Chapter 37

Identification from Bitemarks

I. LEGAL ISSUES

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I. LEGAL ISSUES

§ 37:1 Generally

The analysis of bitemarks for the purpose of identifying a criminal perpetrator is a specialized task within the broader discipline of forensic odontology. Accordingly, it presents more challenging questions to odontologists and, in turn, to courts. Forensic dentists long have been called upon to identify the remains of victims of disasters by comparing the victims' dentition with dental records.[1] In trying to identify perpetrators of crime, the forensic dentist seeks to compare a suspect's dentition with a latent mark left in the victim's flesh or in some material, usually an edible substance, found at the scene of a crime.[2]

§ 37:2 Bitemark identification and the *Daubert* factors

Like all forensic identification sciences, the claims of the field of forensic odontology clearly are empirical in nature and therefore amenable to review under *Daubert*'s[1] criteria for evaluating scientific claims. Against those criteria, bitemark identification encounters several interesting

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[Section 37:1]

[1]In mass disasters dentists are able to identify 20–25% of the victims. See § 37:9.

[2]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 bitemark cases, the number of potential suspects is huge, the bitemarks 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.

[Section 37:2]

[1]*Daubert v. Merrell Dow Pharmaceuticals, Inc.*, 509 U.S. 579, 113 S. Ct. 2786, 125 L. Ed. 2d 469, 27 U.S.P.Q.2d 1200, Prod. Liab. Rep. (CCH) P 13494, 37 Fed. R. Evid. Serv. 1, 23 Envtl. L. Rep. 20979 (1993).

problems. Clearly the nature of dentition and the asserted skills of forensic dentists are testable. Although some of the scientific issues and claims in forensic odontology have been tested more extensively than the scientific issues and claims of most forensic individualization sciences, that is largely because most of the other forensic individualization sciences have conducted or been subjected to remarkably little systematic empirical testing.[2] Important issues about the nature of identification by bitemark comparisons remain unresolved.[3]

Some of the research that has been conducted has been published and, if not peer reviewed before publication, certainly has been afterwards. Troublingly, some of the research has not been published or otherwise made public.[4] Recall that, properly understood, "peer review and publication" is concerned with evaluating the methodology of the "testing" referred to above. The published research in forensic odontology is not without flaws, and those flaws will inevitably and properly affect the seriousness with which the findings of those studies are taken.[5]

The error rate in bitemark identification, particularly the rate of false positive errors, appears to be quite high.[6]

Finally, general acceptance is an issue in forensic dentistry with regard to the task of linking crime scene marks to the dentition of a suspect. Not long ago, many, perhaps a majority, of forensic odontologists doubted that they could make pinpoint identifications in more than the rare case. Due to the eager acceptance by judges of bitemark expert testimony,[7] that number has dwindled, but a significant minority of forensic dentists retain their doubts about some of the field's vital claims. Thus, general acceptance in forensic odontology is not nearly so strong as it is in other forensic science fields.

§ 37:3 Divergence of opinions by bitemark experts

One pattern that has emerged from the testimony presented in bitemark cases is the persistence of forensic odontologists testifying to contrary opinions. This occurs not only for opinions about the identity of the maker of a bitemark, but also on the question of whether or not a wound was caused by a bite.

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[2]See, e.g., Chapters 33 and 34.

[3]Discussed at various places in the Scientific Status section of this chapter.

[4]The results of the fourth round of proficiency testing are reported, § 37:12, but the first three have never been published. Although the results of proficiency testing in other areas of forensic science once were equally secretive (not published and circulated privately within the field), at present anonymous test results from proficiency tests sponsored by the American Society of Crime Laboratory Directors ASCLD are posted on the website of the Collaborative Testing Service.

[5]See discussion at various places in the Scientific Status portion of this chapter.

[6]§ 37:13.

[7]See discussion infra of *People v. Marx* and its aftermath.

In numerous cases, forensic odontologists have disagreed about whether a particular mark on a victim was a bitemark or not.[1] An increasingly well-known article reports on a case in which an injury was initially interpreted as a "possible" bitemark.[2] A suspect was then developed and dental models were taken of his teeth. After comparing the model to the injury, two forensic odontologists "stated that not only was the injury definitely caused by a human bite, but that the individual characteristics of the injury identically matched the suspect's dentition."[3] Thereafter, it was determined through an elaborate series of tests that the injury was not a bitemark after all, even though certain areas "suggested outlines of individual tooth margins."[4] In their article, the authors, both prominent forensic dentists, state the following conclusion:

> [When an injury is initially evaluated, and consideration is given toward the possibility of a human bite origin, *the first question to be asked is*, "Is this truly a bite injury?"]. . . . *If the answer is affirmative, the next two questions are* "What portion or portions of the dental arcade does it represent and what class and individual tooth characteristics does it contain?" These [latter] two questions must be always addressed in sequence, as the application of the second query is wholly dependent upon the answer to the first. *If this process is altered, and the basic presence or absence of an actual bite pattern injury is not adequately addressed, the eventual outcome may be disastrous*.[5]

The other issue, whether a defendant was the source of a bitemark, has generated at least as much disagreement between experts.[6]

In addition to the above-cited decisions, there have been numerous

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[Section 37:3]

[1]See, e.g., *Kinney v. State*, 315 Ark. 481, 868 S.W.2d 463 (1994) (state and defense experts disagree about whether mark was human bitemark); *People v. Holmes*, 234 Ill. App. 3d 931, 176 Ill. Dec. 287, 601 N.E.2d 985 (1st Dist. 1992) (same); *Davis v. State*, 611 So. 2d 906 (Miss. 1992) (same); *People v. Noguera*, 4 Cal. 4th 599, 15 Cal. Rptr. 2d 400, 842 P.2d 1160, 1165 (1992) (same); *State v. Kendrick*, 47 Wash. App. 620, 736 P.2d 1079 (Div. 1 1987) (same); *People v. Smith*, 63 N.Y.2d 41, 479 N.Y.S.2d 706, 468 N.E.2d 879 (1984) (same); *State v. Keko*, Case No. 92-3292 (Parish Plaquemines, Louisiana, 1992) (same).

[2]Sperry & Campbell, Jr., An Elliptical Incised Wound of the Breast Misinterpreted as a Bite Injury, 35 J. Forensic Science 1126 (1990).

[3]Sperry & Campbell, Jr., An Elliptical Incised Wound of the Breast Misinterpreted as a Bite Injury, 35 J. Forensic Science at 1228 (1990).

[4]Sperry & Campbell, Jr., An Elliptical Incised Wound of the Breast Misinterpreted as a Bite Injury, 35 J. Forensic Science at 1235 (1990).

[5]Sperry & Campbell, Jr., An Elliptical Incised Wound of the Breast Misinterpreted as a Bite Injury, 35 J. Forensic Science at 1235 (1990) (emphasis added).

[6]See, e.g., *Milone v. Camp*, 22 F.3d 693 (7th Cir.1994) ("at trial much evidence was adduced by both sides concerning whether Milone's dentition matched the bitemark"; defendant "presented several experts of his own to testify that he could not have made the mark found"); *Wilhoit v. State*, 1991 OK CR 50, 816 P.2d 545 (Okla. Crim. App. 1991) (eleven "well-recognized forensic odontologists" disagree with state's experts that defendant caused the bitemark on victim); *Spence v. State*, 795 S.W.2d 743 (Tex. Crim. App. 1990) ("there was truly a battle between two of today's leading experts in the field of forensic odontology at appellant's trial"); *State v. Sager*, 600 S.W.2d 541 (Mo. Ct. App. W.D. 1980) (defendant's two experts

reports of forensic odontologists reaching opinions that disagreed with the results of DNA and other forensic analysis.[7]

The rather frequent disagreement among forensic dentists, more common than among other forensic identification scientists,[8] could be explained in a number of different ways. Bitemark comparisons may be inherently more ambiguous than other identification types. Forensic dentists may simply be more available to defendants compared to most other forensic scientists, who are more or less exclusively in the employ of the government. Or, relatedly, board-certified forensic odontologists may inadvertently reach conclusions favorable to the party that has retained them[9]—by no means a phenomenon new to the courts. So, whether the fact of frequent disagreement reveals bitemark identification to be a peculiarly unreliable area, or whether areas of expertise that create an illusion of consistency[10] are the more worrisome, is by no means clear.

§ 37:4 The judicial response to expert testimony on bitemark identification

Though expert opinion on bitemark identification is one of the newer areas of forensic identification, having arrived in the courts only in the past generation, it was rapidly admitted in many jurisdictions throughout the United States. The great majority of those cases occurred after 1980.[1]

Several ironies accompany this legal history. One is that forensic

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disagreed with State's experts); *Kennedy v. State*, 1982 OK CR 11, 640 P.2d 971 (Okla. Crim. App. 1982) (defendant's expert disagreed with State's expert); *Harrison v. State*, 635 So. 2d 894 (Miss. 1994) (defense expert files affidavit on appeal disagreeing with state's expert); *Brown v. State*, 690 So. 2d 276 (Miss. 1996) (state and defense experts disagree); *Case v. Mississippi,* No. 91-KA-0872 (Adams Cty., Miss.) (state's expert testifies that marks on victim were bitemarks caused by defendant's dentition; defense expert testifies that he does not know whether marks were bitemarks, let alone what caused them); *Banks v. State*, 725 So. 2d 711, 101 A.L.R.5th 767 (Miss. 1997) (prosecution and defense experts disagree); *State v. Richardson,* No. A-4255-95T4 (Sup. Ct. N.J. App. Div. 1997) (State's expert testifies that defendant's teeth matched a bitemark on the victim's back while defense expert testifies that defendant could not have made the bitemark); Other Lehigh Trials Have Had A Steep Price, 1998 WL 12854106, Allentown Morning Call (7/12/98) (reporting on *Commonwealth v. Gonzalez*, a case in which state's expert concluded that woman could have bitten infant and defense expert concluded that marks were too small to have been caused by defendant).

[7]See infra § 37:7.

[8]Whose principal empirical support for their claim of expertise seems to be that they are rarely if ever contradicted by their peers. See, e.g., David Fisher, Hard Evidence 245 (1996). See § 37:3.

[9]See Nordby, Can We Believe What We See, If We See What We Believe?—Expert Disagreement, 37 J. Forensic Sci. 1115 (1992) (disagreement among honest experts often caused by "expectation-laden observations").

[10]Behind which hides an equal amount of ambiguity and disagreement.

[Section 37:4]

[1]By state:

Arizona—*State v. Garrison*, 120 Ariz. 255, 585 P.2d 563 (1978).

California—*People v. Marx*, 54 Cal. App. 3d 100, 126 Cal. Rptr. 350, 77 A.L.R.3d

odontologists, perhaps reflecting a grounding in scientific skepticism that is absent from the more traditional forensic identification sciences,[2] were more doubtful about whether the state of their knowledge permitted them to successfully identify a perpetrator "to the exclusion of all others." The history of other areas of forensic identification reveals no similar self doubts. Second, the courts began admitting expert testimony on bitemarks while many prominent forensic odontologists still doubted whether the necessary knowledge existed to permit them to make such identifications accurately. Third, and most remarkable, rather than the field convincing the courts of the sufficiency of its knowledge and skills, admission by the courts seems to have convinced the forensic odontology community that, despite their doubts, they were able to perform bitemark identifications after all.[3]

1108 (2d Dist. 1975).

Connecticut—*State v. Ortiz*, 198 Conn. 220, 502 A.2d 400 (1985).

Florida—*Bundy v. State*, 455 So. 2d 330 (Fla. 1984) (abrogated on other grounds by, Fenelon v. State, 594 So. 2d 292 (Fla. 1992)). *Bundy v. State*, 490 So. 2d 1258 (Fla. 1986). *Bundy v. State*, 497 So. 2d 1209 (Fla. 1986). *Bundy v. State*, 538 So. 2d 445 (Fla. 1989).

Illinois—*People v. Milone*, 43 Ill. App. 3d 385, 2 Ill. Dec. 63, 356 N.E.2d 1350 (2d Dist. 1976). *People v. Williams*, 128 Ill. App. 3d 384, 83 Ill. Dec. 720, 470 N.E.2d 1140 (4th Dist. 1984).

Indiana—*Niehaus v. State*, 265 Ind. 655, 359 N.E.2d 513 (1977).

Louisiana—*State v. Wommack*, 770 So. 2d 365 (La. Ct. App. 3d Cir. 2000), writ denied, 797 So. 2d 62 (La. 2001).

Michigan—*People v. Marsh*, 177 Mich. App. 161, 441 N.W.2d 33 (1989).

Minnesota—*State v. Hodgson*, 512 N.W.2d 95 (Minn. 1994).

Mississippi—*Howard v. State*, 697 So. 2d 415 (Miss. 1997), republished as corrected at 701 So.2d 274 (holding bitemark expert testimony inadmissible). *Brooks v. State*, 748 So. 2d 736 (Miss. 1999) (holding bitemark expert evidence admissible).

Missouri—*State v. Sager*, 600 S.W.2d 541 (Mo. Ct. App. W.D. 1980). *State v. Kleypas*, 602 S.W.2d 863 (Mo. Ct. App. S.D. 1980). *State v. Turner*, 633 S.W.2d 421 (Mo. Ct. App. W.D. 1982).

New York—*People v. Middleton*, 54 N.Y.2d 42, 444 N.Y.S.2d 581, 429 N.E.2d 100 (1981). *People v. Smith*, 63 N.Y.2d 41, 479 N.Y.S.2d 706, 468 N.E.2d 879 (1984). *People v. Smith*, 110 Misc. 2d 118, 443 N.Y.S.2d 551 (County Ct. 1981).

North Carolina—*State v. Temple*, 302 N.C. 1, 273 S.E.2d 273 (1981). *State v. Green*, 305 N.C. 463, 290 S.E.2d 625 (1982).

Oklahoma—*Kennedy v. State*, 1982 OK CR 11, 640 P.2d 971 (Okla. Crim. App. 1982).

Rhode Island—*State v. Adams*, 481 A.2d 718 (R.I. 1984).

South Carolina—*State v. Jones*, 273 S.C. 723, 259 S.E.2d 120 (1979).

Texas—*Doyle v. State*, 159 Tex. Crim. 310, 263 S.W.2d 779 (1954). *Patterson v. State*, 509 S.W.2d 857 (Tex. Crim. App. 1974).

