

## Review Article

### Bite Mark: Is it Still Valid??

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#### INTRODUCTION

There is currently a serious problem with misuse and misunderstanding of bite mark evidence within the larger field of forensic odontology. Saks *et al.*,<sup>[1]</sup> forensic evidence used in criminal cases has never experienced greater legal and scientific scrutiny than it does today. Some types of forensic science expert testimony, particularly some of the pattern-matching subfields, have in recent years come to be recognized as standing on foundations so weak and making claims so exaggerated that the justification for admitting them as evidence in court has been called into serious doubt. Some of those types of forensic testimony had been used for decades without any judicial concerns being raised. The most prominent and official pronouncement of such deficiencies were given by the National Academy of Sciences' Committee on identifying the needs of the Forensic Science Community in its 2009 report.<sup>[2]</sup> What the article actually addresses is the very real problem of bite mark comparison or matching, for the purposes of suspect identification. Bite mark comparison, or matching or identification, is by no means the whole discipline of forensic odontology. Many professionals, including forensic odontologists, confuse themselves and other professionals by mistakenly equating bite mark analysis with bite mark comparison or matching, for the purposes of suspect identification. This misuse of terms is a serious problem.<sup>[3]</sup>

#### HOW TO ANALYSIS A BITE MARK

The definition of analysis is: "a careful study of something to learn about its parts, what they do, and how they are related to each other."<sup>[4]</sup> Bite mark analysis is conducted

#### ABSTRACT

Bite mark evidence has been introduced in trials all over the country. Bite mark evidence, an aspect of forensic odontology, is the process by which odontologist's (dentists) attempt to match marks found at crime scenes with the dental impressions of suspects. If a victim is bitten by a perpetrator during a crime and police have a suspect, odontologists can attempt to "match" the bite mark to the suspect's teeth. There have been a lot of controversies in the identification of bite mark analysis in the past 15 years and acceptance by the law. While this review aims to explain the increasing number of wrongful convictions that is associated and related to the past with bite mark analyses and this has resulted in intense scientific and legal scrutiny. This article contains the current status and position of bite mark analysis. It explains about the highlights and drawback of bite mark identification and law's evaluating and responding to unreliable and unscientific evidence.

**KEY WORDS:** Bite mark, forensic odontologist, highlights and drawback of bite mark identification

as a part of a medico-legal autopsy. This involves objective documentation and interpretation of the evidence surrounding patterned injuries that may, or may not, be bite marks. During bite mark analysis, nothing but the patterned injury and the circumstances surrounding it are taken into consideration. The analysis has nothing to do with comparing or matching anything to a suspect or identification of a suspect from a limited population group. Analysis frequently yields valuable information that forensic odontologists testify to in courts of law, just as forensic pathologists do with respect to their objective findings and their interpretations of those findings based on experience, training, and the circumstances of the event.

Bite mark analysis rarely leads to high-profile convictions of suspects, as has sometimes happened when matching or comparing bite marks on a victim to suspects' teeth. However, it can and does produce information that, when provided to the criminal justice system, can dramatically influence outcomes – for investigators, for prosecutors, and for the defense. In bite mark cases, analysis is the bulk, and most important part, of a forensic odontologist's work. It should be done before any suspects are introduced for the purpose of making a comparison to avoid bias. The analysis process involves answering basic, crucial, and questions such as whether or not the pattern injury is a human bite mark. This question can be the most difficult part of the entire process.<sup>[5]</sup>

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## QUESTION TO BE ASKED

After establishing whether a patterned injury is, indeed, a bite mark, other questions must be asked. Is it a human bite mark? Was it made by an adult or a child? Was it swabbed for DNA? Was it made through clothing? If so, was the clothing swabbed for DNA? Where is it located on the victim and in what position was the victim when it happened? Could it have been self-inflicted? What was the position of the biter? Was it offensive or defensive? Was it affectionate or does it demonstrate violence? Will it produce a permanent injury? If so, a simple battery may become an aggravated battery. When was the bite inflicted in relation to the time of death? Is it fresh, a scar or somewhere in between? Was the person bitten alive or dead at the time? Are there any unique dental characteristics that could be used to exclude possible suspects? In cases of multiple bites, did the same biter make them all? Were they all made at the same time or do they establish a pattern of long-term abuse?<sup>[6]</sup>

These are all the questions should be asked while the investigation process and produce a large amount of information that can be valuable for any suspects to be identified or charged.

