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C. Michael Bowers, DDS JD



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Review into a Forensic Pseudoscience: Identification of Criminals from Bitemark Patterns

C. Michael Bowers DDS JD*

* University of Southern California, Ostrow School of Dentistry, 2284 S. Victoria Ave., Suite 1-G, Ventura, CA USA 93003

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Abstract

The forensic sciences are a combination of laboratory procedures and physical comparisons of objects associated with victims, perpetrators, and crime scenes. The former is largely university-based protocols adopted by crime labs. The latter is predominantly pattern-matching tools originally developed by police examiners or experts deemed by courts to be relevant to forensic matters. These Court accepted experts bring their reasoning and conclusions into the legal arena. This subgroup of forensics has undergone significant scrutiny in regards to its history of exaggerated claims and weak scientific foundations. This paper addresses the rise and fall of bitemark pattern analysis (i.e. “matching” bitemarks in human flesh to human teeth) in the environment of opposing interests and agendas.

1. Introduction

The pursuit of human identification in a forensic context accelerated to an unprecedented level in the 20th century. Efforts in matching objects associated with crime follows this trend. The earliest and mostly police affiliated practitioners (during the “birth” of forensics) were legitimate innovators who applied methods developing from chemistry, physics and human biology. Other practitioners made up their own “science” to match their assumptions as to the reliability of their respective domains. Most contained the assumption of physical uniqueness of the material properties related to ballistics, handwriting, toolmarks, fingerprints, hair matching and bitemarks. Today’s forensic literature shows some of these methods of identification moving forward, while others being professionally rejected or irretrievably demoted in status.

The trajectory of forensic identification has been steep and generally inattentive to systemic failures of certain methods already accepted by the Court system. This accelerated reliance by criminal courts on science and, in some cases, science-poseurs, continues to challenge the justice system’s ability to insure validity of the underlying science and soundness of what the proffering experts offer. Courts’ obligations include not only “looking-forward” to the arrival of new methods but also a “looking-back on forensics” component. The legal recovery from false forensics is legally laborious as rules of law allow a very narrow legal scope for appellate review. Hence, judges’ gatekeeper oversight role is of paramount importance.

Over the decades of the 20th century, phrenology, foot wear matching theories, hypnosis aided eye witness statements, witness facial recognition, bullet lead comparison, hair physical matching, and bitemark comparisons were all considered operationally valid by practitioners and the courts. The leading causes of some later experiencing rejection were poor data collection, weak population studies, inadequate examiner reliability, and fundamental testing which largely ignored error rates in testing and actual casework. For example, the relatively recent FBI hair comparison debacle amounts to thousands of unsafe cases. ¹

Taking a broader intellectual view of developing forensics, its environment is predominantly separate from university, medical and commercial empirical scientific rigors. This path was not intentional, but contemporary discussions clearly recognize this separation partly based on the differences in their diverse end-users. Most core forensics are subject to acceptance rules of police groups and the courts. This fact is said to cause a sub-culture of “police-science.” This end-user dichotomy has been laid bare by recent governmental criticisms, from police crime lab leadership aligned with state and federal prosecutors, to the wakening participation of scientific reviewers “outside” the criminal justice industry. ²

2. The occurrence of bitemarks and their context within forensic investigations.

Bitemark injuries occur during violent and commonly horrific crimes. There are two types of physical evidence available when human teeth contact a surface capable

of deforming under biting pressure. They are: 1) DNA evidence from saliva transfer onto the surface and 2) tooth impression or pattern evidence captured by the surface. This paper concentrates on the second category's forensic history, analysis assumptions, methodologies, casework applications and its ultimate failure to reach scientific reliability and Court admissibility thresholds.

The news media and forensic literature is replete with case studies describing the scenarios where human biting takes place during homicides, child and elder abuse, assaults and other domestic violence. Obviously, some of these cases allow victims to identify their assailant while others clearly do not. This paper, however will not differentiate amongst these varied circumstances.