Wisconsin—*State v. Stinson*, 134 Wis. 2d 224, 397 N.W.2d 136 (Ct. App. 1986).

[2]Compared to examiners of fingerprints, footprints, toolmarks, document examiners, firearms, and so on.

[3]In their book on scientific evidence, Andre Moenssens, et al. Scientific Evidence in Civil and Criminal Cases (4th ed. 1995), they conclude concerning the relationship between the courts and expert opinion on bitemark identification:

> The wholesale acceptance, by the courts, of testimony on bitemark identification has transformed the profession. Whereas prior to

§ 37:5 The judicial response to expert testimony on bitemark identification—Cases before *Daubert*

The first case in the United States to confront the admissibility of expert testimony on a bitemark identification was *Doyle v. State*.[1] Doyle was charged with burglary. At the site of the burglary was found a piece of partially eaten cheese. After arresting Doyle, the sheriff asked him to bite a piece of cheese, which the suspect voluntarily did. A firearms examiner compared the two pieces of cheese to try to determine if the questioned and the known tooth marks had been made by the same person. The firearms examiner concluded that they had. At trial a dentist testified that from his own examination of plaster casts of the cheese bitemarks, he also reached the opinion that one and the same dentition had made both sets of bites.[2] The Texas Court of Criminal Appeals upheld the admission of this bitemark opinion testimony.

Although the empirical research necessary to form the scientific ground for such a conclusion had not yet been undertaken,[3] the defense in *Doyle* did not contest admissibility by raising any issue of scientific validity, but instead raised only procedural challenges.[4] Thus, the *Doyle* court did not address the scientific status of bitemark identification. Nevertheless, another Texas court relied on *Doyle* twenty years later as the basis for rejecting an appellant's contention that bitemark test results were of unproven reliability.[5] Both Texas cases seemed to take admissibility as a given, and neither addressed the scientific issues.

The cornerstone case on the admissibility of bitemark identification was decided the following year, in 1975, in California. This case undertook to grapple with the scientific issues on which admissibility of bitemark identification should turn, but in the end succeeded only in eluding them. *People v. Marx*[6] involved a brutal murder of an elderly woman who had an elliptical laceration on her nose. This mark was judged to be a human bite,

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1974 the main thrust of forensic dentistry was to prove identity of persons by means of a comparison of postmortem and antemortem dental records in mass disasters, the profession has changed direction and is now heavily involved in assisting prosecutors in homicide and sex offense cases. Having received judicial approval of bitemark comparisons, there seems to be no more limit on the extent of forensic odontological conclusions.

Andre Moenssens, et al. Scientific Evidence in Civil and Criminal Cases § 16.07, at 985 (4th ed. 1995).

[Section 37:5]

[1]*Doyle v. State*, 159 Tex. Crim. 310, 263 S.W.2d 779 (1954). Although this was the first appellate consideration of bitemark evidence, the technique had been used for related identification purposes for decades. See §§ 37:8 to 37:34.

[2]§§ 37:8 to 37:34.

[3]As leading forensic odontologists today readily note. See studies discussed in the Scientific Status portion of this chapter.

[4]The defense raised only the issue of whether obtaining the bitten cheese from the defendant constituted a confession and thereby violated a Texas statute prohibiting obtaining confessions without warning defendants of their likely use.

[5]*Patterson v. State*, 509 S.W.2d 857 (Tex. Crim. App. 1974).

[6]*People v. Marx*, 54 Cal. App. 3d 100, 126 Cal. Rptr. 350, 77 A.L.R.3d 1108 (2d Dist. 1975).

and impressions were made of the wound for comparison with a cast of the defendant's teeth.

At trial, three odontologists testified that in their opinion the defendant's dentition matched the bite wound.[7] One of those experts took pains to note that in many other cases he had refused to offer a firm opinion or even to testify about an identification. This case, however, was an exception in that the dentition at issue was extremely unusual and the bitemark was exceptionally well defined. The witness characterized these bite impressions as the clearest he had ever seen, either personally or in the literature. Despite the expert's caution, and unusual case facts emphasizing the rarity of both the dentition and the bitemarks, *Marx* pried open the courtroom door for bitemark identification. Having done so, it became the admission ticket for a far wider and more dubious array of dentition in many subsequent cases.

On appeal, the defense challenged the admission of expert opinions on bite wound identification on the ground that the purported skills were not sufficiently established or generally accepted in the field of forensic dentistry. Thus, under California law following *Frye v. United States*,[8] the admission of such testimony would have been error. The field was, after all, sharply divided over the question of whether they could identify biters by the bitemarks left in crime victims. The California Court of Appeals acknowledged that there was "no established science of identifying persons from bite marks . . . ."[9] Moreover, the theory of bitemark identification is in essence based on an assessment of the probability that two or more people could leave the same bitemark,[10] yet no data existed on those probabilities. How did the Court of Appeals reach its decision to admit the testimony, despite the California Supreme Court's repeated announcement of general acceptance as the governing rule in that state, and its prohibition on evidence based on speculative probability estimates?[11] In several ways.

The Court of Appeals deflected the implications of *Frye*, by interpreting that test in these terms:

The *Frye* test finds its rational basis in the degree to which the trier of fact

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[7]Gerry L. Vale et al., Unusual Three-Dimensional Bite Mark Evidence in a Homicide Case, 21 J. Forensic Sci. 642 (1976).

[8]*Frye v. U.S.*, 293 F. 1013, 34 A.L.R. 145 (App. D.C. 1923) (rejected by, State v. Walstad, 119 Wis. 2d 483, 351 N.W.2d 469 (1984)) and (rejected by, State v. Brown, 297 Or. 404, 687 P.2d 751 (1984)) and (rejected by, Nelson v. State, 628 A.2d 69 (Del. 1993)) and (rejected by, State v. Alberico, 116 N.M. 156, 861 P.2d 192 (1993)) and (rejected by, State v. Moore, 268 Mont. 20, 885 P.2d 457 (1994)) and (rejected by, State v. Faught, 127 Idaho 873, 908 P.2d 566 (1995)) and (rejected by, People v. Shreck, 22 P.3d 68, 90 A.L.R.5th 765 (Colo. 2001)).

[9]*People v. Marx*, 54 Cal. App. 3d 100, 126 Cal. Rptr. 350, 353, 77 A.L.R.3d 1108 (2d Dist. 1975).

[10]§ 37:20.

[11]*People v. Collins*, 68 Cal. 2d 319, 66 Cal. Rptr. 497, 438 P.2d 33, 36 A.L.R.3d 1176 (1968).

> must accept, on faith, scientific hypotheses not capable of proof or disproof in court and not even generally accepted outside the courtroom. *Frye*, for example, involved the lie detector test in which the trier of fact is required to rely on the testimony of the polygrapher, verified at most by marks on a graph, to which the expert's hypothesis gives some relevant meaning . . . . [Other cases reflect] [t]he same concern that the trier of fact will be overwhelmed by "ill conceived techniques with which the trier of fact is not technically equipped to cope," sacrificing its independence in favor of deference to the expert.[12]

The paradox, of course, is that expert opinion testimony is permitted precisely because it is believed that the expert's understanding exceeds the jury's, and the expert can tell the jury truths that the jury could not otherwise grasp. Be that as it may, the court thus distinguished *Marx* from *Frye* by reasoning that *Frye* applied to evidence that was indecipherable without an expert's interpretation, whereas *Marx* involved models, X-rays, and slides of the victim's wounds and the accused's dentition, all of which were clearly visible for the jurors to view, assess, and verify on their own during court proceedings, without having to rely on the expert odontologist as a necessary intermediary. Forensic odontologists, no doubt, would be astonished to learn that once the pictures are taken and the molds cast, no special expertise or judgment is required to assess whether the wound was made by the defendant's dentition.

The *Marx* court concluded, alternatively, that the requirements of *Frye had* been met because the methods used to facilitate the bitemark identification were not really novel:

> [T]he experts did not rely on untested methods, unproven hypotheses, intuition or revelation. Rather, they 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.[13]

On this view, *Frye* is about the tools, not the meaning of the information collected with the help of the tools. While the reliability of the tools is by no means unimportant, the most fundamental issues in bitemark identification, as with all forensic identification, are: (a) whether the population variation in the relevant characteristics is immense; (b) whether in practice that underlying variation is adequately captured by the available tools and evidence, particularly; (c) whether the latent mark has enough distinct variation in it to allow the probability that someone else's dentition may have left the mark to fall comfortably low.[14] None of this essential knowledge was, or usually is, available to the jury. The question the court might well be focusing on, however, is whether that information

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[12]*People v. Marx*, 54 Cal. App. 3d 100, 110–111, 126 Cal. Rptr. 350, 77 A.L.R.3d 1108 (2d Dist. 1975).

[13]*People v. Marx*, 54 Cal. App. 3d 100, 126 Cal. Rptr. 350, 77 A.L.R.3d 1108 (2d Dist. 1975).

[14]§ 37:20.

is even available to the expert.[15]

Ironically, the *Marx* court appears to have believed that an inquiry about or offer of evidence on the probabilities underlying bitemark identifications would be inadmissible in California under the rule of *People v. Collins*.[16] It held that, since the experts never had actual data and did no calculations of probability, but instead remained impressionistic and intuitive, "[n]one of the witnesses engaged in a 'trial by mathematics' [citing *Collins*] on or off the stand. There was no error."

First of all, the *Marx* court overstates the *Collins* prohibition. In *Collins*, a major ground of the inadmissibility of a statistically based identification was that it was based on (a) speculative probabilities (rather than known relative frequencies of the attributes at issue), and (b) a lack of proof that the attributes of interest consisted of independent events,[17] thereby resulting in faulty computations. In short, the evidence lacked essential foundation. Absent these flaws, such evidence might well be admissible. Second, whether a *jury* will be allowed to hear the numbers is one thing. Whether they may be heard *by a court* in deciding a preliminary question such as the admissibility of purported scientific evidence is quite another. Any court following FRE 104 or an equivalent rule plainly is authorized to do so,[18] and any court following *Daubert* apparently has a *duty* to do so.[19] Surely the experts ought to have such data, because those are what their conclusions rely upon.[20]

Most interesting, perhaps, *Marx* is one of the rare cases to realize that much forensic identification evidence invokes much the same reasoning that the California Supreme Court found so troubling in *Collins*. To believe that the experts or the court, in deciding a question of admissibility of expert evidence, should eschew consideration of the underlying data and the statistical inferences to be drawn from those data, is a deeply confused extension of *Collins*. It solves few if any of the problems that *Collins* was concerned with; it merely pretends the problems are not there. The existence and nature of probability data are at the heart of the theory of forensic identification, and a court ought to be scrutinizing them, not insisting

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[15]If it is not, in some form or fashion, then the expert is speculating.

[16]*People v. Collins*, 68 Cal. 2d 319, 66 Cal. Rptr. 497, 438 P.2d 33, 36 A.L.R.3d 1176 (1968).

[17]In order to apply the multiplication rule to calculate the probability, each component must be uncorrelated with each other component.

[18]Moreover, in deciding such preliminary questions, the court "is not bound by the rules of evidence except those with respect to privileges." Fed. R. Evid. 104(a).

[19]Among other data to be considered is a technique's "known or potential error rate.'' *Daubert v. Merrell Dow Pharmaceuticals, Inc.*, 509 U.S. 579, 594, 113 S. Ct. 2786, 125 L. Ed. 2d 469, 27 U.S.P.Q.2d 1200, Prod. Liab. Rep. (CCH) P 13494, 37 Fed. R. Evid. Serv. 1, 23 Envtl. L. Rep. 20979 (1993).

[20]Compare the work of experts in DNA identification. See §§ 31:1 et seq..

that all is well because no one looked at or thought about them.[21]

The following year, in 1976, Illinois had its first occasion to consider the admissibility of bitemark evidence. In *People v. Milone*, the Court of Appeals held it admissible as "a logical extension of the accepted principle that each person's dentition is unique."[22] The court based this on its earlier recognition of the identification of accident victims from their dental records. In this case, expert witnesses disagreed sharply on the question of the validity and utility of bitemark identifications. The testimony of three forensic dentists was offered by the prosecution and four by the defense. The defense experts testified and cited odontological literature showing, at the least, considerable disagreement among forensic odontologists as to whether offenders could be uniquely identified from bites left in the flesh of victims. Notwithstanding the controversy in the record and in the literature, the court found that the general acceptance standard had been met.[23] In contrast to the approach a court would be expected to take today under *Daubert*, the *Milone* court held that questions about the truth of the proposition quoted above—of immense variation and unique identifiability—went to the weight of the expert testimony, not to its admissibility.

By 1978, a California Court of Appeals flatly held that the testimony of three forensic odontologists established that bitemark identification had gained the required general acceptance in the relevant scientific community.[24]

Perhaps the most unusual legal development after *Marx* and before *Daubert* was a suit by the defendant who had been convicted in *People v. Milone*. Paroled after serving nearly twenty years in prison for murder, Milone continues to insist upon his innocence and continues to try to clear his name. In federal court, under both the *Frye* and *Daubert* standards, he has challenged the original decision to admit the expert bitemark testimony. Another murder victim was later found in the same area where the victim in the *Milone* case had been found. A potential bitemark from the second murder victim was linked to a suspect, Macek. The crime scene bitemarks in the two cases were judged by at least one forensic odontolo-

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[21]DNA evidence is the best example of a field providing the necessary data and probability calculations, and the chief exception to the rule that the evidence offered by the forensic identification sciences resembles the evidence offered in *People v. Collins*. Forensic odontologists appreciate that these data are needed, and have been developing them. See scientific status portion of this chapter, §§ 37:8 to 37:34.

[22]*People v. Milone*, 43 Ill. App. 3d 385, 2 Ill. Dec. 63, 356 N.E.2d 1350 (2d Dist. 1976).

[23]Incidentally, as a testament to the power of weak or inapt precedents, the court cited the Texas cases of *Doyle* (which had no data) and *Patterson* (which relied on *Doyle*), as well as California's *Marx* (which dealt with highly unusual dentition, in contrast to the apparently more common dentition of the present case).