## LEGAL ORIGINS OF BITE MARK

Before 1974, forensic dentists confined themselves to trying to identify victims of natural or human-caused disasters. Frequently, those situations provided odontologists with the complete dentition of a small, well-defined set of individuals, who needed to be distinguished from each other. The method used for trying to accomplish that was to compare the victims' dentition against their dental records, which often included full-mouth X-rays.<sup>[7]</sup> Until 1974, the discipline refrained from trying to identify the source of a bite mark left in the skin, because the differences between identifying victims of mass disasters and identifying the source of a crime scene bite mark seemed to them prohibitively daunting:

The two tasks differ in important ways. In the disaster situation, there is a finite number of candidates to identify, and full dentition often is available from the victims as well as from the dental charts. In forensic bite mark cases, the number of potential suspects is huge, the bite marks include only a limited portion of the dentition, and flesh is a far less clear medium than having the teeth (of the disaster victim) themselves.<sup>[8]</sup>

## METHODS TO DETECT BITE MARK

There are four comparison methods to detect a bite mark. They are

1. Direct comparison
2. Overlays
3. Three-dimensional (3D) comparison
4. Softwares in bite mark.

## NEW METHODS IN BITE MARK ANALYSIS

1. 3D scanners in tooth mark analysis
2. Geometric morphometric analysis.<sup>[9]</sup>

## DATA CONCERNED ABOUT RELIABILITY OF BITE MARK

The back and forth argument regarding the reliability of bite mark expert testimony has been going on for decades. Beyond the personal opinion arena, the science of this forensic specialty has the following foundation of data to support its adherents and conversely, to support its detractors. The weight of these studies is a paucity compared to DNA basic and applied science.<sup>[10]</sup>

- A 1999 American Board of Forensic Odontology ("ABFO") bite mark workshop, where ABFO diplomats attempted to match four bite marks to seven dental models found 63.5% false positives.<sup>[11]</sup> The ABFO supported publication of a contra response (with accompanying statistical analysis) to this finding by stating, in part, the 4<sup>th</sup> workshop was never formally titled a "proficiency test," the samples were unusable for statistical determinations, and the findings of this study generalize only to cases having moderate-to-high forensic value.<sup>[12]</sup>
- A 2001 study of bites made in pigskin, "widely accepted as an accurate analog of human skin," with dental casts found false-positive identifications of 11.9%–22.0% for various groups of forensic odontologists (15.9% false positives for ABFO diplomats), with some ABFO diplomats fairsing far worse.<sup>[13]</sup> The study cautioned that the "poor performance" is a cause of concern because of its "very serious implications for the accused, the discipline, and society."

## DNA AVAILABILITY AND FORENSIC ANALYSIS

The new millennium has Krone (2002) (LR15). It is the most publicized case of this decade, as the defendant was sentenced to death (later overturned), reconvicted a second time and given a life sentence, and 10 years later exonerated and released. In a stroke of law enforcement luck, the real killer was identified from crime scene DNA and easily found as he was already incarcerated in the same prison as Krone. The primary evidence against Krone in both trials was bitemark testimony from a senior member of the United States odontology community. He successfully swayed the jury in both instances but lost out to a better identification science.