3. Who are the first responders to a bitemark? Bitemark recognition, collection and analysis.

On the issue of who identifies a skin injury as a human bitemark, the reportage varies as much as the circumstances, wherein police officers, nurses, physicians and autopsy professionals act as first responders to purported bitemark evidence. They introduce their theories of source attribution to those consulting dentists who pursue bitemark patterns as an identification method. Case after case of bitemark testimony indicates that when police identify a suspect, they offer said suspect to a bitemark dentist for examination which then leads to the dentist reaching conclusions from just one set of teeth. In police terms, this procedure is called a "one-person lineup" and is an

inexorable source of cognitive bias in the person doing the examination, evidence collection, and pattern-comparing. Even if “blinded” evidence analyses were made mandatory, the lack of established inclusion/exclusion criteria for bitemark comparisons along with the physical vagaries of skin are permanent obstacles for success.

Thankfully, the last two decades has seen increasing reliance on immediate DNA collection from skin injuries or bitten objects.³ This is a much clearer path towards identification of a perpetrator or victim from salivary DNA transfer. Sadly, this continues to be only an option in various jurisdictions as shown in hundreds of criminal cases adjudicated without DNA recovery and testing.⁴

4. The literature: The source of bitemark dentistry claims of the scientific bases for their participation in criminal investigations

Bitemark comparison became a significant addition to their historic forensic role as the identifiers of deceased human dental remains began developing in the 1960's and 1970's in the UK and US.⁵ The seminal legal case in the US occurred in 1975⁶ which while deemed and titled “unusual” by the testifying dentists, became the future rallying point for bitemark acceptance in all 50 US states. Marx passed the court-imposed “scientific” standard and marked the legal dawn of bitemark admissibility. Three years later, the court issued its categorical acceptance of bitemark comparisons with no reference to cautions and limitations.⁷ After these US judicial events, the bitemark literature blossomed with authors who primarily wrote about their contacts with law

enforcement inquiries regarding skin bitemarks.⁸ With one recent exception,⁹ this is the predominate category of topics in the bitemark literature. Anything called “research” regarding bitemarks has been the work of a small cadre, containing ad hoc efforts by dentists isolated from conventional research centers and multi-disciplinary partners. A smattering of dentists, including this author, have published peer-reviewed articles expressing a collection of cautionary principles and demonstrations on the subject of bitemark identification.¹⁰ Up until 2009, the bulk of information about the failures of bitemark comparisons have come from the legal and bioscience literature.¹¹ The remaining cohort of pro-bitemark dentists recently responded in print. Their commentary aggressively rebuts their critics with more anecdotal promises supporting their expertise.¹²

5. The bitemark identification paradigm

Two propositions constitute the bitemark identification paradigm: a) human dental uniqueness and b) skin as an accurate impression material for tooth marks.

Attempts at research about human tooth shape variability and “dental uniqueness” were absent from the literature through the 1970’s., and since has occurred in scattershot and superficial attempts.¹³ Regardless of this, surprising things are seen in the bitemark criminal case law being in the 1980’s. “Uniqueness” became confirmed in courtroom statements by dentists claiming allegiance to the claim of human “dental fingerprints.”¹⁴ The absence of substantive research was little deterrent to bitemark proponents and these data-less “belief” opinions were written into the

substantive acceptance cases for bitemark identification throughout state and federal courts of the United States. Judicial acceptance has not been shaken by the historical record of bitemark comparisons that led to convictions which later became exonerations.¹⁵

The second assumption of bitemark practitioners regards the dimensional accuracy obtained in patterns created from teeth onto skin. To be more precise, these teeth-induced patterns in actual cases reveal themselves as bruising, not indentations. Decades of criminal cases showcase practitioners claiming bitemark patterns as the transferred dental fingerprint of a single defendant to the epidermis of a victim of violence. Putting aside the dental fingerprint for a moment, their claim of the accurate transfer of teeth marks onto skin was never properly tested until the series of cadaver experiments, cited above, occurred at the University of Buffalo Dental School from 2007 through 2013. The results were a massive refutation of the claims of reliable methodology adopted by the bitemark dentists throughout their history.