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

gist to be indistinguishable from each other.[25] Macek signed but later withdrew a confession to having killed the victim for whose murder Milone had been convicted.[26] For present purposes, more important than the question of whether or not Macek killed both victims, is the suggestion that the relevant portions of dentition of two different suspects were indistinguishably alike.[27]

The Court of Appeals for the Seventh Circuit expressed sympathy with Milone's request, in light of the new evidence presented, but declined to rule on the case for want of a constitutional basis for granting relief, and because principles of federalism precluded a federal court from reexamining an issue of fact that is reserved to the states.[28]

§ 37:6 The judicial response to expert testimony on bitemark identification—Cases after *Daubert*

In the post-Daubert era, two federal cases come within hailing distance of applying *Daubert* to bitemark identification. The first is *Burke v. Commonwealth*.[1] The plaintiff brought claims against the Commonwealth of Massachusetts alleging civil rights violations for his wrongful arrest and imprisonment, based importantly on a bitemark examination which identified him as the person whose bitemark was found on the body of a murder victim–apparently falsely, because he later was exonerated by DNA analysis. In the course of drafting recommended findings concerning the Commonwealth's motion to dismiss, the magistrate judge touched on the asserted weaknesses of bitemark identification. The magistrate judge never seemed to doubt the validity of this specie of expertise,[2] though the best the court can do to support it is to cite cases that cite cases that express the same credulousness.

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[25]The forensic odontologist, later President of the American Academy of Forensic Sciences, had been a defense expert in the *Milone* case and wrote about these cases in, Lowell Levine, Forensic Dentistry: Our Most Controversial Case, in 1978 Legal Medicine Annual (Cyril Wecht, ed.).

[26]Discussed in *State v. Sager*, 600 S.W.2d 541 (Mo. Ct. App. W.D. 1980).

[27]Such findings are not unique in the identification sciences. In the present case, however, it might be noted that the comparison was not made using standard methods or procedures because of the full mouth extractions by Macek. The comparisons of the injury to x-rays of pre-extracted teeth hold little similarity to standard comparison procedures of overlaying biting edges onto the injury patterns on the skin.

[28]*Milone v. Camp*, 22 F.3d 693 (7th Cir. 1994).

[Section 37:6]

[1]*Burke v. Town of Walpole*, 2004 WL 502617 (D. Mass. 2004), aff'd in part, vacated in part, 405 F.3d 66 (1st Cir. 2005).

[2]Even after the DNA exoneration, the court seems to place inordinate confidence not only in the soundness of bitemark identification generally but even in the false positive identification in the underlying case: "As of the present time, Dr. Levine remains of the opinion to a reasonable degree of scientific certainty that the bite mark on the breast of Ms. Kennedy matched the dentition of the plaintiff. And plaintiff has proffered no meaningful evidence to the contrary, putting to one side the mere ipse dixit of counsel for plaintiff [footnotes omitted].

In *Ege v. Yukins*,[3] in the context of a petition for habeas corpus relief, the district court found the admission of bitemark expert opinion at the original trial to be so "unreliable and grossly misleading"[4] as to constitute a fundamental denial of due process.[5] The defendant was charged with and convicted of murder nine years after the underlying crime and had served more than ten years of a life sentence by the time the federal court granted her habeas petition.

At the original trial the defendant had been convicted on the strength of evidence that she harbored considerable animus toward the victim combined with the testimony of a forensic dentist who opined that a mark on the cheek of the victim, visible in a photograph of the corpse, was a human bitemark and that the mark matched the dentition of the defendant and not that of other likely suspects. The odontologist went on the state that out of the 3.5 million people residing in the Detroit metropolitan area, the defendant was the only one whose dentition could match the asserted bitemark on the victim's cheek.

The petitioner argued that the bitemark testimony was improperly admitted because it lacked scientific foundation as well as that the statistical probability given had had an exaggerated impact on the jury. The court ruled that "there is no question that the evidence in the case was unreliable and not worthy of consideration by a jury."[6] The court's conclusion could hardly be more clear. But its reasoning, or at least its persuasiveness, is less so.

The judge's conclusions about the weakness of the bitemark testimony do not go to fundamental weaknesses of bitemark comparison, apparently argued by the petitioner and discussed later in this chapter.[7] Rather, the court's misgivings come from three other matters. One is that the comparison was made with a photograph of the wound.[8] The court says almost nothing about this. What about the photograph or its use differs from the most accepted or best comparison methods? The court does not

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[3]*Ege v. Yukins*, 380 F. Supp. 2d 852 (E.D. Mich. 2005), aff'd in part, rev'd in part on other grounds, 485 F.3d 364 (6th Cir. 2007).

[4]*Ege v. Yukins*, 380 F. Supp. 2d 852, 880 (E.D. Mich. 2005), aff'd in part, rev'd in part on other grounds, 485 F.3d 364 (6th Cir. 2007).

[5]"The evidence was 'so extremely unfair that its admission violates fundamental concepts of justice.' " *Ege v. Yukins*, 380 F. Supp. 2d 852, 880 (E.D. Mich. 2005), aff'd in part, rev'd in part on other grounds, 485 F.3d 364 (6th Cir. 2007). Moreover, the trial attorney's failure to challenge the admission constituted ineffective assistance of counsel: "The flaw in Dr. Warnick's statistical opinion should have been obvious and its admissibility readily assailable." *Ege v. Yukins*, 380 F. Supp. 2d 852, 876 (E.D. Mich. 2005), aff'd in part, rev'd in part on other grounds, 485 F.3d 364 (6th Cir. 2007).

[6]*Ege v. Yukins*, 380 F. Supp. 2d 852, 871 (E.D. Mich. 2005), aff'd in part, rev'd in part on other grounds, 485 F.3d 364 (6th Cir. 2007).

[7]See Part II.

[8]"The use of a photograph of the wound to make the comparison appears to be novel." *Ege v. Yukins*, 380 F. Supp. 2d 852, 876 (E.D. Mich. 2005), aff'd in part, rev'd in part on other grounds, 485 F.3d 364 (6th Cir. 2007).

say.

A second factor concerning the court was its perception that this particular expert witness was singularly incompetent: "Dr. Warnick thoroughly has been cast into disrepute as an expert witness and several convictions based on his testimony have been undermined and overturned."[9] Since cases occurring only recently were the basis for that conclusion it is, of course, not something that could have been obvious at trial a decade earlier. The court does not appear to know whether Dr. Warnick was doing his examinations differently or with less skill than other forensic dentists, or whether his work was no different from theirs but he merely had the bad luck of having a cluster of his cases overturned instead of just an occasional one. Thus, this case, too, assumes the general soundness of the methods of bitemark comparison, but finds fault in the particular individual performing the comparisons.

The final flaw found by the court was that Dr. Warnick expressed his opinion in terms of a probability value. The court goes on at some length, discussing and citing numerous cases that raise doubts about inferences based on probability estimates. What the court fails to realize is that all of forensic odonotolgy (and all of forensic identification) rely on these very same notions to reach all of their conclusions of identity. The only difference seems to be that Dr. Warnick expressed his conclusion by uttering a number while his brethren typically do so by asserting in words that dentition is unique among all humans, that the defendant's dentition matches the bitemark, and therefore (explicitly stated or implied) the defendant is the only person on earth whose dentition matches the bitemark on the victim. Why is that less objectionable than Dr. Warnick's testimony? If anything, Dr. Warnick was more reserved than the typical witness. The only explanation can be that Dr. Warnick uttered a number. Do we know that extreme probabilities given in words are less misleading to factfinders than are less extreme probabilities expressed in numbers?

By attacking this particular witness and his particular testimony with such vigor, the court prevented *the field's* more general shortcomings from coming under scrutiny.

A number of state courts have evaluated proffers of bitemark expert testimony in the wake of *Daubert*, producing some interesting opinions.

Garrison v. State[10] notes that the trial court below did not permit the testifying forensic dentist to opine on whether the victim was the source of an apparent bitemark on the defendant because Oklahoma case law had excluded such opinions by bitemark experts as failing to meet the requirements of Oklahoma's *Daubert* decision. That precedent excluding

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[9]*Ege v. Yukins*, 380 F. Supp. 2d 852, 857 (E.D. Mich. 2005), aff'd in part, rev'd in part on other grounds, 485 F.3d 364 (6th Cir. 2007).

[10]*Garrison v. State*, 2004 OK CR 35, 103 P.3d 590 (Okla. Crim. App. 2004).

individualizing bitemark expert testimony, oddly enough, is an unpublished opinion.[11] The lower court had only allowed the expert to opine that the wound was a "probable bite-mark," the admission of which was upheld. The court does not explain the basis for that expertise under *Daubert*, and does not seem aware of studies suggesting that even this skill is an elusive one.

The bitemark evidence in *State v. Hodgson*[12] consisted of apparent teeth marks in a suspect's arm, which a forensic dentist compared to known molds of the dentition of a murder victim. The dentist testified to "several similarities" between the bitemark on the defendant and the victim's teeth. Defense counsel objected to a question calling for the odontologist's opinion as to whether the bitemark and the victim's teeth matched, and the witness did not state her opinion.

On appeal, the defendant challenged the admission of the bitemark expert evidence on the grounds that it was not generally accepted, and therefore should not have been admitted under Minnesota's version of the *Frye* test, *State v. Schwartz*.[13] On the question of the admissibility of bitemark expert testimony, the Minnesota Supreme Court concluded as follows:

> We note that recently the United States Supreme Court, in *Daubert v. Merrell Dow Pharmaceuticals, Inc.*, held that the Rules of Evidence supersede the *Frye* or general acceptance test for the admission of novel scientific evidence. We need not address the issue of what impact *Daubert* should or will have in Minnesota. Suffice it to say, we are satisfied that basic bitemark analysis by a recognized expert is not a novel or emerging type of scientific evidence.[14]

Thus, the court disposed of the issue simply by holding that bitemark expert evidence was not novel.

Similarly, on appeal of the trial court's refusal to conduct a *Davis-Frye* hearing on the admissibility of bite mark expert testimony, the appellate court in *People v. Quaderer*[15] held that such an inquiry is required only when a party seeks to introduce a new scientific principle or technique. The appellate court went on, however, to find that bite mark analysis has gained general acceptance in the relevant scientific community, a conclu-

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[11]*Crider v. State, F-1999-1422 (Oct.11, 2001)*.

[12]*State v. Hodgson*, 512 N.W.2d 95 (Minn. 1994).

[13]*State v. Schwartz*, 447 N.W.2d 422 (Minn. 1989).

[14]*State v. Hodgson*, 512 N.W.2d 95, 98 (Minn. 1994), citing C. Herasimchuk, A Practical Guide to the Admissibility of Novel Expert Evidence in Criminal Trials Under Federal Rule 702, 22 St. Mary's L.J. 181, 210–11 and n. 122 (1990) and Annot., Admissibility of evidence tending to identify accused by his own bite marks, 77 A.L.R.3d 1122 (superseded by Admissibility and Sufficiency of Bite Mark Evidence as Basis for Identification of Accused, 1 A.L.R.6th 657). for the proposition that bitemark expert testimony is no longer novel.

[15]*People v. Quaderer*, 2003 WL 22801204 (Mich. Ct. App. 2003).

sion based on the conclusions of another Michigan case.[16]

Whether non-novel evidence ever was insulated from fresh scrutiny under *Frye*-type tests once the issue of the evidence's unreliability, or its unproven reliability, was raised, has always been doubtful, but it certainly is not supported by any apparent logic. Why should non-novelty, by itself, shelter from reexamination erroneous scientific claims that have lost the support of the field or fields from whence they came? Under any test, the more coherent view is that novelty should serve not as a prerequisite for judicial scrutiny, but as a hair trigger for it. *Daubert* itself had this to say on the role of non-novelty:

> [W]e do not read the requirements of Rule 702 to apply specially or exclusively to unconventional evidence. Of course, well-established propositions are less likely to be challenged than those that are novel, and they are more handily defended.[17]

Though Wyoming is a *Daubert* state, a challenge to bitemark expert evidence received no more consideration there than it had in Minnesota. The defendant in *Seivewright v. State*[18] had been convicted of a burglary during which the burglar had taken a bite out of a block of cheese. At trial an orthodontist who had made an impression of the cheese and of the defendant's teeth testified that the defendant had bitten the cheese. The trial court did not hold a hearing to consider the challenge to bitemark expertise. On appeal, the Wyoming Supreme Court cited *Daubert*, *Joiner*[19] and *Kumho Tire*,[20] but did not conclude that an evidentiary hearing is required to hear a challenge to forensic bitemark evidence. Apparently it was enough to cite a number of cases in which such testimony had been admitted. On the other hand, the Court reversed the conviction because the prosecution had not provided a copy of the expert's curriculum vita or his report.

This case reflects two ironies. One, *Daubert* seems to have been adopted in Wyoming in name but not in spirit or practice. Rather than supporting inquiry into the empirical and theoretical underpinnings of bitemark opinions, both the trial and Supreme Court were content to deny a hearing and look to cases of admission in other courts as the basis for gatekeeping. Second, while the failure of the government to provide information on the

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[16]*People v. Marsh*, 177 Mich. App. 161, 441 N.W.2d 33 (1989).

[17]*Daubert v. Merrell Dow Pharmaceuticals, Inc.*, 509 U.S. 579, 593 n.11, 113 S. Ct. 2786, 125 L. Ed. 2d 469, 27 U.S.P.Q.2d 1200, Prod. Liab. Rep. (CCH) P 13494, 37 Fed. R. Evid. Serv. 1, 23 Envtl. L. Rep. 20979 (1993).

[18]*Seivewright v. State*, 7 P.3d 24 (Wyo. 2000).

[19]*General Elec. Co. v. Joiner*, 522 U.S. 136, 118 S. Ct. 512, 139 L. Ed. 2d 508, 18 O.S.H. Cas. (BNA) 1097, Prod. Liab. Rep. (CCH) P 15120, 48 Fed. R. Evid. Serv. 1, 28 Envtl. L. Rep. 20227, 177 A.L.R. Fed. 667 (1997).