It seems that the manner and the outer trappings of the state dental expert's lacked the scientific where the withal to be sustainable. It is fascinating to read recounts from the jury regarding their certainty that the teeth marks were a "perfect match." Mr. Krone has recently received a considerable settlement from the State of Arizona and various other individuals [Figure 1].<sup>[14]</sup>

## HUMAN SKIN: BITEMARK REGISTRATION

The issues surrounding human skin as a registration material for tooth marks and the work of researchers to attempt to quantify the potential confounding factors with the skin. Readers are directed to studies such as DeVore's 1971 ink-stamping experiment, which was a simple but elegant way to demonstrate the degree of distortion that can occur in a bite mark on the skin based on postural or anatomical factors.<sup>[15]</sup>

Bite mark assessors to be aware of the presence of Langer's lines, changes to the skin following trauma, and the fact that odontologists were "still ignorant of many of the conditions that occurred during the biting process."<sup>[16]</sup> With the single exception of an article concerning the likely impact of breast morphology on bitemark distortion in 1986,<sup>[17]</sup> there has been little empirical work of note on skin factors in bitemark assessments. Instead, researcher's attention seemed to turn to photographic techniques, which ignored the fundamental principle of garbage in, garbage out. If the skin is a poor registration material, then no amount of high-quality photography will improve this.

### CADAVERIC BITEMARK EXAMPLE

While many agree that it is possible to detect distortion in bite marks due to their gross appearance, subtler changes are real possibilities and ones that can lead to potential mismatches between suspect and injury for the unaware. The second article further examines the nature, biological properties, and the role of skin in recording sufficient details of the biter's dentition.<sup>[18]</sup> In this study, four to six bites were created perpendicular to Langer's lines (to minimize distortion) using the dentition of a single individual that was adjusted by the serial removal of teeth to decrease the surface area of the dentition. Confounding factors, such as the tissue type, were assessed, for example, the skin over muscle and tight skin over the bone (where distortion is minimized) versus skin adherent to either fat or soft muscle (where distortion exists). Many of the findings could have been predicted, and yet this study provides empirical evidence that distortion occurs, happens often, and can be associated with a plethora of biological factors that, due to the nonlinear relationship, cannot be easily predicted or managed. As we have seen before, it will be the visual impact of this study illustrating distortion that will catch the attention of the lay public, including defense lawyers and others. Figure 2 demonstrates the variability of a bitemark inflicted by a single individual on three occasions. The same degree of force has been used. The difference in the appearance of the bite marks is obvious.

### FIRST LEGALLY APPEARED BITEMARK CASE IN COURT

Bitemark analysis has been used in the United States courts since 1954 (LR4). In this first legally published case from Texas, a certain Doyle was charged with burglary. At the crime scene, a piece of cheese was discovered that possessed tooth marks. A suspect was captured by the police and asked to bite a piece of cheese to which he voluntarily complied. A firearms examiner compared the two pieces of cheese to investigate similarities or dissimilarities of the tooth marks. This nondentist concluded the marks were made by the same person. At trial, a testifying dentist made the same conclusion from plaster models of the original crime scene cheese and the defendant's cheese exemplar. Appellate court review accepted this method.

In later years, this acceptance was judicially stretched to include tooth marks in the skin and occasionally other objects. Still lacking up to today is accompanying scientific validation of the chances for misidentification in the processes

used by court recognized bitemark experts (LR5). This void in scientific support for bitemark identifications reliability was ignored 20 years after Doyle by the Patterson (LR6) court, also in Texas. Both courts ignored the unanswered scientific questions and are mentioned here as a reflection of the persistent in the United States judiciary's avoidance of scientific validation in certain forensic disciplines, with bite marks being among them. This article discusses the current legal climate where DNA exonerations of previous bitemark convictions have become the primary fuel to support earlier odontological and legal opinions doubting the reliability of the method.<sup>[14]</sup>

### ERRONEOUS OF FORENSIC SCIENCE TESTIMONY IN COURTS

An article which said about the forensic errors targeted in the judicial history of legal miscues, false confessions, witness, police, and scientific testimony in relation to the same cases later becoming DNA exonerations. Figure 3 shows the distribution of trial court opinion and scientific evidence in 86 convictions that have been overturned in the United States. The original judicial decisions were in favor of better investigatory, forensic, and biological methods.<sup>[19]</sup>