6. Doubts about this paradigm

Bitemark comparison in forensic and legal literature has a timeline beginning with guarded professional conservatism, then universal acceptance, and finally the realization that the field's claims must be rejected.¹⁶ Those outside the control of the bitemark practitioners have come to clearly recognize the facts of weak foundational science, absence of empirical proofs, dependence on group acceptance¹⁷ as a

substitute for validity, and resulting damaging effects to the criminal justice system. The tide against its continued use can be summed up in succinct terms:

- A lack of valid evidence to support many of the assumptions and assertions made by forensic dentists during bite-mark comparisons.
- Error rates by forensic dentists are perhaps the highest of any forensic identification specialty still being practiced.
- Bitemark testimony has been 'introduced in criminal trials without any meaningful scientific validation, determination of error rates, or reliability testing.'¹⁸

7. The light of new science shining on bitemark identification flaws. Bitemark identification conflicts with DNA evidence

Analysis of the published literature, court documents and reports lead to the conclusion that bitemark aspects of forensic odontology and its accompanying bitemark evidence analyses are irretrievably flawed. They are invalid, unreliable and should not be considered acceptable in the light of new science and professional changes in forensic odontology concerning bitemark evidence in the last few years. Changes within the bitemark profession largely occurred due to the emergence of DNA profiling in the 1990s. It took until 2016 for bitemark analysts within the US American Board of Forensic Odontology to publish a rejection of past practices of using bitemarks for human identification.¹⁹

The advent of DNA profiling and DNA collection from saliva transferred to a victim's bite site are closely associated in time. The first salivary collection noted in the forensic literature occurred in 1999.²⁰ Since then, assailant identification associated in

numerous criminal cases have occurred where a trial level bitemark identification was later rejected by subsequent post-conviction biological testing. This post-conviction DNA testing is largely done by criminal defense attorneys and the Innocence Project Network.²¹

8. Bitemark terminology related to identifying a particular person from any population of suspects is no longer allowed.

In February, 2016, the ABFO approved more restrictive guidelines to limit the bite mark testimony of its members. This recent event was spurred by scientific criticisms, false convictions, and its members' professional and moral concerns. These newest Guidelines, as published in March 2016, prohibit individualization testimony in all cases. The current bitemark guidelines expressly limit opinions regarding bitemark matching to: 1) the evidence is insufficient to reach a conclusion (i.e., "inconclusive), 2) not excluded (a possible biter, or 3) excluded as a possible biter.

Though these changes trim the sails of bitemark dentists, the position remains inadequate as it continues the use of unsupported beliefs regarding teeth variability and skin's acceptable ability to capture patterns. In addition, its continued reliance on the disconfirmed "science" contains no safeguards to prevent the membership producing false positive identifications (FPI) from these reduced choices.

9. Error rates of bitemark opinions are unknown: However, false positive identifications of defendants are now a fact.

Bitemark analysts have no data regarding either “known” bitemark data (i.e., bites of verified origin) or their error rate in suspect identification bitemark procedures. This is in sharp contrast to other pattern comparison matching methods such as contemporary fingerprint examiners who firmly believe in known evidence analysis and successful proficiency testing within law enforcement crime labs. In many cases, the bitemark opinion was based on “enough characteristics”²² to enable the dentist’s personal level of confidence. Unfortunately for bitemark evidence, the amount of “enough” to ensure reliable identifications has never been quantified or scientifically validated.

10. Scientific review of bitemark identification.

The intense criticism of bite mark analysis by the objective scientific community was well-merited, given that throughout its 65-year US history, bite mark practitioners’ personal assertions have masqueraded as a “science.”