[20]*Kumho Tire Co., Ltd. v. Carmichael*, 526 U.S. 137, 119 S. Ct. 1167, 143 L. Ed. 2d 238, 50 U.S.P.Q.2d 1177, Prod. Liab. Rep. (CCH) P 15470, 50 Fed. R. Evid. Serv. 1373, 29 Envtl. L. Rep. 20638 (1999).

expert's background and the report of his findings were sufficient for reversal, it is hard to imagine that anything in either the vita or the report could have led to the exclusion of the expert's opinion. That is to say, if the heart and soul of the expertise are of no interest or consequence, why would the details of the dentist who reached the opinion, or how he reached the opinion, make any difference?[21]

Mississippi has decided a pair of bitemark cases that are difficult to reconcile with each other or with Mississippi case law on admissibility. Mississippi is not, as of this writing, a *Daubert* state, and asserts that it follows *Frye*,[22] though it is not evident from its bitemark cases that general acceptance was a criterion the Court attended to. Despite its avowed lack of allegiance to *Daubert*, in *Howard v. State*[23] the Mississippi Supreme Court seemed inclined to critically evaluate, rather than blindly accept, the assertions of forensic odontologists concerning the scientific validity and evidentiary reliability of their field's conclusions. The Court wrote:

> This Court has never ruled directly on the admissibility or reliability of bitemark identification evidence, though it has addressed cases in which bitemark evidence was an issue. [Citation omitted.] While few courts have refused to allow some form of bite-mark comparison evidence, numerous scholarly authorities have criticized the reliability of this method of identifying a suspect. [Citation omitted.] It is much easier to exclude a suspect through such comparison than to positively identify a suspect. [Citations omitted.]
>
> There is little consensus in the scientific community on the number of points which must match before any positive identification can be announced. [Citation omitted.] Because the opinions concerning the methods of comparison employed in a particular case may differ, it is certainly open to defense counsel to attack the qualifications of the expert, the methods and data used to compare the bitemarks to persons other than the defendant, and the factual and logical bases of the expert's opinions. Also, where such expert testimony is allowed by the trial court, it should be open to the defendant to present evidence challenging the reliability of the field of bite-mark comparisons. [Citation omitted.] Only then will the jury be able to give the proper weight, if any, to this evidence.

Howard's initial capital murder conviction was reversed. Following retrial, he was again convicted and again sentenced to death. On the appeal of *Howard II*, the Mississippi Supreme Court again considered a challenge to the admissibility of bitemark identification expert evidence.[24] On this most recent occasion to opine on the admissibility of bitemark evi-

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[21]Indeed, one member of the Supreme Court dissented that the errors on which the reversal was based were harmless errors.

[22]See *Kansas City Southern Ry. Co., Inc. v. Johnson*, 798 So. 2d 374 (Miss. 2001), and cases cited therein.

[23]*Howard v. State*, 701 So. 2d 274 (Miss. 1997).

[24]*Howard v. State*, 853 So. 2d 781 (Miss. 2003). A dissent in the case pointed to a paucity of testing of the claims, lack of independent confirmation of the technique, the highly subjective nature of the technique, contested general acceptance in the scientific community, and it expressed doubts

dence, the Court held without explanation that such testimony "was admissible, and the trial court did not abuse its discretion in so holding" though of course "subject to challenges to weight and credibility." Without explanation, the Court had moved from its apparent awareness in *Howard I* of weaknesses and controversy in the bitemark field, to unhesitating admission in *Howard II*. At no point has any published judicial opinion in Mississippi canvassed the actual scientific data bearing on the issues raised, and explained how the proper resolution was admission. It should be said, though, that, judging from the opinion in *Howard II*, the challenge was rather lame, limited to offering legal arguments and not raising the empirical issues.[25]

In *Brooks v. State*,[26] a trial court admitted bitemark identification expert testimony and the Mississippi Supreme Court affirmed, holding that such evidence was now admissible. The majority opinion contained not the slightest review of the science (so it was not taking the *Daubert* approach), but it also did not look to the status of bitemark individualization among forensic odontologists. The opinion does little more than to announce that bitemark expert testimony is admissible because the Court says so.[27] The only reasoning behind the decision appears to be that the defense is free to cross-examine and offer rebuttal witnesses. This would appear to be no gatekeeping of any kind: everything is admissible so long as the defense is afforded the opportunity to attack the weight of the opinion during trial. Ironically and paradoxically, a concurrence implies that the opinion is consistent with *Daubert* and its progeny:

> The majority view is correct and long overdue. The U.S. Supreme Court recent decisions [citing *Kumho Tire*, *General Elec. Co. v. Joiner*, and *Daubert*] stress that the federal district courts must be gatekeepers on the admission of expert testimony. I am confident that our learned trial judges will properly determine, on a case-by-case basis, whether an expert may testify to certain matters if the proper procedures are followed by the parties seeking the admission of such expert's testimony.[28]

Like the main opinion, the concurrence is silent on the criteria for all of that confidence and correct gatekeeping, and does not venture to demon-

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about the statistical probability data claims. These considerations led the dissent to conclude that bite mark comparison is "junk science." The dissent also noted that in this particular case the defendant was wearing a partial denture which likely was mass-produced (implying that the forensic dentist might have mistook class characteristics as individual features), and that the victim's body had deteriorated for five days before the bite mark was examined (implying changes on the questioned bitemark). Finally, the dissent questioned the particular expert in the case, Michael West. See comments concerning Dr. West, infra this section. (*Howard v. State*, 853 So. 2d 781 (Miss. 2003) (McRae, J., dissenting.).

[25]Which are explored in this chapter.

[26]*Brooks v. State*, 748 So. 2d 736 (Miss. 1999).

[27]"We now take the opportunity to state affirmatively that bite-mark identification evidence is admissible in Mississippi." *Brooks v. State*, 748 So. 2d 736, 739 (Miss. 1999).

[28]*Brooks v. State*, 748 So. 2d 736, 747 (Miss. 1999).

strate any of it.

A dissenting opinion by one justice noted that many questions still surround bitemark identification opinions[29] and, in this instance, the expert who testified for the state.[30]

Louisiana is a *Daubert* state. In *State v. Wommack*[31] a defendant was convicted of attempted murder and burglary, and the Court of Appeals affirmed. Some of the evidence against the defendant consisted of a bitemark: the victim had bitten her assailant. At trial two experts testified concerning the bitemark on the defendant, an oral-maxillofacial surgeon and a forensic pathologist. They both testified that marks on the defendant's arm came from a human bite, but they did not link the marks specifically to the victim, and they acknowledged the possibility of error and uncertainty in their opinions. On appeal the defendant challenged the experts who testified about the bitemark. The Court of Appeals held that "the *Daubert* standards do not appear to be readily applicable to the present case. Neither expert used complex testing in identifying the wound found on [the defendant's] arm . . . . Expert opinion testimony based upon personal observation and experience is admissible." Here, then, is a

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[29]"1. The timing of the bite mark injury; 2. Enhancement procedures and techniques (note that in this case, West testified that he used ultraviolet light to enhance the wound enabling him to find "several unique marks" that corresponded to the flaws on the back side of Brooks's teeth; this technique is what allowed West to be positive that only Brooks could have made the two indentations); 3. The type of material for test bites or the accuracy of test bites under various mockup conditions; 4. The pressure necessary to produce the various levels of tissue injury under normal and unusual circumstances has not been reliably measured; 5. Manipulation of various types of distortion to produce correction; 6. The problem faced by forensic dentists today is not necessarily one of matching the bite mark to a set of teeth. It is demonstrating whether another set of teeth could have produced the same or similar mark; 7. There is not universal agreement on which injuries are bite mark related; 8. Research on the minimum number of points of concordance or the minimum number of teeth marks needed in a bite mark for certainty is not as well established as the uniqueness of the dentition." *Brooks v. State*, 748 So. 2d 736, 748 (Miss. 1999).

[30]Michael West is infamous in forensic dentistry and the courts for asserting conclusions that go well beyond what the data allow, with a confidence unsupported by the data (West is notorious for emphasizing to juries that his conclusions are "indeed and without doubt"), inventing his own unverified technique (which he termed the "West Effect"), and misrepresenting evidence and data to bolster his testimony. For his accumulated misdeeds he has been professionally punished by the American Academy of Forensic Sciences, the American Board of Forensic Odontology, and the International Association for Identification. See *Brooks v. State*, 748 So. 2d 736, 748–750 (Miss. 1999). Some may find the most remarkable things about this to be that with such a record there still are prosecutors who will hire him (owing either to ethical or tactical concerns), defense attorneys who cannot have him declared unqualified, or juries that believe him.

In a civil suit against West for damages in another case in which his fallacious testimony led to an erroneous conviction, a federal court denied West's motion to dismiss. *Keko v. Hingle*, 1999 WL 155945 (E.D. La. 1999), aff'd, 207 F.3d 658 (5th Cir. 2000).

[31]*State v. Wommack*, 770 So. 2d 365 (La. Ct. App. 3d Cir. 2000), writ denied, 797 So. 2d 62 (La. 2001).

court—a year after the Supreme Court held in *Kumho Tire* that all expert evidence, regardless of how it is labeled or characterized, must pass a test suitably calculated to evaluate its validity—which believes that only "complex testing" but not "personal observation and experience" are subject to scrutiny, and that the latter are ipso facto admissible.

The Indiana Supreme Court, in *Carter v. State*,[32] states that, although in interpreting Indiana evidence rules it is not required to follow the United State Supreme Court's interpretation of the same or similar rules (in *Daubert* and *Kumho Tire*), Indiana had "coincidentally announced an analytical framework for Indiana procedure akin to the federal analysis declared shortly thereafter in *Daubert*."[33] Nevertheless, *Carter* held bite mark expert testimony admissible without examining the empirical data on which such a conclusion presumably must be based. Instead, the Court noted that in 1977 it had found "no reason why [bite mark] evidence should be rejected as unreliable . . .."[34] "when bite mark evidence was a relatively new procedure," and in the present case nothing had been presented to it suggesting "that it has become less reliable." All of this language seems to suggest, incorrectly, that the burden of proof is on the opponent of the evidence. More important, perhaps, as detailed in the chapter sections below, between the mid 1970s and today, a paucity of research has been replaced by a limited body of research—earlier assumptions of accuracy have been replaced by data suggesting that moderate to high error rates are typical. These are troubling developments that require the thoughtful attention of courts.

Even at this somewhat late date and with a field that does not stand on very solid ground, some lawyers still grasp at peripheral and legalistic straws rather than inquiring into the core of the expertise. Yet these peripheral attacks sometimes are not without some effect.

In *Calhoun v. State*,[35] the defendant's objection to the bite mark evidence was that the molds and photographs used for comparison were not properly marked. The court, however, held that this objection went to the weight the evidence should be given, not its admissibility.

The defendant in *State v. Swinton*,[36] made two claims about improper admission of evidence. First, the defendant contended that the trial court improperly admitted into evidence computer enhanced photographs of the bite marks without an adequate foundation. Second, the defense argued that exhibits produced using Adobe Photoshop, which showed superimposed images of the defendant's dentition over the photographs of the bite

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[32]*Carter v. State*, 766 N.E.2d 377 (Ind. 2002).

[33]Citing *McGrew v. State*, 682 N.E.2d 1289 (Ind. 1997) and *Steward v. State*, 652 N.E.2d 490 (Ind. 1995).

[34]*Niehaus v. State*, 265 Ind. 655, 359 N.E.2d 513, 516 (1977).

[35]*Calhoun v. State*, 932 So. 2d 923 (Ala. Crim. App. 2005), cert. denied, 548 U.S. 926, 126 S. Ct. 2984, 165 L. Ed. 2d 990 (2006).

[36]*State v. Swinton*, 268 Conn. 781, 847 A.2d 921 (2004).

marks, were improperly admitted. In this instance, the expert could not testify as to whether the process used was accepted in the field, whether proper procedures were followed and whether the program used was reliable. As the expert himself did not create the overlays, the court was also concerned that the effectiveness of cross-examination was seriously undermined. The court therefore found that this evidence was improperly admitted, but the error was deemed harmless.

§ 37:7 Erroneous identification and conviction

DNA typing has exposed numerous errors in the conclusions of bitemark experts. Recognition of these errors might serve, along with the error data cited in Part II of this chapter, as cautionary lessons to forensic dentists regarding the state of their art and to courts regarding the value of bitemark identification expert evidence.

In *Mississippi v. Bourne*,[1] a forensic odontologist stated that the defendant's teeth matched the bitemarks on the crime victim, but the defendant was excluded by DNA testing, hair analysis and fingerprint analysis.

After the forensic odontologist in *Mississippi v. Gates*[2] concluded that the defendant's teeth matched bitemarks on the victim, the defendant was eliminated as a suspect from investigation by DNA typing.

In *Florida v. Morris*,[3] prosecutors had first degree murder charges dismissed after the defense odontologists disagreed with the conclusion of the state's experts that a bitemark on the victim matched the defendant's dentition and subsequent DNA results also excluded the defendant.

A forensic odontologist testified at a "preliminary examination" that Otero[4] was "the only person in the world" who could have inflicted the bitemarks at issue. After spending five months in jail awaiting trial, the State dismissed the charges after a newly available DNA test excluded Otero as the source of DNA found on the victim.

Otero, a suspect in Michigan arrested based on a bitemark identification

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[Section 37:7]

[1]*Mississippi v. Bourne*, No. 93-10,214(3) (Cir. Ct., Jackson County, Mississippi).

[2]*Mississippi v. Gates*, No. 5060 (Humphrey Cty. Cir. Ct. 1998).

[3]*Florida v. Dale Morris (Pasco County, 97-3251 CFAES, 1997)*. See also, Dentist Defends His Advice in Slaying, Tampa Tribune (3/3/98), 1998 WLNR 692526 (dentist matched defendant's teeth to alleged bite on 9-year-old neighbor; "Although renowned Miami forensic odontologist Richard Souviron supported Martin's finding [of a match], they were disputed by two defense-hired experts: Phil Levine of Pensacola and Lowell Levine of Albany, N.Y."); Two Forensic Dentists Added to Wrongful Arrest Lawsuit, (St. Petersburg Times, Dec. 24, 1999).

[4]*Otero v. Warnick*, 241 Mich. App. 143, 614 N.W.2d 177 (2000).

sued for false arrest after DNA tests excluded him.[5]

Twelve years after being convicted based on testimony from a forensic odontologist linking Young to a bitemark on the victim, prosecutors agreed to a new trial and dropped all charges after DNA testing excluded Young. A codefendant, Hill, was also released in a separate proceeding.[6]

More than a decade after Brewer's conviction and death sentence, DNA obtained from the decomposed victim indicated two male sexual assault perpetrators. Brewer was not the contributor of either DNA profile. The only remaining forensic evidence against Brewer was bitemark testimony that the District Attorney thought sufficient to try Brewer a second time.[7]

Raymond Milton Krone has become known as the 100th innocent person to be sentenced to death and later exonerated.[8] Krone was convicted of murder in 1992 and sentenced to death by lethal injection. After 32 months on death row, the Arizona Supreme Court overturned his conviction due to the government's failure to disclose to the defense a crucial bitemark videotape of the asserted dental match that was to be used at trial.[9] At his retrial, Krone was convicted again of murder, and this time sentenced to life in prison. After 10 years in prison in Arizona, in the spring of 2002 Krone was determined through DNA testing to be innocent of the crime and released (with the prosecution's blessings and apologies). Post-conviction DNA testing revealed that blood and saliva which almost certainly were left at the crime scene by the real killer belonged not to Krone but to another man, Kenneth Phillips, who already was in prison in Arizona for committing another sex crime, and who lived about 600 yards from the scene of the murder for which Krone had been convicted.