The bitemark expert evidence was admitted at trial, and the resulting conviction was appealed. The court of appeals turned away the first ground of attack by interpreting a technique's novelty to refer not to the novelty of the identification theory being employed, but to the tools employed to visualize the bitemark and the suspect's dentition. On that, the court opined that the experts "applied scientifically and professionally established techniques – X-rays, models, microscopy, photography – to the solution of a particular problem which, though novel, was well within the capability of those techniques."<sup>[11]</sup>

### ARISING OF DOUBTS

Doubt is the biggest problem happening in bitemark analysis where there is a lot of cross-examinations were undergone. Even though the intra- and inter-observer errors have also been cross verified. That growing doubt is based on the emerging realization that the field stands on a quite limited foundation of scientific fact, that there is "a lack of valid evidence to support many of the assumptions and assertions made by forensic dentists during bitemark comparisons,"<sup>[20]</sup> and that error rates by forensic dentists are perhaps the highest of any forensic identification specialty still being practiced.<sup>[21]</sup>

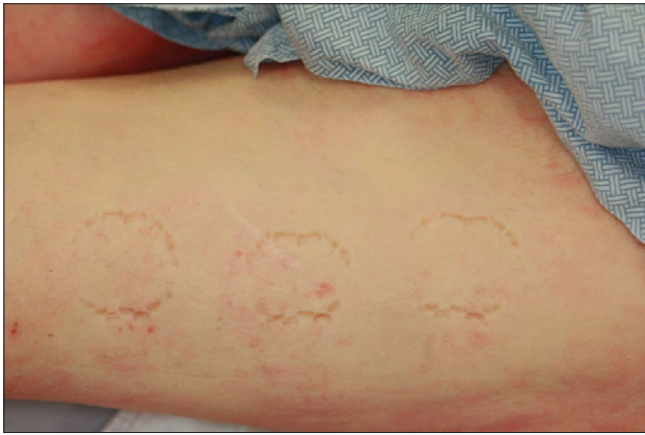
### CASE REPORT GONE WRONGFUL IDENTIFICATION

#### ROY BROWN

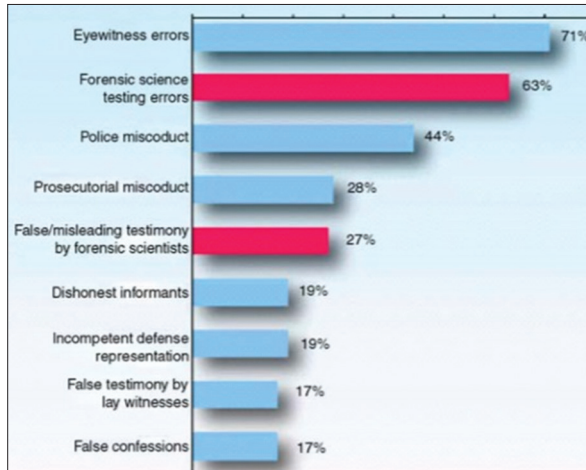
In January 2007, Roy Brown was exonerated of stabbing and strangling Sabina Kulakowski after spending 15 years in prison. He was convicted of her murder in January 1992 based on bitemark evidence that was the centerpiece of the prosecution's case against Brown. Kulakowski's body had been discovered with multiple bite marks on her back, arm, and thigh, all of which board-certified ABFO Diplomate Dr. Edward Mofson<sup>5</sup> claimed was a match to Brown's



**Figure 1:** The Krone case had a senior forensic dentist testifying twice to the positive correlation between these plaster models of the defendant and the injury pattern depicted underneath. DNA proved the defendant was not involved in the murder and rape of the victim



**Figure 2:** Example of three bites on cadaveric tissue from the same dentition and same degree of force from Bush *et al.* (used with permission)



**Figure 3:** Reported that of the 86 DNA exoneration cases they studied, 63% had erroneous forensic science testimony that contributed to the original conviction. They stated published results of bitemark proficiency workshops had false-positive opinions ranging as high as 64%<sup>[19]</sup>

teeth. Mofson testified to a “reasonable degree of dental certainty” that Brown’s dentition was “entirely consistent” and “completely consistent” with all of the bite marks, noting that the bite marks depicted the absence of the same two teeth Brown was missing. Fifteen years after the conviction, however, DNA testing performed on saliva stains left by the

perpetrator excluded Brown and matched another suspect, Barry Bench. Nevertheless, citing the prosecution’s bite mark evidence at the original trial, which the jury asked to review during deliberations, the judge in the case initially refused to release Brown. Ultimately, in January 2007, the district attorney acknowledged Brown’s innocence, and he was exonerated after spending 15 years in prison for a murder he did not commit.