Prior studies have demonstrated a “disturbingly high false-positive error rate” in bitemark comparisons.”²³ Additional reviews detailed the following findings:

- A 1975 study found that bitemark examiners made “[i]nncorrect identifications[s] of bites” on pig skin 24% of the time even when the bites

were made “under ideal laboratory conditions” and 91% of the time when the bites were photographed 24 hours after being made;²⁴

- A 1999 American Board of Forensic Odontology Bitemark workshop in which “ABFO diplomates attempted to match four bitemarks to seven dental models” resulted in up to 63.5% false positives.²⁵
- A 2001 review article cites a study of “bites made in pig skin” which resulted in between 11.9 and 22.0% “false positive identifications for various groups of forensic odontologists.”²⁶

11. Changes in the field of science and forensic evidence admissibility statutes due to erroneous convictions.

The record of wrongful convictions associated with bitemark identification opinions has expanded extensively over the last 2 decades. These cases in US jurisdictions exist where, prior to 2016, defendants have been exonerated after forensic dentists have, at trial, used the conventional terminology, techniques and non-science-based assumptions. This author has been involved in post-conviction bitemark matters in a number of these cases; Krone, Young, Hill, Brewer, Starks, Stinson, Swinton, Brooks, and Richards.²⁷

As of 2018, there have been 31 exonerations, dismissal of charges, and releases from incarceration, where the wrongful conviction or indictment originally used bite mark evidence. It is telling that the prosecutorial dental experts in these exoneration cases

generally had the highest level of forensic dental training, professional accolades and experience. Although all testimony was given with attestations of “science,” these dentists provided shockingly erroneous results to the courts.

12. Newly discovered evidence. Independent scientific reviewers of bitemark analysis since 2009.

A counterpoint exists to the habitual court approval of bitemark “matching.” Contemporary independent scientific reviews of forensic expertise use surprisingly similar language in rejecting its use. In the clearest terms possible, they describe a framework of scientific rigor and supporting research that should exist but are absent from proffering bitemark analysts. The material reads like a primer for the Scientific Method and these groups, rich with scientific qualifications, are outside the insular community of bitemark matching dentists – in contrast to the membership of the American Board of Forensic Odontology.²⁸ The qualifications of these external reviewers exist at the highest levels of the relevant physical and biological sciences.

In the mid 2000’s, the United States Congress initiated two investigations into mainstream forensic disciplines. Senators Leahy and Rockefeller initiated top level inquiries of forensic practitioners, physical and biological researchers, prosecutors and defense lawyers. These in-depth scientific reviews produced, for the bitemark analysis advocates, a general rejection of their bitemark assumptions and practices. These Congressional reviews provided the impetus to future studies which are described in the

following discussion. They both resulted in conclusions casting doubts on the long-accepted practices of bitemark practitioners. They created an unprecedented rejection, by the relevant scientific community, of bitemark identification methods and testimony.

13 The National Academy of Sciences look into forensic science.

The NAS is the scientific advisory agency for the Executive branch of the US government. They are the best of the best regarding vetting science and technology of both commercial, governmental, and research aspects of our society. The NAS involvement with forensic science is long standing as it extensively reviewed DNA profiling technology and provided meaningful direction to the current state of DNA acceptance within the US court system.

Starting in 2007, the NAS began a deeper examination into bitemark evidence.²⁹ This culminated in their 2009 final report. This interdisciplinary scientific consortium rigorously interviewed bitemark practitioners, bitemark researchers, and relevant science experts. They also compiled all professional literature and research regarding bitemark analysis. The Committee found no scientific bases answering questions regarding validity and reliability of bitemark practices.

The NAS found the underlying research had not been undertaken to test bitemark procedures and conclusions in order to assess whether forensic dental expert opinions could be considered reliable.³⁰ They expressly stated: “the committee received

no evidence of an existing scientific basis for identifying an individual to the exclusion of all others.” This directly implies that ANY determination of identification, be it “highly probable,” or “possible”, as well as “to the exclusion of all others” is scientifically unsupportable and therefore is fraught with the risk of error.