The strongest evidence against Krone at both trials had been bitemark identification testimony which asserted that bitemarks on the victim had

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[5]*Otero v. Warnick*, 241 Mich. App. 143, 614 N.W.2d 177 (2000).

[6]Twelve Years Behind Bars, Now Justice at Last (Chicago Tribune, Feb. 1, 2005).

[7]*Brewer v. State*, 725 So. 2d 106 (Miss. 1998) and *Brewer v. State*, 819 So. 2d 1169 (Miss. 2002).

[8]Not all of the exonerations of death row inmates have been the result of DNA typing. Krone is one of 12 who were.

The facts recited are taken from the extensive news accounts of the case. See, e.g., Henry Weinstein, Death Penalty Foes Mark a Milestone: Crime: Arizona Convict Freed on DNA Tests is Said to be the 100th Known Condemned U.S. Prisoner to be Exonerated since Executions Resumed, Los Angeles Times, April 10, 2002, at A16; Teresa Ann Boeckel, A Measure of Justice: He Knew it Was Wrong: The Man Who Sat in Judgment on Ray Krone Disagreed with Jurors, But Felt Obliged to Let Their Ruling Stand, York Daily Record, April 13, 2002, A01; Teresa Ann Boeckel & Laura Laughlin, DNA Frees Former Death-Row Inmate: Two Juries Found Him Guilty, But New DNA Evidence Persuaded Prosecutors to Seek His Release, York Daily Record, April 9, 2002, at A01; Amanda J. Halligan, Lethal Injustice: Freeing the 100th Innocent Death Row Prisoner, Amnesty Now, Summer, 2002, at 4.

[9]*State v. Krone*, 182 Ariz. 319, 897 P.2d 621 (1995).

been put there by Krone.[10] Judging from interviews with jurors, the forensic odontology expert testimony had a powerful impact.

> Those bitemarks on [the victim's] body had been the key to the prosecution's case against Krone. Janet Olmstead, a juror in the second trial in 1996, said forensic dentistry was what primarily convinced the jury of Krone's guilt. Although she is "delighted" that Krone is now free and that advances in DNA testing have made that possible, she believes the jury made the right decision with the information available at the time.
>
> "We had several molds of his teeth. It was pretty awful. You could roll these teeth around and they were a perfect match. The whole pattern of his teeth were significant with the match to the injury," she said.[11]

At the time of the original trial, a decade ago, little if any empirical evidence on the error rates of bitemark identification existed. That being the case, and given that the proponent of evidence has the burden of establishing its validity, one can question why the evidence was offered or admitted in the first place. Today, the government in offering such evidence, or a court in passing on its admissibility, can advert to the only body of data testing the accuracy of bitemark identifications, which shows remarkably high false positive error rates by even the most highly qualified forensic dentists.[12] Thus, it should be harder today for a proponent of bitemark identification testimony to ethically offer it or, if offering it, to succeed in having it admitted. Were the courts to enforce *Daubert*'s admissibility standards, in light of the known high error rates, one would expect to see bitemark expert testimony admitted less often or not be admitted at all.

Arizona, however, is a *Frye* state, and bitemark evidence might be admitted as readily today as it was a decade ago, notwithstanding the error rate data, provided that a sufficient number of forensic dentists disregard their field's error rate data and satisfy a court's notions of what constitutes general acceptance among the field of forensic dentists.[13]

II. SCIENTIFIC ISSUES

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[10]The State's bitemark experts in both trials were Drs. Raymond Rawson and John Piakis.

[11]Amanda J. Halligan, Lethal Injustice: Freeing the 100th Innocent Death Row Prisoner, Amnesty Now, Summer, 2002, at 4. Dentist Piakis, who testified in the second trial that Krone's teeth matched the bitemark on the victim's breast, now says that "Phillips' dentition is more consistent with those bite marks on the victim's body than is Krone's."

[12]See, infra Table 2.

[13]James McDougall, one of the judges who presided over one of Krone's trials is reported as expressing deep regret at the error, saying that he had doubts about the quality of the evidence presented at the trial, but that "It's not easy to tell a jury you think they're wrong." Another question to be asked is whether the judge's decision to admit the dental testimony rested on a sound basis.

*by C. Michael Bowers**

§ 37:8 Introductory discussion of the scientific status of bitemark comparisons

The definition and breadth of forensic odontology has evolved over the centuries and now includes identification by means of dental DNA and salivary DNA.[1] "Odontology" is well established in the European dental language where it means the "study of teeth." The United States counterpart, "Forensic dentistry," is synonymous.

The initial United States historical case that utilized dental information occurred during the Revolutionary War period. Paul Revere recognized a prosthetic gold device he had previously constructed for a deceased patriot, General Joseph Warren, an American military casualty from the Bunker Hill engagement.[2] The primary duties of dentists in the medico-legal arena are to help identify the dead, apply dental facts and reliable methods to legal problems regarding identification from bitemarks, and, finally, interpretation of quality issues concerning the practice of dentistry. Dental identification of unknown persons relies on the similarities of anatomical and artificial structures (tooth restorations) and is achieved during a comparison process that focuses on shape and measured physical characteristics. Bitemark identification is a relatively recent arrival on the dental-legal scene.[3] Its inception was promoted by judicial interest in physical evidence left at crime scenes and bitemarks present on the skin of assault and homicide victims.

The materials used by forensic dentists to capture impressions of bitemarks and teeth are products accepted by the American Dental Association for the general practice of dentistry. Manufacturers stringently maintain the stability and physical duplication accuracy of these products. Dental science has progressed tremendously in the latter 20th century in its ability to create exemplars and replicas of dental structures that are used for later comparison analysis. This replication process uses materials commonly seen in dental offices.

Dental evidence collected in a bitemark case falls into two categories: (1)

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*Dr. Bowers practices dentistry and law in Ventura, CA. He has been a Deputy Medical Examiner for the Ventura County Coroner's Office since 1988. He is a diplomate of the American Board of Forensic Odontology. The author would like to thank the following for their contributions to this chapter: Iain A. Pretty (University of Liverpool, School of Dentistry), Mary Bush and Peter Bush (SUNY, Buffalo), Dr. Duane Spencer (Diplomate of the ABFO), David Averill (Diplomate of the ABFO), Gary Bell (Diplomate of the ABFO).

[Section 37:8]

[1]Sweet et al., PCR-based DNA Typing of Saliva Stains Recovered from Human Skin, 42 J. Forensic Sci. 320 (1997).

[2]Lester Luntz & Phyllys Luntz, Handbook for Dental Identification (1973).

[3]*Doyle v. State*, 159 Tex. Crim. 310, 263 S.W.2d 779 (1954).

physical evidence that is a concert of photography and dental impression materials; and (2) biological evidence that is derived from serological swabbing of bitemarks on skin and objects that could have trace saliva DNA deposited by the biter.[4] Subsequent analysis of the latter is the realm of the biomolecular expert, while the former is the traditional bitemark venue of forensic dentists. Forensic dentists traditionally make the following postulates: the dental characteristics of teeth involved in biting are unique among individuals and this asserted uniqueness is faithfully transferred and recorded in the injury. Because these postulates and their dental science foundations constitute the field's most controversial scientific predicates, discussion of them will form a large part of this chapter.

§ 37:9 Introductory discussion of the scientific status of bitemark comparisons—Areas of dental testimony

Forensic dentists testify in court regarding medical evidence involving teeth. This involves areas of both criminal and civil law, when dental testimony might help answer a question that is at issue in the proceedings.

The predominant subject matter in criminal cases includes bitemark analysis, the identification of human remains and the dental aging of known individuals. The latter two are well founded in traditional dental and anthropological science. These use methods derived from studies of developmental dental biology and individuating characteristics of the cranial skeleton, dental structures, and dental restorations.

Human identification testimony has been utilized in the United States since the 1800s.[1] This identification of unidentified persons from their dental characteristics is the primary duty of forensic dentists. In mass disaster incidents, dentists can be expected to identify 20–25% of the victims. This is performed with a considerable degree of accuracy, due, in part, to a finite pool of candidates for identification (passenger lists) and the availability of dental records for comparison. This process emphasizes the comparison of postmortem victims to dental restorations placed during a person's life and certain anatomical structures that had been recorded in the course of radiographic examinations by medical and dental practitioners. Occasionally, old photographs showing unusually positioned front teeth may be superimposed onto postmortem images of a decedent's teeth. The forensic dentist conducts a postmortem dental examination to establish physical findings of a decedent in much the same way as with a living patient, and then compares dental records derived from investiga-

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[4]The effect of salivary DNA on bitemark investigations will be discussed, §§ 37:27, 37:28.

[Section 37:9]

[1]Lester Luntz & Phyllys Luntz, Handbook for Dental Identification at 5–15 (1973) (narration of the 1850 Massachusetts homicide trial against John White Webster; a charred skull and denture fragments taken from the cellar of the defendant were identified by the first dean of the Harvard Dental School as those of the victim, Dr. George Parkman.)

tive efforts and missing person reports.

Bitemark analysis is a product of the latter half of the 20th century. The small number of dentists in early court bitemark proceedings has increased substantially over the last twenty-five years. This is due, in part, to (1) the acceptance by the forensic odontological community of the notion that questions of reliability of methods and opinions are satisfied by their years of experience, their credentials, anecdotal reporting, and, in a display of circular logic, (2) the fact that the judiciary has allowed them to offer their opinions in trials.[2]

The physical evidence available in a bitemark case is considerably less than in dental identification. The vast array of potential biters can be large due to the fragmentary and diffuse features seen in skin injuries. The likelihood of a coincidental match of a defendant's teeth to a bitemark injury has not been quantified.

The recognition and admissibility of the discipline of forensic odontology rests on a fragile foundation of minimally relevant empirical research and a mountain of casework articles and commentaries. The caselaw evinces little doubt on the part of judges that dentists can play a role in determining questions of fact relevant to identification in particular cases.

Of particular interest to readers may be § 37:14, which is intended to summarize the areas of bitemark inquiry and accumulated knowledge into various categories. This should aid the reader in determining how this material compares to the explicit reliability standards of the law announced in *Daubert* and *Kumho Tire*. Sections 37:23 to 37:26 describe recent technical efforts to improve the accuracy of bitemark opinions and the application of DNA analysis as it relates to this area of forensic investigation. § 37:13 will introduce data and interpretation regarding scientific reliability from a recent proficiency examination of dentists who have been certified by the American Board of Forensic Odontology.[3]

§ 37:10 Introductory discussion of the scientific status of bitemark comparisons—Training and professional forensic organizations

Unlike forensic pathologists, forensic dentistry is not a recognized specialty of dental practice. It may be best characterized as a subspecialty of the general field of forensic human identification. This is reflected by the lack of full time residency programs in the United States and the part-

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[2]Rawson & Brooks, Classification of Human Breast Morphology Important to Bitemark Investigation, 5 J. Forensic Sci. 19 (1984).

[3]Founded in 1976, this U.S. organization now has 113 dentists. Thirteen were grandfathered in as Diplomates. The ABFO provides a certification examination to applicants who have met qualifications of actual casework experience, participation in training seminars and presentations at the American Academy of Forensic Sciences (AAFS) meetings, and affiliations with medico-legal agencies.

time nature of forensic dental consultants. By contrast, colleges and universities in the United Kingdom, Europe and Australia have graduate training (Masters level) devoted entirely to forensic dentistry.

The typical forensic dental expert is either: (1) a practicing dentist; (2) retired from dental practice; or (3) a dental educator. The large majority of dental forensic specialists come from the first category.

Dentists have created their own forensic organizations and have joined others. The American Board of Forensic Odontology is recognized by the American Academy of Forensic Sciences (AAFS) which has an Odontology Section with a membership of over 250 dentists. The American Society of Forensic Odontology has a membership of over 900 and meets concurrently with the AAFS once a year.

The ABFO has created Guidelines and Standards for Human Identification and Bitemark Analysis. This compilation has produced some uniformity in the methods and terminology used by dentists. But it is silent regarding reliability of comparison methods and opinions,[1] as well as the scientific validity issues often raised in court concerning bitemark methods.[2]

The regulatory nature of the AAFS and the ABFO occasionally come into play when transgressing members are expelled or are otherwise sanctioned for departures from accepted practices or ethical violations.[3]

Training for dentists interested in pursuing forensic training has remained largely unchanged in recent years. The one U.S.-based program, at the University of Texas, San Antonio (UTSA) dental school, offers a fellowship course which is composed of on-site weekend training, take-home projects and a final exam testing the attendee's abilities. The fellowship has been met with enthusiasm but generally has only 4–6 students every two years.

The University of Montreal Institute of Legal Medicine has an online program that provides a certificate in forensic odontology. The program

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[Section 37:10]

[1]Sweet & Bowers, Accuracy of Bitemark Overlays: A Comparison of Five Common Methods to Produce Exemplars from a Suspect's Dentition, 43 J. Forensic Sci. 362 (1998). This computer evaluation of four techniques produced recommendations to: (1) eliminate hand drawing of a suspect's teeth; and (2) use digital images of dental characteristics. These images are placed (after flipping horizontally) onto a picture of a bitemark in order to evaluate concordance or dissimilarities between the two samples.

[2]C. Michael Bowers & Gary Bell (eds.), Manual of Forensic Odontology (3rd ed. 2001) (privately published by the American Society of Forensic Odontology).

[3]Mark Hansen, Out of the Blue, 82 ABAJ 50 (Feb.1996) (Reporting on a trial court rejection of a technique where the prosecution's dental expert positively linked metal rivets on a butcher knife's handle to marks he purportedly observed on the defendant's hand. These observations on the hand occurred during illumination by 450 nanometers visual (and blue) light. The dentist was unable to photograph the marks on the hand, but testified in court with a Xerographic copy of the defendant's hand as evidence of his findings.)

includes on-site class meetings necessary for a completion certificate.