**GERARD RICHARDSON**

On December 17, 2013, Gerard Richardson was exonerated after postconviction DNA testing proved his innocence in a 1994 murder case. He spent nearly 20 years in prison for a crime he did not commit. At Richardson’s 1995 trial, ABFO board-certified Diplomate Dr. Ira Titunik testified that a bite mark found on the victim’s back “was made by Gerard Richardson there was no question in my mind,” and the prosecutor argued that the bite mark was indisputably made by Richardson: “Mr. Richardson, in effect, left a calling card. It’s as if he left a note that said, “I was here,” and signed it because the mark on her back was made by no one else’s teeth.” There was no other physical evidence tying Richardson to the crime. He was sentenced to 30 years in prison without the possibility of parole. More than 19 years after Monica Reyes was murdered, new evidence demonstrated that Richardson was innocent.

**LEVON BROOKS**

Levon Brooks spent 16 years in prison for the rape and murder of a 3-year-old girl that he did not commit. Forensic dentist, Dr. Michael West claimed that the marks on the victim’s body were human bite marks, and he testified at Brooks’ trial that, of 13 suspects whose dentitions he had compared to the wounds on the victim’s body, Brooks’ teeth “matched” the marks on the victim. As he explained, “it could be no one but Levon Brooks that bit this girl’s arm.” Based on this, Brooks was convicted of capital murder and sentenced to life in prison. In 2001, DNA testing and a subsequent confession revealed that Justin Albert Johnson committed the murder. Johnson had been one of the 12 other suspects whose dental impressions Dr. West had determined did not match the bite marks on the victim’s body. Following Johnson’s confession, Brooks was freed on February 15, 2008.

**STEVEN MARK CHANEY**

Steven Chaney was convicted of the murder of John Sweek, a Dallas area cocaine dealer, in 1987; Sweek’s wife was also killed. Although nine alibi witnesses accounted for Chaney’s whereabouts on the day the crime occurred, the state’s case relied largely on the testimony of two ABFO board-certified forensic dentists, Drs. Jim Hales and Homer Campbell. At trial, Dr. Hales purported to match a bite mark on the victim’s arm to Chaney and claimed that there was a “one to a million” chance that someone other than Chaney was the biter. Similarly, Dr. Campbell opined to a reasonable degree of dental certainty that Chaney left the bite mark. Decades after Chaney’s conviction, Dr. Hales admitted that his matching testimony exceeded the limits of the science and that, in contrast to his claims at trial, there was no basis for his statistical testimony in the “scientific literature.” In

**Table 1: Wrongful Bitemark Convictions and Indictments by Odontologists and ABFO Diplomate Status**

Forensic Odontologist	Wrongful Convictions and Indictments	ABFO Diplomate Status
Lowell Levine	-Keith Harward -Edmund Burke	Diplomate
Alvin Kagey	-Keith Harward	Diplomate
Lowell Johnson	-Robert Lee Stinson	Diplomate
Raymond Rawson	-Robert Lee Stinson -Ray Krone	Diplomate
Ira Titunik	-Gerard Richardson -Edmund Burke	Diplomate
Robert Barsley	-Willie Jackson	Diplomate
Edward Mofson	-Roy Brown	Diplomate
Homer Campbell	-Calvin Washington -Joe Sidney Williams -Steven Chaney	Diplomate
Jim Hales	-Steven Chaney	Diplomate
Harvey Silverstein	-James O'Donnell	Diplomate
Michael West	-Levon Brooks -Kennedy Brewer -Anthony Keko -Johny Bourn -James Earl Gates	Diplomate
Allan Wamick	-Michael Cristini -Jeffrey Moldowan	Diplomate
Pamela Hammen	-Michael Cristini -Jeffrey Moldowan	Diplomate
John Kenney	-Harold Hill -Dan Young, Jr.	Diplomate
Norm Sperber	-William Richards	Diplomate
Richard Souviron	-Dale Morries, Jr.	Diplomate
Kenneth Martin	-Dale Morries, Jr.	Diplomate
Russell Schneider	-Bennie Starks	Not Board Certified
Carl Hagstrom	-Bennie Starks	Not Board Certified
Constantine( Gus ) Karazulas	-Crystal Weimer	Not Board Certified