In addition, the Report stated bitemark experts have no basis for testifying to the “uniqueness” or rarity value of a suspect or defendant’s teeth. Since 2009, extensive research confirmed this judgment, establishing the fact that random matches of human dentition do exist. This refutes the assumption of bitemark uniqueness, as the biting surfaces of many people’s teeth are not distinct to just one individual.³¹ In simpler terms, no available data ascertain the chance or prevalence of a misidentification of an innocent defendant associated to a victim’s injury. This absence of data-driven criteria to establish investigative conclusions is a symptom of pseudoscience.

The NAS Report also spoke directly about dentists’ assertions of bitemark “value” for testimonial admissibility.

“A standard type, quality, and number of individual characteristics required to indicate that a bitemark has reached a threshold of evidentiary value has not been established.”³²

The NAS also delved into bitemark research that debunks the assumption that human skin is capable of accurately capturing the assumption of dentition uniqueness. The NAS 2009 Report noted:

- [These] “features may severely limit the validity of forensic odontology”
- “[t]he ability to analyze and interpret the scope or extent of distortion of bite mark patterns on human skin has not been determined on the subject of skin variability as an impression material of teeth marks created during biting.”³³

14. The 2016 rejection of bitemark analysis by the State of Texas: The Texas Forensic Science Commission.

Despite the shift in the scientific community’s stance on bitemark comparisons, no state or federal courts have not yet excluded this evidence in their venues. Ironically, the originating bitemark caselaw allowing its admissibility rests on convictions that later became exonerations. The shift has not been ignored by a non-judicial agency of one state in the US. In 2015 a Texas court freed a man who had been imprisoned for nearly 30 years on the basis of bitemark evidence. In 2016, the Texas Forensic Science Commission reviewed a complaint regarding the Chaney bitemark evidence and determined that bitemark analysis were flawed and issued a moratorium rejecting further use of bitemark comparison in the State’s criminal courts. The State had recently passed a statute allowing its appellate courts to review forensic testimony that had become outdated or come to be considered to be flawed.³⁴ This Texas bitemark exoneration case, State v. Chaney, was the first application of the Texas “junk science” statute.³⁵ Besides concluding that bitemark analysis was based on unsound science, the Committee made salient legal points on bitemark “science”:

- a. “New relevant scientific evidence related to the field of forensic odontology – bitemark evidence – contradicts the evidence relied upon by the State at trial. And that evidence had been presented, on the preponderance of the evidence, he [Chaney] would not have been convicted.”³⁶

“Additionally, the reviewing court must make findings establishing that, had the scientific evidence been presented at trial, on the preponderance of the evidence, the person would not have been convicted.”³⁷

15. The 2016 President’s Council of Advisors on Science and Technology

The chronology of the complete rejection of bitemark evidence by scientific bodies has progressed to The President’s Council of Advisors on Science and Technology (i.e., “PCAST”). Established by President Dwight D. Eisenhower, PCAST is an advisory group of leading US scientists and engineers, appointed by the President to augment the science and technology advice available from other federal agencies.³⁸

On September 20, 2016, PCAST released its unanimous report to the President entitled “*Forensic Science in Criminal Courts: Ensuring Scientific Validity of Feature-Comparison Methods.*”³⁹ This new document, approved by PCAST on January 6, 2017, included bitemark comparison among the seven currently active pattern “matching” forensic analyses such as ballistics and fingerprints. One PCAST administrator-scientist publicly suggested that bitemark pattern evidence “should be eradicated.”⁴⁰

PCAST aligned itself with the overwhelming consensus of rejection of bitemark comparisons and discussed in its Report the scientific evidence which supports this conclusion.⁴¹ In its totality, PCAST affirmed the NAS 2009 Report's dismissal of the decades-long acceptance of bitemark comparisons with statements such as: [b]itemark evidence is "clearly scientifically unreliable" at present; the foundational flaws of bitemark evidence "cast[s] serious doubt on the fundamental premises of the field;" and that random population studies found "matches occurred vastly more often than expected during empirical studies."⁴² PCAST also noted that "[e]mpirical research suggests that forensic odontologists do not consistently agree even on whether an injury is a human bitemark at all."⁴³

16. Newly discovered evidence. The inability of bite mark analysts to properly identify human bite marks as such.

In 2015, the ABFO performed testing of its membership regarding the fundamental step of determining whether or not an injury is a bitemark. This marked the third US bitemark examiner certification board sanctioned performance testing (the last of three since 1999). The ABFO-designed testing results failed even nominal expectations of reliability.