The Armed Forces Institute of Pathology (AFIP) has the longest running entry level short program. It is held each March and contains 5 days of presentations with short training modules. It is considered a course for introduction to forensic methods. The only equivalent program in the U.S. is the UTSA semi-annual symposium on odontology. The course contents are similar at both locales.

Professional organizations in the U.S. relevant to odontology continue to be the American Academy of Forensic Sciences (AAFS), The American Board of Forensic Odontology (ABFO) (which offers board certification and at this writing has about 100 members) and the American Society of Forensic Odontology. The American Board of Forensic Dentistry (ABFD), an affiliate of the American College of Forensic Examiners, is not recognized by the AAFS due to the ABFD's lax qualifications to achieve "diplomate" status.

The American Dental Association continues to have no interest in establishing odontology as a "dental specialty." On the other hand, the organization has used forensic dentistry as an example of the profession's "outreach" to the unidentified victims of mass disaster and terrorist caused catastrophes.[4]

§ 37:11 NRC Report and Odontology

As it pertains to forensic odontology, the report of the Committee on Identifying the Needs of the Forensic Science Community of the National Research Council[1] (*NRC Report*) largely confirms the information provided in far greater detail this Chapter. The *Report* underscores the problems with bitemark comparisons and the consequent risks of error in trying to identify the perpetrator of a crime through the use of bitemarks. Several specific areas addressed in the *NRC Report* are highlighted below.

Sample Data and Collection. The *NRC Report* stated that human identification from teeth is experiencing no problems with scientific standards, but:

> Unfortunately, bite marks on the skin will change over time and can be distorted by the elasticity of the skin, the unevenness of the surface bite, and swelling and healing. These features may severely limit the validity of forensic odontology (for biter identification). Also, some practical difficulties, such as distortions in photographs and changes over time in the dentition of

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[4]Forensic teams face grim task in Katrina's wake. Dental experts called to action, ADA News, Sep. 9, 2005.

[Section 37:11]

[1]Committee on Identifying the Needs of the Forensic Science Community of the National Research Council, Strengthening Forensic Science in the United States: A Path Forward (2009).For a more complete discussion of the NRC Report generally, see Chapter 29 of this work.

suspects, may limit the accuracy of the results.[2]

Sections 18 and 22 of this Chapter describe these limitations in detail.

Analyses. The *NRC Report* also focused on the lack of analytical testing of bitemark methods and how their use in reaching conclusions on biter identification is determined by dental bitemark experts.

> The guidelines, however, do not indicate the criteria necessary for using each method to determine whether the bite mark can be related to a person's dentition and with what degree of probability. There is no science on the reproducibility of the different methods of analysis that lead to conclusions about the probability of a match. This includes reproducibility between experts and with the same expert over time. Even when using the guidelines, different experts provide widely differing results and a high percentage of false positive matches of bite marks using controlled comparison studies.[3]

Sections 15 and 33 of this Chapter describe in greater detail these failures of the discipline's to test its techniques and procedures.

Uniqueness. The *NRC Report* continued with its findings about forensic odontology's first commandment of bitemark opinions: the assumption of the "uniqueness" attribution of everyone's teeth and the individuality of the resultant bitemark patterns.

> No thorough study has been conducted of large populations to establish the uniqueness of bite marks; theoretical studies promoting the uniqueness theory include more teeth than are seen in most bite marks submitted for comparison. There is no central repository of bite marks and patterns. Most comparisons are made between the bite mark and dental casts of an individual or individuals of interest. Rarely are comparisons made between the bite mark and a number of models from other individuals in addition to those of the individual in question. If a bite mark is compared to a dental cast using the guidelines of the ABFO, and the suspect providing the dental cast cannot be eliminated as a person who could have made the bite, there is no established science indicating what percentage of the population or subgroup of the population could also have produced the bite. This follows from the basic problems inherent in bite mark analysis and interpretation.[4]

Section 23 of this Chapter discusses the fallacy of dental uniqueness.

Concluding Summary on Bitemark Identification. In synthesizing its review of bitemark analysis, the *NRC Report* summarizes the various deficiencies of bitemark identifications into three categories.

> Some of the basic problems inherent in bite mark analysis and interpretation are as follows:
>
> (1) The uniqueness of the human dentition has not been scientifically established.
>
> (2) The ability of the dentition, if unique, to transfer a unique pattern to

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[2] *NRC Report*, at 5-35.

[3] *NRC Report*, at 5-36.

[4] *NRC Report*, at 5-36.

human skin and the ability of the skin to maintain that uniqueness, has not been scientifically established.

i. The ability to analyze and interpret the scope or extent of distortion of bite mark patterns on human skin has not been demonstrated.

ii. The effect of distortion on different comparison techniques is not fully understood and therefore has not been quantified.

(3) A standard for the type, quality, and number of individual characteristics required to indicate that a bite mark has reached a threshold of evidentiary value has not been established.[5]

The final sentence of the bitemark portion of the *NAS Report* implies doubts that forensic odontology has much value in most circumstances for which it might be proffered as evidence in trials.

§ 37:12 Introductory discussion of the scientific status of bitemark comparisons—Recognition and analysis of human bitemarks

A contemporary review of bitemark analysis techniques has summarized certain causes of unreliability in bitemark opinions used in court.[1] These include: changes in suspects' teeth from subsequent dental disease and treatment, examiner subjectivity that overvalues common tooth characteristics,[2] poor bias control,[3] lack of forensically relevant population studies to establish the frequencies of occurrence of common dental features, the dimensional accuracy of skin as a substrate for bitemark impressions made by these teeth,[4] and the multitude of unvalidated comparison methods and analytical procedures recognized and generally accepted.[5]

The issue of inter-examiner agreement and accuracy was studied briefly in the mid-1970s and its findings have not been altered by later research.[6] Using ideal laboratory conditions and evidence, experienced examiners who studied bitemark patterns in pig skin correctly identified the biter 76% of the time. Another author noted the subjectivity of this comparison process and has suggested that the strongest opinion linking bitemarks to

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[5]*NRC Report*, at 5-37.

[Section 37:12]

[1]Rothwell, Bitemarks in Forensic Dentistry: A Review of Legal, Scientific Issues, 126 J. Am. Dental Ass'n (1995).

[2]The common debate between sparring forensic odontologists is (1) the identification value of a bitemark and (2) the degree of concordance of the injury to certain teeth of the defendant. The proof of a positive opinion is not based on any formal population studies that state the frequency of chance random match with other members of a relevant population.

[3]The addition of a "dental lineup" of similar sets of teeth to the sample studied by the dentist has never been mandated. Some of the larger DNA labs separate extraction and comparison activities.

[4]DeVore, Bitemarks for Identification? A Preliminary Report, 11 Med. Sci. & L. 144 (1971). This study is described in detail infra at § § 37:18, 37:22.

[5]See Appendix 36A, ABFO Bitemark Methodology Guidelines.

[6]MacFarlane et al., Statistical Problems in Dental Identification, 14 J. Forensic Sci. Soc'y 247 (1974).

suspects be limited to "possible" until the time comes that bitemark analysis is more satisfactorily tested in relation to reliability, error rate of dentists, and perhaps comes to be conducted pursuant to court appointed, rather than adversarial, expert testimony.[7]

The experimental evaluation of bitemark examiners has been attempted in the United States by the ABFO. It initiated a series of four studies, starting in 1983, and ending in 1999, where diplomates were sent sets of teeth and a series of actual bitemark photographs. They were asked to evaluate the evidence as they would in a conventional bitemark case. The cases were provided by members who attested to the identification of the true biter through means other than the bitemark evidence. The 1983 test resulted in an attempt to develop a scoring sheet that created values for specific dental features seen as concordant between the suspect and a bitemark. This led to the publication of a scoring system in 1986.[8] The quantitative values were soon discarded as being unreliable.[9] The descriptors of dental features, however, carried over into the later published ABFO Standards and Guidelines for Bitemark Analysis.

In seeking explanations for the unsatisfactorily high error rates, the previous edition of this chapter suggested that "[t]he lack of a proper match [by the examiners] was partly a reflection of the difficulty in recognizing the features found in a bitemark, partly an issue of experience and training in interpreting bitemark characteristics and matching procedures, and partly a function of the difficulty in setting up realistic situations."[10] The situations for the tests were certainly not unusual. An interesting interpretation is that, at the very least, the ABFO's membership may not generally have attained the skill necessary to achieve reliable results. The notion that experience is the key to reliability is a common theme that is seen throughout the literature.

Another explanation of this is that the human dentition is not as unique as suspected, and that when an impression of the dentition is distorted by skin properties and subsequent bruising, a large percentage of an open population could fit. This concept has been recently explored in a paper that will be discussed further below.[11]

Two subsequent studies performed after 1983 failed to generate publishable results. The difficulties have been described as a combination of poor

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[7]C. Michael Bowers, A Statement Why Court Opinions on Bitemark Analysis Should be Limited, 4 Newsletter of the ABFO 4 (Dec. 1996).

[8]ABFO, Guidelines for Bitemark Analysis, 112 J. Am. Dental Assoc. 383 (1986).

[9]ABFO, Letter, 33 J. Forensic Sci. 20 (1988).

[10]David L. Faigman, David H. Kaye, Michael J. Saks & Joseph Sanders, Modern Scientific Evidence: The Law and Science of Expert Testimony, Identification from Bitemarks: The Scientific Questions: Recognition and Analysis of Human Bite Marks § 24-2.1.1[2] 171 (1997).

[11]Raymond Miller et al., Uniqueness of the Dentition as Impressed in Human Skin: A Cadaver Model, 54 J. Forensic Sci. (in press 2009).

experimental design and limited analytical prowess by the profession.[12]

The fourth test—the 4th ABFO Bitemark Workshop—was performed in 1999.[13] The results relate to a number of issues raised throughout the history of bitemark analysis in the United States. Following is a summary of the study and its findings.[14]

§ 37:13 Introductory discussion of the scientific status of bitemark comparisons—Recognition and analysis of human bitemarks—Proficiency testing of board certified odontologists

The intent of the study was to determine the ability of board certified forensic odontologists to correctly analyze bitemark evidence in a small population. All 95 board certified diplomates of the American Board of Forensic Odontology were eligible to participate in the study. Of the 60 diplomates who requested and were sent the study material, 26 returned the necessary data by the deadline and were included in the data results.

Complete case material typical of an actual bitemark case was sent to those diplomates requesting to participate. Each diplomate had six months to analyze and anonymously return findings. The study was based on four bitemark cases with known biters whose identity was substantiated by other means. Three of the cases were actual criminal cases where the bitemark was in skin. The fourth case was a fabricated bite into cheese, in which case each examiner was sent a model of the actual cheese in addition to the typical multiple color and black-and-white photographs. In addition to the four sets of models from the known biters each diplomate was sent an additional three dentitions that were selected at random from the laboratory of a unidentified dentist. These seven models made up the population from which the bitemarks were to be identified. Thus, examiners were asked to look at each unknown (3 sets of wound photos and one cheese model) and to compare each of those to the seven known dentitions, in an effort to determine which, if any, of the knowns matched an unknown.

In each case the expert was required to render an opinion in the below three areas. The expert was given the following choices in each of the three areas as defined by the ABFO Standards for Bitemark Terminology.

(1) Wound Analysis—Does the Injury Represent a Bitemark?
   (a) Definite bitemark—no doubt that teeth created the pattern
   (b) Probable bitemark—pattern strongly suggests origin from teeth but could be caused by something else
   (c) Possible bitemark—pattern may or may not have been caused

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[12]None of these studies have been published. The author gleaned this information from personal communications.

[13]The Journal of Forensic Sciences rejected for publication the ABFO's analysis of the 4th Bitemark Workshop data.

[14]This description and analysis is an independent review of the raw data by this author and Dr. David Averill.

by teeth; could have been caused by other factors

(2) Evidentiary Value

(a) High forensic value—could support reasonable certainty in identification

(b) Medium forensic value—could support possible opinion in identification

(c) Low forensic value—would not support a linking

(d) No forensic value—should not be used in investigation

(3) Degree of Certainty Describing the Link between the Bitemark and the Suspect

(a) Reasonable medical certainty—virtual certainty; no reasonable or practical possibility that someone else did it

(b) Probably—more likely than not

(c) Possible—could be; may or may not be; can't be ruled out

(d) Improbable—unlikely to be the biter

(e) Incompatible—not the biter

(f) Inconclusive—insufficient quality/quantity/specificity of evidence to make any statement of relationship to the biter

For purposes of this study, a positive linkage of the suspect's dentition to the bitemark consisted of those opinions recorded as: reasonable medical certainty, probably, and possible. Negative linkage consisted of: improbable, incompatible, and inconclusive. Conclusions could be correct in two different ways: by correctly linking an unknown bitemark to the suspect who made it (true positives) or by excluding a suspect who did not make the unknown bitemark (true negatives). Conclusions could be incorrect in two different ways: by incorrectly linking an unknown bite to a suspect who had not made it (false positives) or by excluding a suspect as having made an unknown bite when that suspect had in fact made that bite (false negatives). Table 1 graphically depicts these four possible decision outcomes.

Table 1
Four Possible Decision Outcomes.

	Reality	
Decision	Suspect bit victim	Suspect did not bite victim
Positive: Suspect bit victim	True Positive	False Positive
Negative: Suspect did not bite victim	False Negative	True Negative

Table 2 summarizes the results of the study. It is important to say something, first, about the meaning of the data and the way they are presented. Suppose one were told that the overall accuracy rate for a test case was 85%. One might conclude from that number that the examiners were doing reasonably well—not as well as one might hope from a forensic science that claims the ability to connect crime scene bitemarks to suspects "to the exclusion of all others in the world," but not terrible either. In truth, however, the performance is far more troubling than is apparent. What is not made evident by that number is the fact that the poorest level of performance that examiners could achieve in this study—if they got every single answer as wrong as they could get it—would still make them appear to be accurate 71% of the time. That is because if an examiner failed to match a bitemark with the correct dentition (one error) and linked it instead with the dentition of an innocent suspect (second error) he still gets the remaining five dentitions "right" by not erroneously inculpating them.[1]

[Section 37:13]

[1]Once one set of dentition is linked (correctly or incorrectly) to a bitemark, the others are not linked, and therefore are scored as "correct." In other words, given the test design, an examiner could never make more than two mistakes, and all remaining dentitions are scored as "correct." If instead of providing a set of seven dentitions from which to choose, there had been 100, then the overall accuracy rate, using this seemingly straightforward method of counting, could never be lower than 98% correct—one false positive inculpation of an innocent suspect, one overlooked guilty suspect, and 98 remaining dentitions that get scored as "correct." And, thus, the poorest possible performance would be "2% error."

