is to analyze bite marks on highly curved surfaces. Many different forms of dental wax have been the standard use in the analysis of bite marks.

In 1990, West et al. suggested a new material for the production of bite marks templates. The material is called Styrofoam, and is a more stable medium. The bite mark for study can be produced by letting the suspect bite into Styrofoam, or let the study model "bite" into the material. The bite is pressed down for several millimeters. This is to accurately register the oclusal and incisal patterns of the teeth. After that a template is made and can be used in the comparison. Acetate overlay tracings, photography, and different radiographic techniques are used to produce the template. The template is compared with the patterned injury. This is usually done by observing the bite injury in a photograph viewed through the overlay.

All these methods can result in errors since there are differences in the physical properties of skin and wax or Styrofoam. Both Styrofoam and dental waxes are materials, which are non-elastic, and are most often used in a flat configuration. Skin is elastic, and the areas that have been injured are often curved to some degree. During biting, the skin is stretched and compressed by the teeth. It is also pushed between the dental arches. The skin may come in contact with the distal, mesial, facial, labial, incisal or occlusal surfaces of the teeth. It can also be any combination of these surfaces. The fact that the skin is forced between the teeth gives rise to the patterned injury (Sweet & Bastien, 1991).

Bite marks evidence can be obtained from both living and deceased victims. Impression techniques are used to record the surface topography of the area of the skin affected by the injury. Some materials - like dental impression materials and other molding compounds - have been used extensively for this purpose. If the victim is deceased, it may also be possible to remove the skin for a more detailed investigation of the injury pattern's deeper layers. Trans-illumination techniques used to study the severity and pattern of subcutaneous hemorrhage in a bite mark injury, can help the forensic scientist to reach conclusions about the approximate time of the bite, and provide additional information about the perpetrator's dentition (Sweet & Bowers, 1998). If a suspect has been apprehended and a cast of his teeth is available, it is possible to compare the suspect's dentition and the study model of the bite mark with comparative metric analysis and pattern association studies. This is done in an attempt to implicate or exonerate the suspect. If the victim is alive, and an impression of the tissue surface is to be taken, the odontologist will need a rigid matrix to support the impression material. Also, when the skin is to be removed from a deceased victim a rigid supporting matrix is needed to maintain the anatomical contour of the surface.

Many techniques of doing this have been described and utilized with varying success. In 1991, Sweet and Bastien suggested a method, where a ring of plastic is adapted to the victim's body to produce a dimensionally stable matrix. These rings can also work as markers to record the anatomical orientation of the injury.

Dental Identification and The Uniqueness of The Human Dentition

Bite mark analysis is based on two postulates: (1) the dental characteristics of anterior teeth involved in biting are unique amongst individuals, and (2) this asserted uniqueness is transferred and recorded in the injury (Hale, 1978). A distinction must be drawn from the ability of a forensic dentist to identify an individual from their dentition by using radiographs and dental records, and the science of bite mark analysis. Dental identification, as opposed to bite mark identification, utilizes the number, shape, type, and placement of dental restorations, root canal therapies, unusual pathoses, root morphology, trabecular bone pattern, and sinus morphology (Sweet & Pretty, 2001).

The debate over the uniqueness of human teeth is probably one of the fiercest in current forensic dental discourse. Many forensic dentists, appellants, and lawyers have questioned the validity of dental uniqueness determination and demand to know from testifying experts the relative frequency of dental features identified in bite marks. An examination of the literature divulges the scientific evidence for this commonly held belief.

The first article to consider the statistical nature of dental uniqueness was published by MacFarlane and Sutherland in 1974 (MacFarlane et al.). The authors began by differentiating between "positive" and "negative" features of the dentition. A positive feature was described as the presence of a tooth with a certain rotation or other individualizing feature. A negative feature was the absence of a tooth. This study concentrated on the positive features that occurred on the anterior teeth (canine to canine, maxillary and mandibular). A total 200 study casts (maxillary and

mandibular) were produced. The authors only studied the dental casts, not bite marks that would have been produced by such casts. The investigators noted four categories: the number and shape of each tooth, the presence of any incisor restoration, relationship of teeth to arch form, and tooth rotation.

MacFarlane and Sutherland concluded that a particular dentition would only be seen in eight people in 100,000 of the population with natural teeth. The authors also concluded that they had not confirmed the individuality of the human anterior teeth, nor had they considered the impact or representation of any of the features examined on a bite mark in human skin. The highly subjective examination of the casts by multiple examiners and lack of tabulated results make this study weak. However, a large sample was used of a defined population and efforts were made by the researchers to ensure that this sampling was randomized.