"Among the 39 examiners who completed the study, it was reported that there was unanimous agreement on the first question in only 4 of the 100 cases and agreement of at least 90 percent in only 20 of the 100 cases. Across all three

questions, there was agreement of at least 90 percent in only 8 of the 100 cases.”⁴⁴

The study described by PCAST is named *Construct Validity Bitemark Assessments Using the ABFO Bitemark Decision Tree* (“Construct Validity Study”).⁴⁵ Photographs of 100 patterned injuries were shown to 103 ABFO board-certified diplomates. They were asked to decide three questions: first, whether there was sufficient evidence to render an opinion on whether the patterned injury was a human bite mark; second, whether, consistent with the ABFO decision tree, the injury could be determined to be either a human bitemark, not a human bitemark, or suggestive of a human bitemark, (the three options the ABFO’s guidelines then provided); and third, if a human bitemark, whether it had distinct, identifiable arches and individual tooth marks.

⁴⁶ As stated above, the results were disturbing.

17. The Scientists Brief of William J. Richards

Only recently, the truth of bitemark identification’s severe limitations have become public due to added research, changes in dental expert standards, the recent research debunking the abilities of skin to accurately record teeth marks, and exonerations by post-conviction DNA testing refuting bitemark experts’ trial testimony. A prime example is an Amicus Brief of scientists and statisticians compiled in 2016.⁴⁷ This document, submitted in support of the California release after 23 years in prison of William J. Richards, incorporated much of what has been presented in this article.

This prominent group of law-and-evidence scholars, scientists, biologists, practitioners, and statisticians evaluated the validity and reliability of bitemark analysis and found it unable to achieve what was claimed for it.

15. Conclusions

This brief look at changes in scientific understanding of bitemark status as a “science” underscores the breadth and scope of the effect of the NAS 2009 Report. The progeny of NAS 2009 includes case law, legislative statutes, and independent research about bitemark analysis. Adjustments made by a relevant scientific community which decommissions an “old science” must be adopted and considered grounds for appellate review as “reversible error.”

The “myth” of scientific facts infected decades of criminal cases where bitemark dentists were presented as scientific experts. Their testimony was not supported by scientific data and led to conclusions professing their subjective probabilities of certainty. Hundreds of cases of bitemark identification used personal confidence as a substitute for empirical data and acceptable statistical testing. This terminology describing confidence is now not supported within the scientific professions and are unacceptable in today’s courts.

It remains only for courts to view the accumulated disconfirming evidence on bitemark identification and the lack of supporting empirical evidence through the lenses

of the law's demanding standards. When they do, bitemark identification will join the ranks of other deceased forensic science.

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¹ Hsu, Spenser S. FBI Admits Flaws in Hair analysis Over decades, Wash. Post, 18 April, 2015. Available from: http://wapo.st/1OrujpH?tid+ss_mail. Accessed date: 6 August 2018.

"The Justice Department and FBI have formally acknowledged that nearly every examiner in an elite FBI forensic unit gave flawed testimony in almost all trials in which they offered evidence against criminal defendants over more than a two-decade period before 2000." "The cases include those of 32 defendants sentenced to death. Of those, 14 have been executed or died in [prison]."

² In the last decade, scientific and legal communities outside the sphere of forensic groups have thoroughly investigated the application of bitemark analysis (also known as bitemark "identification"). Their comments form a substantial portion of this paper's reasoning due the lack of scientific balance and scientific clarity in the peer-reviewed bitemark literature.