**Table 2: Statistical Summary of Cases of Wrongful Bite Mark Conviction and Indictment**

Those Wrongful Bite Mark Convictions and Indictments	Number of Cases and Percentage (%)
Total Wrongful Bite Mark Convictions and Indictments:	28
Wrongful Bite Mark Convictions and Indictments Where Forensic Dentist (s) Are Named:	26
Forensic Dentists Involved In Wrongful Bite Mark Conviction and Indictments:	20
ABFO Diplomates Involved in Wrongful Bite Mark Convictions and Indictments:	17
Non Board Certified Odontologists Involved in Wrongful Bite Mark Convictions and Indictments Cases:	3
Percentage of Dentists Responsible for Wrongful Bite Mark Conviction and/or Indictments With ABFO Diplomate Status:	85%(17 of 20)
Percentage of Wrongful Bite Mark Convictions and Indictments With ABFO Diplomate Involvement:	92.3%(24 of 26)

light of the change in the scientific understanding of bite mark evidence since 1987 and Dr. Hales's recantation, the Dallas County District Attorney's Office agreed to vacate Mr. Chaney's conviction pursuant to Texas's "junk science writ," which provides an avenue for postconviction relief where the science used at trial is subsequently discredited. In October 2015, Chaney was released after 28 years of wrongful incarceration; his case is currently pending before the Texas Court of Criminal Appeals, which has final authority in Texas overall habeas determinations.

### ANTHONY KEKO

Anthony Keko was convicted in 1994 for the 1991 murder of his estranged wife, Louise Keko. Dr. Michael West testified that a bite mark on the victim's shoulder matched Anthony Keko's dentition. Dr. West's testimony was the only direct evidence linking Keko to the crime, and prosecutors conceded that without the bite mark evidence there was no case. Keko was found guilty and sentenced to life in prison. In December 1994, however, the trial judge became aware of previously undisclosed disciplinary proceedings against Dr. West. The

judge began to express doubts regarding West's forensic abilities and ultimately reversed Keko's conviction.<sup>[22]</sup>

### STEVEN MARK CHANEY

Steven Chaney was convicted of the murder of John Sweek, a Dallas-area cocaine dealer, in 1987; Sweek's wife was also killed. Although nine alibi witnesses accounted for Chaney's whereabouts on the day the crime occurred, the state's case relied largely on the testimony of two ABFO board-certified forensic dentists, Drs. Jim Hales and Homer Campbell. At trial, Dr. Hales purported to match a bite mark on the victim's arm to Chaney and claimed that there was a "one to a million" chance that someone other than Chaney was the biter. Similarly, Dr. Campbell opined to a reasonable degree of dental certainty that Chaney left the bite mark. Decades after Chaney's conviction, Dr. Hales admitted that his matching testimony exceeded the limits of the science and that, in contrast to his claims at trial, there was no basis for his statistical testimony in the "scientific literature." In light of the change in the scientific understanding of bite mark evidence since 1987 and Dr. Hales's recantation, the Dallas County District Attorney's Office agreed to vacate Mr. Chaney's conviction pursuant to Texas's "junk science writ," which provides an avenue for postconviction relief where the science used at trial is subsequently discredited. In October 2015, Chaney was released after 28 years of wrongful incarceration; his case is currently pending before the Texas Court of Criminal Appeals, which has final authority in Texas overall habeas determinations.<sup>[23]</sup>