A different study performed by Dr. Rawson – a forensic dentist, examined 397 bites and applied a statistical probability theory to the results. Twelve hundred wax bites were obtained from forensic odontologists in various geographic locations in the United States. The article assumed that the position of each of the teeth was entirely independent of the position of any others. However, the independence of these features has not been established by this or any other study. This lack of independence renders Rawson's certainties of individualization invalid. Rawson's results also showed a possible sampling error, as evidenced by the data sets regarding possible tooth position for each unit (Rawson, 1984).

Techniques for Permanent Recordings of Bite Marks

Criminals seem to have difficulties resisting food, candy or fruit found in places entered illegally. The unconsumed portions containing more or less exact impression of at least some of the criminal's teeth are often left behind (Hale, 1978). If the investigating officer finds a suspect, permission can be granted to have impression taken of the suspect's teeth. These impressions can later be compared with the impressions found on the crime scene by a forensic odontologist. Unfortunately, it often takes time before a suspect is found, and by then the bite marks and the substance containing them have deteriorated to such extent that worthwhile comparison is impossible.

The Manual of Forensic Odontology discusses three main methods of permanent recording of bite marks: (1) Preserving the material; (2) Photography; (3) Permanent model in a suitable hard material. To preserve the material, the substance is placed in an airtight bag in a refrigerator, or in a preserving fluid. A mixture of equal parts of glacial acetic acid, formalin and alcohol is the best medium in current use. Both these methods are useful, but unfortunately some shrinkage and detiriation take place.

When a permanent record is needed, a good method is to take photographs of the material in both monochrome and colors. The photos have to be taken from different angles, taking care to include a ruler or a scale in all photographs in the same plane as the bite marks. When it's done, the comparison can be made using the method first described by Sörup (1924), which meant placing a negative of the bite marks over a positive of the suspect´s teeth. This procedure is very useful and is

considered by Euler (1931), Frykholm (1958), Ström (1963) and many others to be the best.

By utilizing the third method, a model is made, which is identical with the bitten material. The model is compared with the suspect's teeth. This method has the advantage of not destroying the evidence, and can also be used in conjunction with photography and preserved materials.

It is certainly no new idea to produce models. In 1955 Svensson and Wendel did experiments with hydrocolloids, but they did not fulfil the essential requirements. Alginates are subject to dimensional change unless they are cast within 15 to 30 min. Unfortunately, fine detail is lost on the removal of the specimen, due to the lack of strength and cohesion. Reversible hydrocolloids were found to reproduce the finest details. Problems occurred with the models since the separation of the resultant model was not always clean, even when a potash alum fixing solution was used. The time and the apparatus required make its use at the site impracticable.

In 1959 Luff and Hess evaluated the properties of an impression material they had used. These were the properties they found important; (1) the material must flow easily, and have to be capable of reproducing the finest details;(2) Be quick setting at room temperature in 15 to 30 minutes; (3) Be durable; (4) Be possible to use in the field without the need for elaborate apparatus. In 1963 Ström recommended silicone materials. When these are used for impressions of bite marks on the skin, the area will not be distorted because of the elasticity.

In 1966 Gustafson described the method used in the laboratory in Malmö. These materials, which are easily available, can be used to produce very similar

replicas for forensic purposes. Use of these materials in the mouth is on the other hand not recommended. The silicone materials are good materials to produce flexible materials or flexible areas on models that are otherwise rigid.

In 1974, Ruddick described in his article the use of ultra-violet (UV) photography in forensic medicine. UV photography is usually applied on "hidden" lesions, where the initial trauma to the skin has disappeared. The method can also be used in cases where implements have been used, which can be identified by UV photography.

The use of UV photographing in forensic medicine differs with regard to the lesion's age. If the lesion can be seen faintly an Ilford fine grain ordinary film (N.5.31) should be used. In cases were the lesions are not visible in normal light, it is advisable to use ultra-violet radiation. This can be done in different ways: (1) using a high output ultra-violet source, (2) using an electronic flash with a Wood glass filter over the flash head, (3) using an electronic flash with UV filter on the camera.