Table 2
Error Rates of Forensic Odontology Diplomates on the Four Test Cases

	Overall Error Rate (maximum possible error rate = 27%)	False Positive Errors as Percentage of Examiners Offering Opinions	False Negative Errors as Percentage of Examiners Offering Opinions
Case 1	14%	62%	38%
Case 2	7	42	4
Case 3	12	65	15
Case 4	13	65	27
Medians	12.5%	63.5%	22%

Accordingly, Table 2 seeks to convey a more meaningful idea of how well examiners did by relating their performance to how well they could have done—or more to the point, how poorly they did in relation to how poorly they could have done. The median overall error rate[2] is 12.5%—out of a maximum possible error rate of 27%. Thus, examiners came nearly half the way to being as wrong as they could be. More specifically, it is their false positive error rate—the tendency to conclude that an innocent person's dentition matches the bitemark—that accounts for the bulk of that overall error rate. Table 2 indicates how many examiners committed a false positive error in each test case. In their least bad performance, 42% of them gave a conclusion that inculpated an innocent person's dentition. On average, 63.5% of the examiners committed false positive errors across the test cases. If this reflects their performance in actual cases, then inculpatory opinions by forensic dentists are more likely to be wrong than right. They were, however, much less likely to overlook a true biter—reflected in a median false negative error rate of 22%.

These are not novices; these are diplomates, the most accomplished members of the field. But experience provided no assurance of accuracy. The demography of the test takers failed to disclose any correlation between years in forensic practice case work and correct results.

The results confirm Whittaker's earlier findings discussing the difficulties inherent to bitemark identification.[3] The findings of this most recent ABFO study cast serious doubt on earlier conclusions that the field has "produced a significant number of well trained and capable forensic dentists who have accepted guidelines to follow for evidence collection and analysis. The work of these organizations has contributed to the develop-

[2]That is, the median of the false positives plus false negatives across the four test cases.

[3]Whittaker, Some Laboratory Studies on the Accuracy of Bitemark Comparisons, 25 Int'l Dental J. 166 (1975).

ment of a systematic approach capable of producing reliable opinions."[4]

The ABFO membership opted to submit their report of the Fourth Bitemark Workshop results to the respected Journal of Forensic Sciences. Their submission was twice rejected.[5] The group then published their results in a secondary publication.[6] The ABFO subsequently reversed itself and adopted the position that the raw data were unusable and any inferences from the data were misleading.[7]

The original attempt to study accuracy and intra-examiner agreement of dentists was undertaken by Whittaker in 1975.[8] That study is cited by some writers as a validity test which proves biter identification is reliable. A more accurate description of this test's result is to say that within the four corners of the study certain types of bitemark evidence produced relatively more reliable results than other types. In Whittaker's study, two forensic dentists were tested for accuracy (choosing the correct biter) and reliability (agreement with each other) to examine bites recorded on wax, pigskin and in photographs. Dental study models were used as exemplars of possible biters. The number of possible biters was not recorded. Transparent overlays were not available, although the examiners were able to use metric analysis. The two examiners were able to correctly identify 98.8% of the impressions in wax to the appropriate study model, and achieved similar accuracy when comparing to stone models produced from the wax bites. When photographs of the bites were employed, the accuracy decreased slightly to 96% when measurements were taken and fell further to 67.5% without taking measurements. When the pigskin was tested, accurate assessments hit 63.7%, but when photographs of the pigskin taken 24 hours after biting were used, accuracy fell to 16%.

The study clearly identified operational and examiner difficulties with different methods and bitten objects studied in the analyses. These difficulties still exist more than thirty years later. The use of wax test bites posed no problem. This has little if any relevance to bitemarks in human flesh. The pigskin results, clearly a better analogue to human skin, showed

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[4]David L. Faigman, David H. Kaye, Michael J. Saks & Joseph Sanders, Modern Scientific Evidence: The Law and Science of Expert Testimony, Identification from Bitemarks: The Scientific Questions: Recognition and Analysis of Human Bitemarks, § 24-2.1.1[2] 171–172 (1997).

[5]The last revision was rejected with no recommendation by JFS for resubmission.

[6]Arheart & Pretty, Results of the 4th ABFO Bitemark Workshop — 1999, 124 Forensic Sci. Int'l 104 (2001).

[7]See ABFO Position Paper on Bitemark Workshop #4, at www.ABFO.ORG. "It has come to the attention of the American Board of Forensic Odontology, Inc. (ABFO) that some persons have misinterpreted the purpose of and statistical analysis of the ABFO Bitemark Workshop #4 conducted on February 14 and 15, 1999, in Orlando, FL. The Board has an obligation to correct these erroneous statements." The remainder of the narrative argues against the notion that the examination can be considered a proficiency review of Board Certified forensic dentists.

[8]Whittaker, Some Laboratory Studies on the Accuracy of Bitemark Comparisons, 25 Int'l Dent. J. 166 (1975).

the diminishing accuracy of the dentists' efforts to find the correct biter.

Iain Pretty and David Sweet undertook a study of the proficiency of volunteer bitemark examiners.[9] The study employed digital tooth overlays (two-dimensional outlines of suspect teeth) and simulated human bites in pigskin. The purpose of the paper was to study decision outcomes of three groups of odontologists. The methods used were restricted to the application of digital overlays of suspects' teeth to the bitemarks. The testing materials and the bitemarks created for this study were at the high end of forensic identification value. This value exceeded any actual casework most or any forensic dentists encounter because of the three dimensional depth the authors achieved in the bitten pigskin. A series of ten postmortem bites were created in pigskin using dental casts mounted in a vise-grip. Each of the bites was photographed according to ABFO guidelines. Two suspects were associated with each case, although in two of the cases, neither of the suspects supplied to the examiners was responsible for the bite. The examiners were divided into three groups based on their levels of experience and training. They were provided with photographs of the bites, the suspect's study models and transparent overlays of each suspect. The examiners were asked to reach a conclusion regarding each suspect and report their conclusions using the ABFO conclusions for bitemark analyses. The examiners conducted their examinations twice, using the same evidence samples, following a hiatus period of three months. This allowed the examiners to voluntarily change their opinion (since all sample materials were to be returned after the first test) during the subsequent testing. Thirty dentists participated, with the most experienced (all ABFO members) placed into one cohort. The other two dentist groups were those with low forensic bitemark experience and no forensic bitemark experience. The ABFO group was tested for inter-examiner reliability during the first testing. The second test studied intra-examiner reliability. Seven of the original 10 ABFO respondents were used to test intra-examiner reliability. This tests whether these same examiners, using the same evidence, changed their opinions after three months. The results for intra-examiner consistency are presented in Table 3. The performance results were considered "fair" by the reporting authors. Three of the original ten were eliminated for not returning the material to the authors after completing the first test. The study's authors, using more elaborate statistical analysis for other conclusions, considered the mean accuracy of these examiners to be 85.7% in the first test and 83.5% for the second. The percentage agreement ranged from 65% to 100%. These results underscore the variability of bitemark examiners' opinions even when given exceptionally high quality bitemark evidence with which to work.

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[9]Pretty & Sweet, Digital Bitemark Overlays—An Analysis of Effectiveness, 46 J. Forensic Sci. 1385 (2001).

Table 3. Intra-Examiner Agreement

Examiner	Percent Agreement
1	65
2	70
3	100
4	100
5	80
6	95
7	100
Mean	87.2%

The inter-examiner reliability results (test one) had ten diplomates returning completed answer sheets (100%). The level of agreement was considered "moderate." Two of the group were extremely conservative, with their "inconclusive opinions" heavily contributing to the group's total of this response type (12%). The remaining eight examiners used "I don't know" only two percent of the time. These two examiners scored 100% accuracy in the cases on which they did render conclusive opinions. Overall, accuracy ranged from 65% to 100% with a mean value of 83.2%. When the two most conservative examiners were removed from the testing group, mean accuracy dropped to 78.5%. False positive responses were 15.9% (ranging from 0 to 45.5%) and false negatives were 25.0% (ranging from 0 to 71.4%).

The final finding from this study was that none of the three groups (the ABFO and two non-ABFO groups) differed statistically from each other in any of the measured values of this study. These groups were given the best possible experimentally derived bitemark evidence (three dimensional bites and excellent photography protocol). The variation in individual outcomes and less than high general agreement (reliability) raises concerns about the ability of examiners presented with more forensically typical materials to identify a biter to the exclusion of all others (ABFO terminology would be that the suspect is the biter with reasonable medical/dental certainty).

Proficiency testing is a topic of discussion with a small number of concerned dentists. The intent of this testing is to insure quality control of previously qualified forensic dentists after their initial certification. This notion is prevalent in the established scientific laboratory disciplines but is not seen in the health care field per se. The onset of DNA proficiency testing of biologists and lab technicians has produced a "filter down" effect to the less rigorously scientific fields seen in forensic practice (fingerprints, ballistics, and bitemark analysis). Previous attempts by the ABFO to achieve some measure of bitemark examiner outcome calibration have repeatedly been repudiated by the organization. The ABFO is silent regarding establishing a mandatory testing of its membership. The ABFO's as-

sociation with the AAFS (as in "recognition of certification. . . is for information purposes only")[10] as a forensic certification board will change this status quo due to the AAFS establishment of a Forensic Specialties Accreditation Board (FSAB).[11] The FSAB has developed criteria for the AAFS recognized boards (criminalistics, forensic pathology and psychiatry, forensic anthropology, forensic toxicology, questioned documents, and odontology) which will demand, in the near future, ongoing proficiency review of their members' reliability in performing their analyses.[12]

The sections that follow may illuminate the reasons why accuracy has been so disappointing and what steps may improve accuracy and judicial expectations in the future.

§ 37:14 Introductory discussion of the scientific status of bitemark comparisons—Scientific methods applied to comparison techniques

A major aspect of the bitemark comparison process targets the two- and three-dimensional characteristics of the suspect's teeth. Two studies[1] report data suggesting a high degree of variability in these features, and the authors argue that it shows bitemarks to be unique (infinitely variable) among the human population. Unfortunately, there are no studies relating this hypothesis to actual bitemarks on skin or other substrates. In addition, neither study attempted to prove the independent occurrence of each dental feature. The latter study misapplied probability theory to reach a conclusion of uniqueness of any human being.

In practice, the odontologist compares the Questioned bitemark to duplicates (exemplars) of Known teeth. The assortment of exemplar materials and methods in use are well documented in the literature. Computer imaging, hand-traced outlines, Xerographic copying, and wax impressions, among others, are used to duplicate two and three dimensional features of a suspect's teeth. These methods produce an image of the teeth,

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[10]2005 AAFS Membership Directory, at xxiii.

[11]http://www.thefsab.org. "The goal of this program is to establish a mechanism whereby the forensic community can assess, recognize and monitor organizations or professional boards that certify individual forensic scientists or other forensic specialists. This program has been established with the support and grant assistance of the American Academy of Forensic, (AAFS), the National Forensic Science Technology Center (NFSTC) and the National Institute of Justice (NIJ)."

[12]FSAB Guidelines, Sec. 6.2. Continuing Competency.

6.2.2. Measurement of continuing competency may include, but not be limited to, proficiency testing, case audits, relevant work experience, relevant publication, conducting training, audit of court testimony, case presentation and relevant work experience (sic)."

[Section 37:14]

[1]Reidar F. Sognnaes & Rawson, Computer Comparison of Bitemark Patterns in Identical Twins, 105 J. Am. Dental Assoc. 449 (1982); Rawson & Ommen, Statistical Evidence for the Individuality of the Human Dentition, 29 J. Forensic Sci. 245 (1984).

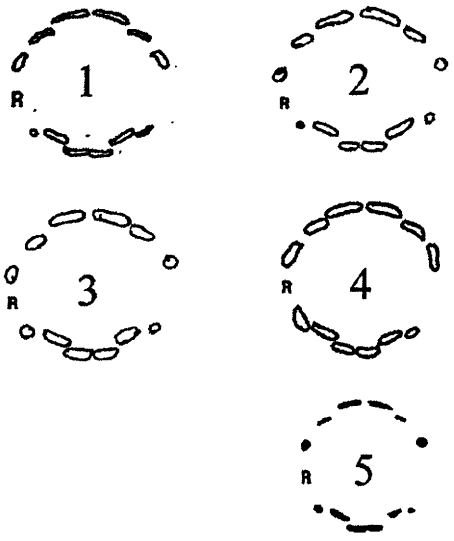
called an "overlay" since it is transferred to transparent acetate and superimposed (after being flipped horizontally), onto an image of the bitemark. The examiner studies the relationships between the two images, and reaches an opinion about their similarity.

A study was completed in an effort to validate the most popular of these methods.[2] This was the first attempt to compare methods in relation to a reference standard. The study obtained sample data (n=30) from plaster dental study casts of a Caucasian population pool, pertaining to tooth position and area of each tooth biting surface (also called a hollow-volume overlay) using a computer-based optical imaging method. The relative rotation of teeth in each sample was obtained using a geometric analysis. Five commonly used bitemark overlay production techniques were analyzed by computer and statistically to determine how accurately each reproduced the shape, size and rotation of the upper and lower front teeth of the research sample. (See Figure 1.) The computer-based method produced digital images of the dental plaster casts that were found to be very accurate. This method was treated as the "gold standard" and the other methods were compared to it.

Figure 1

Overlays Produces from the Same Dental Cast Using a Variety of Different Techniques. (Note: not to scale.)

1 = computer-generated
2 = hand-traced from study cast
3 = hand-traced from wax bite
4 = xerographic method
5 = radiographic method



[2]§ 37:9.