### ANALYSIS OF FORENSIC ODONTOLOGIST'S WRONGLY INVESTIGATED

The misapplication of forensic sciences is a leading contributing factor to wrongful conviction,<sup>[24]</sup> and of the unvalidated techniques that have contributed to wrongful convictions and indictments later overturned through DNA testing, bite mark comparison poses an acute threat to the reliability and fairness of the criminal justice system. Of the<sup>[23]</sup> known wrongful convictions and indictments secured through the use of bite mark comparison evidence, the forensic dentist (s) who performed the comparisons are known in all but two cases.<sup>[25]</sup> Among those 26 cases with available data, a total of 20 dentists offered bite mark comparison opinions or testimony.<sup>[24]</sup> In this 87% or 17 of those dentists were Diplomates of the American Board Of Forensic Odontology.<sup>[26]</sup> The raw data are presented below in Table 1; ABFO Diplomates are highlighted in yellow. A brief statistical analysis is offered in Table 2.

### CONCLUSION

Of concern is that, because of the undisputed misuse of bite mark comparison, and the unfortunate, but common, belief that bite mark analysis is the same as bite mark comparison, valuable information available to the criminal justice system from bite mark analysis may be deemed inadmissible in a court of law – unless experts in the field wake up to the distinction between comparison and analysis, and communicate that distinction to the legal system. Moreover, I am strongly insisted that bitemark analysis in India also wrongly

investigated and 94% of wrongly going and many involved innocent. The long tail of unsound science in the case of bitemark evidence suggests that: (i) the scientific community must more carefully engage with the research foundations of forensics, and not just in landmark but infrequent national commissions; (ii) lawyers must aggressively brief challenges to foundations of forensic techniques; and (iii) judges must be far more willing to carefully examine forensic evidence before admitting it. Many observers, including the National Academy of Sciences in its report, have called for a systemic renewal of such legal and scientific efforts and progress has been slow. The rise and impending fall of bitemark evidence powerfully illustrates the costs of the failure to assure that what enters our criminal courts are sound science.<sup>[26]</sup>

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Nil.

### CONFLICTS OF INTEREST

There are no conflicts of interest.

### REFERENCES

1. Saks MJ, Albright T, Bohan TL, Bierer BE, Bowers CM, Bush MA, *et al.* Forensic bitemark identification: Weak foundations, exaggerated claims. *J Law Biosci* 2016;3:538-75.
2. Committee on Identifying the Needs of the Forensic Science Community National Research Council. *Strengthening Forensic Science in the United States: A Path Forward*; 2009.
3. Souviron R, Haller L. Bite mark evidence: Bite mark analysis or identification. *J Law Biosci* 2017;49:617-22. [doi: 10.1093/jl16/Isx026].
4. Analysis 2017. Available from: <https://www.merriam.webster.com/dictionary/analysis>. [Last accessed on 2017 Apr 16; Last retrieved on 2017 Apr 16].
5. In several of the, now notorious, overturned conviction cases that involved bite mark comparison, the comparison, the patterned injury that was said to be 'indeed and – Google Search injury that was said to be 'indeed and without doubt' the defendant's teeth was deemed by other forensic deontologists to not be a bite mark at all. See wrongly conviction cases. Brewer K. Leven Brooks and Anthony Keko. Available from: <http://www.Innocenceproject.com>. [Last accessed on 2017 Apr 16].
6. Silver WE, Souviron RR. *Dental Autopsy*. Ch. 13. 1<sup>st</sup> Edition, London, New York: CRC Press, Taylor and Francis Group, Boca Raton; 2009. p. 157.
7. Bowers CM. Identification from bitemarks. In: Faigman DL, Kaye DH, Saks MJ, Sanders J. *Modern Scientific Evidence: The Law and Science of Expert Testimony*. West Group 2010;S3:1254-62.
8. Saks MJ, Albright T, Bohan TL, Bierer BE, Bowers CM, Bush MA, *et al.* Forensic bitemark identification: Weak foundations, exaggerated claims. *Id.*, Sec. 37:1, note 2. *J Law Biosci* 2016;3:538-75.
9. Kuttikara SJ. *Methods in Bite Mark Analysis Literature Review*. Master Thesis. Problemveien 7, 0315 Oslo, Norway: Universitetet Ioslo; May, 2017.
10. Bowers CM. Problem-based analysis of bitemark misidentifications: The role of DNA. *Forensic Sci Int* 2006;159 Suppl 1:S104-9.
11. Faigman DL, Kaye DH, Saks MJ, Sanders J. *Modern Scientific Evidence: The Law and Science of Expert Testimony*. California: Thompson West; 2006. p. 543-6.