In 1984, Rao and Souviron researched the topic of preservation, collection, and subsequent interpretation of bite marks. They used a method of dusting and lifting of a bite mark. When the bite mark was dusted and lifted it yielded a quite clear and detailed picture of the arches (Rao & Souviron, 1984). A set of dental models from a given suspect was made, either on voluntary basis or after a court order or search warrant. By using photographs, the "bite print" card and acetate tracings of the incisal edges, analyses and comparisons could be made. Using stone models of the suspect's teeth and either a live victim or a corpse, imprints could be made by the stone model and a "bite print" card prepared from this imprint. A

comparison could once more be made between the initial bite print lifted from the victim and that prepared using the dental model of the suspect's teeth.

Many studies have been carried out regarding preservation and documentation of bite marks. The method described by the researchers has many advantages, but does not show the disadvantages, if any, of the traditional impression and stone model technique. The materials are cheap and readily available. Expertise is not required to lift the print, and any crime scene technician can lift the print of a bite mark after the saliva has been swabbed off. This method does not require subsequent use of the impression and stone model. The method yields information, which can be extremely important in court, and can be used for a court order to get a suspect's co-operation in the producing of dental cast for future comparison. This method provides the forensic odontologist with the tool for the analysis of the bite mark. The lifted print of the bite mark can be viewed under the microscope, which can bring out details of the internal anatomy of the biting surface.

Issues of Validity and Reliability of Bite Mark Evidence

The use of bite marks evidence is accepted in courts, but its fundamental validity and the scientific basis for its use as evidence, as well as the lack of standards in collecting and use of this type of evidence has sometimes been questioned. Therefore, the American Board of Forensic Odontology in 1980 appointed a committee to develop a guideline for the investigating and collecting of bite marks. The committee of the American Board of Forensic Odontology used a consensus approach in the development of the preliminary guidelines for bite mark evidence.

The committee addressed the following question: how strong must the evidence be before an examiner reliably can conclude that there is, or is not, a match between a bite mark and the teeth of the suspect? To answer this question it was decided that the term matching point must be defined. The number of matching points that could give positive identification must also be decided. A method as precise as this would not exist in fingerprint analysis, but the committee thought it was essential to try to quantify and measure the value of a bite mark, since there had been many different expert opinions in trials regarding the interpretation of bite marks. The committee also aimed at forming a uniform scoring board. This would improve communication, and make the number of matching points significant in evaluating the evidence. The committee drafted the preliminary scoring guidelines, and these were then tested in studies of bite marks on experimental animals and cases in which the perpetrator was known. Thereafter, the guidelines were submitted to further testing, including a study in which 52 forensic dentists participated.

In 1984 the American Board of Forensic odontology conducted a workshop on the analysis of bite marks, and regarded each suggestion as the basis for rewriting the guidelines. The result of the workshop led by the American Board of Forensic Odontology was a guideline for bite mark analysis. The guideline states that it is not static, and will be modified as significant development evolves. A careful use of this guideline will enhance the quality of the investigations and conclusions. The guideline includes instructions for:

Table 2: Guidelines

DESCRIPTION OF THE BITE MARK	COLLECTION OF EVIDENCE
Demographic	Photography
Location of bite mark	Salivary swabbing
Shape	Impressions
Color	Tissue samples
Size	Examination
Type of injury	Study Casts

The guidelines also include a scoring board for bite mark analysis. As long as all guideline instructions are followed and other limitations of specific techniques are taken in consideration, all results from the techniques described in this chapter should be found admissible in the courts (Bell & Bowers, 1997).

An essential component of the determination of the validity of bite mark analysis is that the techniques used in the physical comparison between suspect dentition and physical injury have been assessed and found valid. One of the fundamental problems with this task is the wide variety of techniques that have been described in the literature.

Techniques using confocal, reflex and scanning electron microscopes, complex computer systems, typing of oral bacteria, special light sources, fingerprint dusting powder and overlays have all been reported. It is a widely held belief, that while methods that are more esoteric exist, the dominant technique for comparison of exemplars is transparent overlays.

The lack of direction from the forensic dental organizations, both European and American, complicates this matter. The American Board of Forensic Odontology

(ABFO) has reported advice and guidance on many aspects of bite marks and yet one of the most pivotal questions, i.e. what is the best comparison technique to use, has not been addressed (Sweet &Pretty, 2001). Should a Court wish to review the literature to ensure that a testifying expert is using generally accepted techniques they would find the task daunting and ultimately unrevealing.

Transparent overlays utilize materials found in any dental office. The vast majority of forensic dentists use techniques that utilize materials that are inexpensive and easily obtainable, hence the popularity of overlays.