³ Sweet D, Lorente M, Lorente JA, et al. An improved method to recover saliva from human skin. The double swab technique. *J. Forensic Sci* 1997; 42:320.

⁴ Pitluck HM. *Bite mark citations* in Stimson PG, Mertz CA (eds). *Forensic Dentistry*. 1997; Boca Raton, FL, CRC; pp 269-276. 260 judicial appellate decisions allowing bitemark testimony from 1954 to 1996.

⁵ Furness J. A new method for the identification of teeth marks in cases of assaults and homicide. *Br Dent J* 1968; 1214:261. Sognaes RF: The case for better bite and bite mark preservations. *Int J Forensic Dent* 1977; 4:17.

⁶ Vale GL, et al., *Unusual Three-Dimensional Bite Mark Evidence in a Homicide Case*, 1976 21 *J Forensic Sci*. *California v Marx*. 642. 54 Cal. App. 3d 100, 126 Cal. Rptr. 350, 77 A.L.R.3d 1108 (2d Dist. 1975).

⁷ *People v. Slone*, 76 Cal. App. 3d 611, 143 Cal. Rptr. 61 (2d Dist. 1978).

⁸ Asen DP. *If your chewing gum lose its flavor, don't spit it out at a murder scene* [abstr F32], in *Proceedings of the American Academy of Sciences*, San Francisco, 1998, p132.

⁹ See variously: Bush MA et al. Statistical Evidence for the similarity of the human dentition, 56 *J Forensic Sci*, 2011; 118; Sheets HD et al. Dental Shape Match Rates in Selected and Orthodontically Treated Populations in New York State: A Two Dimensional study, 56 *J Forensic Sci*. 2011; 621; Bush MA et al. Similarity and Match Rates of the Human Dentition in Three Dimensions: Relevance to Bitemark Analysis. 125 *Int'l J. Leg. Med.* 2011, 799. Multidisciplinary University of Buffalo-based research projects that overturned the bitemark "paradigm" of skin accuracy and cast significant doubts about bitemark dental uniqueness. Also see, Page M, Taylor J, Blenkin M. Reality bites--A ten-year retrospective analysis of bitemark casework in Australia. *Forensic Sci Int*. 2012 Mar 10;216(1-3):82-7. doi: 10.1016/j.forsciint.2011.08.023. Epub 2011 Sep 17. Accessed date: August 13, 2017.

¹⁰ Whittaker DK. Some Laboratory Studies on the Accuracy of Bite Comparison. *Int Dent J*. 1975; 25:166-71. "Expert witnesses involved in presenting evidence on bite marks in a court of law should be aware of the difficulties of making valid comparisons even under standardized laboratory conditions. Further studies to improve and substantiate the reliability of the technique are clearly required." Bowers CM, Pretty IA. Expert disagreement in bitemark casework. *J Forensic Sci*. 2009; 54(4): 915-918. "Bitemark cases continue to raise controversy due to the degree of expert disagreement which is frequently seen."

¹¹ Faigman D, Saks M et al. eds. C. Michael Bowers, *Identification from Bitemarks* in *Modern Scientific Evidence: The Law and Science of Expert Testimony*. 2017. Forensic Bitemark Identification weak foundations, exaggerated claims. *Journal of Law and the Biosciences*, Volume 3, Issue 3, 1 December 2016, Pages 538–575, <https://academic.oup.com/jlb/article/3/3/538/2544494>. Accessed date; 15 August 2018. Erica Beecher-Monas, "Reality Bites: The Illusion of Science in Bitemark Evidence" 2009 30:4 *Cardozo Law Review* 1369-1410 at 1389-1401.

¹² Barsley RD, Bernstein ML, et al. Epidermis and Enamel, Insights Into Published Gnawing Criticisms of Human Bitemark Evidence. *Am J Forensic Med Pathol.* 2018 Jun; 39(2): 87–97. 2018 Apr 5. DOI: [10.1097/PAF.0000000000000392](https://doi.org/10.1097/PAF.0000000000000392). Accessed date: 15 August 2018.