12. Arheart KL, Pretty IA. Results of the 4<sup>th</sup> ABFO bite mark workshop. *For Sci Int* 1999;124:104-11.
13. Pretty IA, Sweet D. Digital Bite mark overlays – An analysis of effectiveness. *J For Sci* 2001;46:1385-9.
14. Bowers CM. Problem-based analysis of bitemark misidentifications: The role of DNA. *Forensic Sci Int* 2006;159 Suppl 1:S104-9.
15. DeVore DT. Bite marks for identification? A preliminary report. *Med Sci Law* 1971;11:144-5.
16. Barbenel JC, Evans JH. Bite marks in skin – Mechanical factors. *J Forensic Sci Soc* 1974;14:235-8.
17. Rawson RD, Brooks S. Classification of human breast morphology important to bite mark investigation. *Am J Forensic Med Pathol* 1984;5:19-24.
18. Bush MA, Thorsrud K, Miller RG, Dorion RB, Bush PJ. The response of skin to applied stress: Investigation of bitemark distortion in a cadaver model. *J Forensic Sci* 2010;55:71-6.
19. Saks MJ, Koehler JJ. The coming paradigm shift in forensic identification science. *Science* 2005;309:892-5.
20. A Dentist Takes The Stand. *Newsweek*; 19 August, 2001. Available from: <http://www.newsweek.com/dentist-takes-stand-151357>. Hansen M. Out of the Blue, *ABAJ* 1996. Available from: [http://www.abajournal.com/magazine/article/out\\_of\\_the\\_blue/print/](http://www.abajournal.com/magazine/article/out_of_the_blue/print/). [Last accesses on 2018 Dec 07].
21. Emily J. Dallas County Man Freed after Serving 25 Years for Murder over Faulty Science of Bite Marks. *The Dallas Morning News*; 2015. Available from: <http://crimeblog.dallasnews.com/2015/10/dallas-county-man-freed-after-serving-25-years-formurder-over-faulty-science-of-bite-marks.html/>. [Last accessed on 2018 Dec 16].
22. The Innocence Project, Unvalidated or Improper Forensic Science. Available from: <http://www.innocenceproject.org/causes/unvalidated-or-improper-forensic-science/>. [Last accessed on 2019 Jan 28].
23. Innocent Project, Description of Bite Mark and Statistical Analysis. Available from: [https://www.innocenceproject.org/wp-content/uploads/2019/01/Description-of-bite-mark-exonerations-and-statistical-analysis\\_UPDATED-01.28.19.pdf](https://www.innocenceproject.org/wp-content/uploads/2019/01/Description-of-bite-mark-exonerations-and-statistical-analysis_UPDATED-01.28.19.pdf). [Last accessed on 2019 Jan 30].
24. The Innocence Project - News: Cases where DNA Revealed That Bite Mark Analysis Led to Wrongful Arrests and Convictions. Available from: <http://www.innocenceproject.org/cases-where-dna-revealed-that-bite-mark-analysis-led-to-wrongful-arrests-and-convictions>. [Last accessed on 2019 Jan 30].
25. American Board of Forensic Odontology Diplomate Information. Available from: <http://www.abfo.org/wp-content/uploads/2013/02/ABFO-Diplomate-Information-revised-9-29-2015.pdf>. [Last updated on 2016 Sep 09].
26. American Board of Forensic Odontology Diplomate Information. Available from: <http://www.abfo.org/wp-content/uploads/2013/02/ABFO-Diplomate-Information-revised-9-29-2015.pdf>. [Last updated on 2016 Sep 25].