There are numerous techniques for the fabrication of transparent overlays. The only article that has assessed the accuracy of such overlays is that of Sweet and Bowers in 1998. It compared five common techniques of producing transparent overlays. Of all the techniques, an examination of case reports and experiments reveals that the xerographic and radiographic techniques are the most popular.

Sweet and Bowers used 30 randomly selected study casts to examine the accuracy of overlays produced from each of the five techniques concerning tooth rotation and surface area. From these results, it can be seen that the computer technique represents the most accurate method with respect to representation of rotation and area of the biting edge. The authors of the paper concluded that the fabrication methods that utilized the subjective process of hand tracing should not be used in favor of techniques that are more objective. The use of computer-generated techniques was advised over any other method.

Frykholm *et al.* wrote an article about stereometric reproduction or three-dimensional plotting of a bite mark. Photographic recordings and measurements had

only been evaluated qualitatively which made it difficult to find the identification method reliable. A clinical study was also conducted to further study the method and to test it under clinical conditions, and to also find the variance of the standard deviations when identity between tooth-mark and tooth-model exist and when it does not. The method also determines as to whether it is possible to record and analyze a bite mark so that this could, within defined statistical limits, be bound to a certain individual.

The result of the analysis of stereometric reproduction showed that the characteristic individual tooth position is statistically different from the bite characteristics of any other person.

Results also found that the characteristics of the dental arch are also strongly individual. Therefore, this method could make it possible to identify one person from a group, if the bite mark is of good quality and involves a sufficient number of teeth.

When in 1993 the United States Supreme Court changed the basis for admitting scientific evidence in the Daubert case, the Court established that the Federal Rules of Evidence supersede Frye and that scientific testimony "must be derived by the scientific method" (Bell & Bowers, 1997).

There are different opinions among scientists on the effect that Daubert is going to have on the introduction of new methods and techniques for bite marks. On one hand, if the new method or technique is based on sound scientific procedure, it should be found admissible, no matter how controversial it may be. Therefor Daubert might make it possible to introduce novel scientific methods once barred by Frye (Moenssens & Starrs, 1995). On the other hand, it is no longer sufficient for the

scientists to testify that the bigger majority of experts in the field agree with the new proposition. Under Daubert, the expert must be ready to describe the tests conducted and standards used, verify the hypothesis, and analyze the error rate. The method will not be accepted if it hasn't be adequately tested. But the judge in the courtroom is the ultimate gatekeeper determining whether a particular technique's reasoning or methodology is scientifically valid, and whether that technique can properly be applied to the issue at hand (Bell & Bowers, 1997).

CHAPTER 4

IMPLICATIONS FOR FUTURE USE OF SCIENTIFIC EVIDENCE

Proposed testimony must be supported by appropriate validation- i.e., "good grounds," based on what is known... In a case involving scientific evidence, evidentiary reliability will be based upon scientific validity.

-Daubert v. Merrell Dow Pharmaceuticals, Inc., 509 U.S 579, 590-591 & N.9

The impact of forensic science evidence may be measured in terms of the assistance it provides decision-makers at key points in the judicial process. It reduces the uncertainty surrounding important decisions and leads to a higher percentage of guilty persons charged, convicted, and punished and a higher percentage of innocent persons being acquitted (Peterson, 1987).

The use of science in the courtroom raises two issues: scientific uncertainty and the misuse of science (Foster & Huber, 1999). The first issue - uncertainty, arises because science often cannot provide clear-cut answers to questions that have grave implications in the courts or other branches of government. Risk assessment is disfavorably imprecise, and the data are mixed so it can be interpreted to support a range of positions held by the various sides. Science has been unsuccessful in identifying causes of specific birth defects, cancers, and other chronic diseases, that are

decided on the basis of uncertain scientific evidence. Validity in science is not a dual attribute; grossly invalid data or a theory can usually be identified for what they are, but the decisions for validity depends on the needs one has for the data. This is to say that science has limited ability to answer questions of social importance (Foster & Huber, 1999).

The second issue – “junk science” - arises when a witness presents grossly misleading interpretation of scientific data or opinions not supported by scientific evidence. Junk science is a legal problem, cultivated by the adversarial nature of legal proceedings, and it depends on the difficulties associated with evaluating technical arguments. In science the ultimate test of validity is time, and science is cumulative and self-correcting (Foster & Huber, 1999). Scientists collect new data and propose new theories, some of which will withstand the test of time, while the grossly flawed will not of science they do not trust. Just the mere fact that DNA and fingerprint evidence is presented to them and the jury by scientists in white coats, indirectly affects the presumed scientific validity of such evidence.