¹³ Rawson, RD, Ommen RK, Statistical Evidence for the Individuality of the Human Dentition, *Journal of Forensic Sciences* 1984 29(1):245-53. Accessed date: August 15, 2018. DOI: [10.1520/JFS11656J](https://doi.org/10.1520/JFS11656J). This study was considered the foundational proof for dental uniqueness. The paper used flawed methods to reach its conclusions.

¹⁴ Cole, SA. Forensics Without Uniqueness, Conclusions Without Individualization: The New Epistemology of Forensic Identification, 2009 8 L. Probability & Risk. 233.

¹⁵ Robert Lee Stinson was exonerated in 2009 after 23 years in prison. *State v. Stinson*, 134 Wis.2d 224, 228, n. 2, 397 N.W.2d 136, 137, n. 2 (1986). <https://www.innocenceproject.org/cases/robert-lee-stinson/> Accessed date: 15 August 2018. A number of US state courts still use his original conviction as legal precedents for the acceptance of bitemark testimony. One example of this is *Alabama vs. Handley*, which uses Stinson as legal precedence for acceptance. <https://law.justia.com/cases/alabama/court-of-appeals-criminal/1987/515-so-2d-121-0.html> Accessed date: 19 August 2018.

¹⁶ Chin JM, White DA. Bitemark Identification Evidence in Canada. 2018. Available from: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3201061 Accessed date: 15 August 2018.

“We found 14 cases in which courts relied on a forensic bitemark identification, a number that likely underestimates the use of this practice.”

¹⁷ The US legal system possesses two methods of expert evidence. Legal thresholds for “scientific” acceptance are contained in the *Frye* and *Daubert* appellate opinions. Both claim a cohort of practitioners “generally accepting” their own hypotheses as evidence of acceptability. *Daubert* also possesses 4 other factors. By inference, palm reading and astrology also fall within this scope of legal acceptability. Federal *Rule 702* overlays these with the “gatekeeping” judge determining that “scientific knowledge” exists for expert testimony.

¹⁸ Saks J, Albright T, Bohan TL, *Journal of Law and the Biosciences*, Volume 3, Issue 3, 1 December 2016, Pages 538–575, <https://doi.org/10.1093/jlb/lsw045>. Accessed date: 19 August 2018.

¹⁹ The highly qualified wording of this 2016 ABFO bitemark document removes the possibility of linking a particular suspect to a bitemark bruise. <http://abfo.org/wp-content/uploads/2016/03/ABFO-Bitemark-Standards-03162016.pdf> Accessed date: 6 August 2018.

²⁰ Sweet D, Shutler GG. Analysis of salivary DNA evidence from a bite mark on a body submerged in water. *J Forensic Sci* 1999;44(5):1069–1072. <http://www.forensicdentistryonline.org/wp-content/uploads/2015/10/Analysis-of-Salivary-DNA-Evidence-from-a-Bite-Mark-on-a-Body-Submerged-in-Water.pdf> Accessed date: 6 August 2018.

²¹The Innocence Network. <http://innocencenetwork.org/> Accessed date: 19 August 2018.

²² *New Jersey v Fortin 2007*. 13 November 2007. Page 76. Line 7. Testimony of prosecution bitemark expert Dr. Lowell Levine.

²³ Bowers CM. Problem-Based Analysis of Bitemark Misidentifications: The role of DNA, 2007.159S *Forensic Sci. Int'l* S104.

²⁴ Whittaker DK. *supra*, note 10.

²⁵ Faigman D, Saks MJ, et al. Modern Scientific Evidence. Chapter 34 on “Forensic Odontology.”

²⁶ Pretty IA, Sweet DJ. “Digital bitemark overlays - an analysis of effectiveness” *J Forensic Sci.* 2001 46(6):1385-139.

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Declaration of interest

None

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