Science and the law have completely different goals – science searches for a comprehensive understanding, which develops through a collective process involving many scientists, while a legal trial seeks to resolve a focused legal dispute in a finite amount of time (Foster & Huber, 1999). Scientists also weigh evidence without distinguishing admissible from inadmissible, while a legal trial must make a final choice between one side and the other. The difference between " this bite mark might belong to the suspect " and " this bite mark probably does belong to the suspect" is fundamentally one of probabilities, and the reliability of techniques for conducting bite

mark analysis used to draw such inferences is also a matter of probabilities. The question is what evidence is needed to prove a technique or a theory? A technique partially developed, presented as if it were a reliable technique, is very likely to be misleading and confusing. If that same technique in question is presented in a criminal trial, it should be excluded not because it is wrong, but rather because it is incomplete or because more research to determine its accuracy is needed. Incomplete techniques shouldn't be used, but a jury might have difficulties telling the difference if a dentist were to present the argument using forensic and dental terms none understands.

Another argument can be the face validity of scientific evidence. Face validity of bite mark evidence is far greater than that of fingerprints or DNA evidence, and since jurors and judges are more familiar with their teeth than DNA, bite mark evidence might be taken in consideration more frequently than other forms of scientific evidence.

In matters of health and disease, there is never proof, but something less: evidence that would lead a rational individual to accord greater or lesser credence to a theory. The line of reasoning can be tested and the reliability of the techniques can and should be examined (Foster & Huber, 1999). Different views among scientists themselves about the reliability of dissimilar techniques used to recover bite marks and the potential errors in the data collected will never be resolved, particularly when the effects being discussed are small. The use of the term reliable in Daubert raises the question: how reliable do court want their own judgements to be? The Federal Rules of Evidence do not distinguish one legal context from another. Trial judges must screen all theories and techniques presented and make the binary choice whether to admit or reject them. They must use guidelines, which are qualitative and in some measure

subjective. Perfect decision rules do not exist, however imperfect ones do exist, and they can be applied methodically, in a reasonably neutral and objective manner, to enhance the overall reliability of legal judgments (Foster & Huber, 1999)

The reliability and validity of dental forensic evidence should go through the same process of acceptance as DNA and fingerprints have. The Daubert case ruling directed federal judges to determine the reliability of expert scientific testimony and offered for guidance a selection of criteria that scientists use: 1) has the theory or technique been tested, 2) have the findings been peer reviewed and published, 3) are the findings generally accepted in the relevant scientific community. These criteria are neither exclusive nor exhaustive and none of them is a necessary condition for establishing the scientific reliability of evidence and testimony and hence for satisfying the demands for admissibility (Weil, 2001).

Another question needing an answer in reference to forensic evidence is: are jurors smart enough to understand the scientific evidence presented to them and apply that evidence to arrive at just resolutions for disputes? Most literature suggests that jurors are poor information processors, but whether the answer to the question is yes or no, if not jurors then who in society is going to resolve disputes? The role of the jury is to render a verdict based only on the evidence and the law presented to them at the trial in the courtroom (Meyer, 1999). A jury verdict represents a collective understanding and evaluation by a particular group of people who share a common experience of jury service, and if that verdict is supported by a reasonable interpretation of the evidence, it is acceptable (Ayd & Troeger, 1999). Although most jurors have no science or legal education, they bring to the courtroom different backgrounds of life experience,

education, intelligence, memory capacity, all of which deserve respect. Jurors should participate in legal decision-making even when complex scientific ideas are presented to them.

The analysis of bite marks has never progressed through the rigorous scientific examination process as DNA and fingerprints to determine its accuracy or reliability. This paper in part highlights the lack of hard scientific evidence to support the assumptions made by forensic dentists when they analyze bite marks. This concern should be the focus of future research, since there is no definite opinion or research concerning them, especially in connection to the dental/ bite mark uniqueness issue. Another focus for research should be the impact of bite mark evidence on jurors. There are studies conducted about the way jurors perceive scientific evidence in general. But since the familiarity people have with teeth as opposed to DNA might give bite marks a higher face validity, studies on the way bite mark evidence is perceived are essential for our future understanding of the subject.

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