The findings established that there are significant differences among these five methods. The resulting ranking of the various methods is seen in Table 4. The authors suggested that the computer generated bitemark overlays provided the most reproducible and accurate exemplars and recommended that hand tracing of a suspect's teeth be discontinued due to its consistently low ranking for precision in both surface area and rotational accuracy. Findings such as these have played a part in the development and revision of various aspects of bitemark identification practice, although no data exist to measure the reliability of any of these methods in bitemark identification.[3]

Table 4
Various Overlay Fabrication Techniques Ranked According to Accuracy

Rank	Area	Rotation
1	Computer-based	Computer-based
2	Radiopaque wax	Xerographic
3	Hand-traced from wax	Hand-traced from wax
4	Hand-traced from study casts	Hand-traced from study casts
5	Xerographic	Radiopaque wax

After Sweet and Bowers (1998)

§ 37:15 Introductory discussion of the scientific status of bitemark comparisons—Scientific methods applied to comparison techniques—Analysis of suspect teeth: the conundrum of multiple methods

The issue of the multiple methods of bitemark analysis continues to thwart any attempts to standardize procedures to any sort of "gold standard." The use of digital methods in the superimposition of bitemark evidence appears to be increasing, although the older, more experienced forensic dentists still seem to resist the use of two dimensional computer methods.

> Since being introduced to the profession these new tools have had little use in certain Prosecution bitemark cases seen by this author while acting as a

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[3]Raymond Johansen & C. Michael Bowers, Digital Analysis of Bitemark Evidence (2000).

Defense Counsel expert. This disregard of almost 10 year old scientific literature possibly indicates the established dental experts (trained in the previous Millenium) do not consider common digital procedures will change their opinions or improve their accuracy.[1]

A survey study[2] of volunteering odontologists produced results indicating that 90% of the respondents used a dental exemplar (overlay) of suspect teeth. The use of digitally generated overlays was acknowledged by 70% of the respondents. The remainder of the study sample either hand drew their tooth exemplars or used some other alternative method. This flies in the face of a published findings indicating that digital methods were superior in detail and accuracy.[3]

There are three major choices of how to generate a digital dental exemplar:

1. The Naru technique.[4]
2. The Sweet method.[5]
3. The Bowers modification of Sweet.[6]

A 2005 paper[7] stated these methods are all reliable for tooth position data, but the area of the each tooth varies among the three methods. The likely reason for area variations of the dental overlays is due to operator choice of the amount to tooth structure to include in the dental exemplar. A contributing factor is that each of the three methods uses different digital "tools" available in the Adobe Photoshop computer program.

The scientific literature shows some recent advance into 3D laser scanning methods that are still experimental.[8] 3D laser scanning has leaped forward in recent years. There are now three commercially available systems for dental practices, and laser scanning is routinely employed in orthodontic treatment and custom splint fabrication. It may be expected that 3D methods will become powerful tools in courtroom testimony.

[Section 37:15]

[1]Id. Raymond Johansen & C. Michael Bowers, Digital Analysis of Bitemark Evidence (2000) at S104.

[2]Pretty, A Web-based Survey of Odontologists's Opinions Concerning Bitemark Analysis, 48 J. Forensic Sci. 117 (2003).

[3]Sweet and Bowers, Accuracy of Bite Mark Overlays: A Comparison of Five Common Methods to Produce Exemplars from a Suspect's Dentition, 43 J. Forensic Sci. 1050 (1998).

[4]Naru and Dykes, The Use of a Digital Imaging Technique to Aid Bite Mark Analysis, 36 Sci. & Justice 47 (1996).

[5]Sweet, Parhar and Wood, Computer-based Production of Bite Mark Comparison Overlays, 43 J. Forensic Sci. 1050 (1998).

[6]Raymond J. Johansen and C. Michael Bowers, Digital Analysis of Bitemark Evidence, 2nd ed. (2003).

[7]McNamee, Sweet, Pretty, A Comparative Reliability Analysis of Computer-generated Bitemark Overlays, J. Forensic Sci. 50 400–405 (2005).

[8]Blackwell et al., 3-D Imaging and Quantitative Comparison of Human Dentition and Simulated Bite Marks, 4 Int'l J. Legal Med. 1 (2006).

§ 37:16 Introductory discussion of the scientific status of bitemark comparisons—Scientific methods applied to comparison techniques—Analysis of a bitemark pattern

The "dental profile" physically present in a suspected bitemark injury is currently undergoing some experimental testing. Pigskin has been used in similar testing over the last four decades as a substitute for human skin. This use of pigskin as a substrate for artificial bitemarks was revisited in 2001.[1] The findings indicated average agreement amongst examiners to be 80%. Reliability of the examiners (i.e., intra and inter examiner) was indicated as "not strong." This underscores the historically subjective nature of the interpretation of forensic identification value seen in bitemark injuries. The authors in the 2001 paper revisited the 1999 ABFO 4th Annual Bitemark Workshop results and found a marked agreement with their own experimental results in the area of intra-examiner reliability ranging from 86% to 59%.[2]

The threshold opinion of a bitemark investigation is what dental information or data are present in the pattern, be it on human skin or some inanimate object. The ABFO Guidelines are of no help in terms of "weighing" what is significant. Rather, these Guidelines give only descriptive terms of dental features that should be used in a written report. The actual practice of bitemark investigations commonly shows no descriptors at all and little compliance regarding data specific to the conclusions. This renders any independent examiner no help in determining the reasoning for an opposing dentist's opinion. The more experienced bitemark experts consider their opinions inviolate and therefore object to giving the specifics during the discovery phase of an actual case. This attitude, coupled with the indiosyncratic basis for bitemark evaluation nourishes the opinion of some outside the field that bitemark analysis is flawed. The lack of an appropriate "scale" of standardization for bitemark patterns makes their continued use in court a point of concern. The outcomes of a criminal trial are not a benchmark for scientific proof.

§ 37:17 Introductory discussion of the scientific status of bitemark comparisons—The scientific limitations of bitemark testimony

The phrase "evidence based" has recently been introduced into the forensic odontology literature.[1] The health care profession uses this concept to title scientifically derived proofs for established protocols and studies that

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[Section 37:16]

[1]Pretty and Sweet, Digital Bitemark Overlays—An Analysis of Effectiveness, 46 J. Forensic Sci. 1385 (2001).

[2]Arheart and Pretty, Results of the 4th ABFO Bitemark Workshop 1999, 124 Forensic Sci. Int. 104 (2001).

[Section 37:17]

[1]Pretty, The Barriers to Achieving an Evidence Base for Bitemark Analysis, 159 Forensic Sci. Int. 110 (2006).

provide the knowledge base for accepted treatment modalities. If we consider bitemark diagnoses as a health care method, the proof of diagnostic effectiveness should be revealed in the case history and peer-reviewed articles studying and validating the treatments normally performed by court approved bitemark experts. The bitemark literature is predominantly case reports whereas substantive proofs of both validity and reliability do not yet exist. Any argument that the primary bitemark literature is sufficient for continued court admission should be considered in the context that the actual casework observed in court has little to no relevance to the experimental studies some consider adequate. This disconnect is showing itself in the published judicial record where bitemark diagnoses have been refuted or at least severely weakened by later DNA evidence.[2]

The following section describes several scientific issues involving bitemark analysis. This is presented to illuminate the interface between the rules of scientific admissibility and reliability issues involving forensic dentistry.

The limitations of bitemark testimony find their origins more in legal than scientific requirements, leading very few of the early scientific papers to mention[3] pitfalls of the methods adopted by the profession. The use of bitemarks, carrying the same weight as DNA analysis, continues without any judicial scrutiny in criminal trial and appellate courts. The determination of dental profiles present in injured skin that are solely bruising is confounded by the multiple variables that exist in typical injury patterns. The checklist for these limitations continues to be the following:

1. Individual differences in victims' response to trauma.
2. The differences in the anatomical locations of the bitemarks.
3. Physical stretching and distortion of skin during the act of biting.

The effects of these variables on the appearance of a human bitemark have never been controllable and most likely are beyond domestication by any scientific application. The examiner's interpretation of the forensic value of such injuries continues to be intuitive and not the product of any scientific knowledge.

§ 37:18 Introductory discussion of the scientific status of bitemark comparisons—The scientific limitations of bitemark testimony—The accuracy of skin as a substrate for bitemarks

Central to bitemark analysis are the characteristics of the skin receiving

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[2]Bowers, Problem-based Analysis of Bitemark Misidentifications: The Role of DNA, 159 Forensic Sci. Int. 104 (2006).

[3]MacFarlane, MacDonald and Sutherland, Statistical Problems in Dental Identification, 14 J. Forensic Sci. Soc. 247 (1974).

the mark, because, in cases of physical assault having skin injuries, the anatomy and physiology of the skin, and the position of the victim, affect the detail and shape of the bitemark. DeVore[1] showed how the positioning of the test bite (actually, it was an inked circle) on a bicep varied depending upon whether the arm was flexed or pronated. (See Figure 2.) What is significant in casework and report writing is the need to experimentally control or establish the amount of positional variation in an actual bitemark case. Use of a live victim in a reenactment is difficult and a deceased individual will not be available. No important papers have been published on this subject since DeVore's in 1971.

More recently empirical research has been published using human cadavers as a model. The first paper to seriously consider the biomechanical properties of human skin and attempt to understand distortion seen in experimentally created bitemarks appeared in 2009.[2] In the Bush et al. paper, 23 bites were created on three cadavers using the same dentition. The authors note that no two bites were measurably identical, and that skin anisotropy, tissue type and anatomy play a large role in distortion. This study also investigated postural distortion after bitten limbs had been moved to a new position. Distortion ranges were found of up to 80% in angle of rotation between teeth, 27% in inter-canine distance, and 42% in mesial to distal dimensions in a bitemark as compared with the dentition that caused the injury. In this study, fresh indentations caused by the biting apparatus were measured. The authors concluded that "interpretation of a bitemark in a live individual in which indentations have faded and only a diffuse bruise remains should be approached with caution."

Continuing with the human cadaver model, the same group published a second article in which overlays from 100 dental models were compared to 10 bitemarks made from selected models within the population of 100. The models were first sorted into groups of similar mal-alignment, and overlays from within each group and from the whole model set were compared to the bitemarks. Results showed difficulty distinguishing the biter from individuals with similarly aligned dentitions and in some cases, an incorrect biter appeared better correlated to the bite. It was found that up to 86% of models within a group could not be excluded, and in the larger set, up to 16% could not be excluded. The authors conclude "…this study suggests that an open population postmortem bitemark should be carefully and cautiously evaluated . . ."[3]

These papers represent the first serious attempt to study bitemarks in human skin. The authors acknowledge that cadavers do not have vital re-

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[Section 37:18]

[1]§§ 37:12 to 37:13.

[2]Mary A. Bush et al., Biomechanical Factors in Human Dermal Bitemarks in a Cadaver Model, 54 J. Forensic Sci.167 (2009).

[3]Raymond G. Miller et al., Uniqueness of the Dentition as Impressed in Human Skin: A Cadaver Model, 54 J. Forensic Sci. (in press 2009).

sponse and may not replicate the living, but cadaver skin retains biomechanical properties and allows for experiments in which there is a gold standard (the biter is known). The authors' conclusions appear understated in light of the significance of these papers.

Figure 2

Two Identical Marks on Human Skin. The Lower Has Been Distorted by Applying Pressure to the Area (Duplicating Devore's Test).

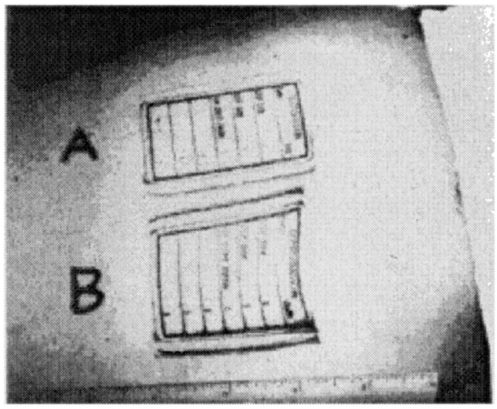
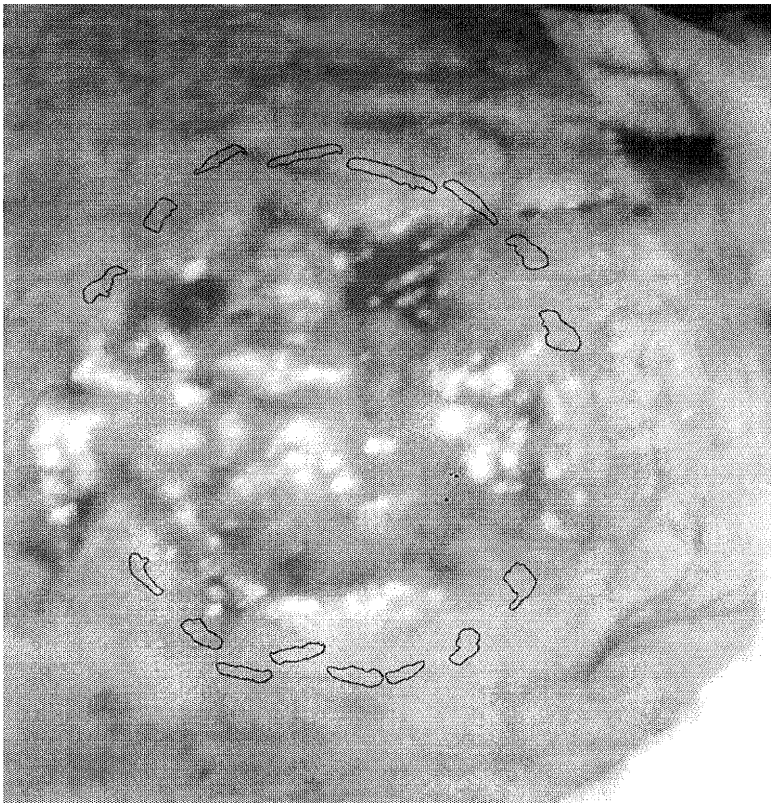


Figure 3

Bitemark on Skin with Known Biter's Teeth Outlines Placed Next to the Biting Pattern. Skin Distortion From Biting Dynamics Makes This Bitemark Useless for Dental Comparison Purposes.



§ 37:19 Introductory discussion of the scientific status of bitemark comparisons—The scientific limitations of bitemark testimony—Bruising and other considerations

Recognition of the fact that bruising is actually subcutaneous bleeding[1] requires that the investigator not assume that the reddened areas that appear to be teeth are an accurate representation of individual teeth.

Dailey and Bowers[2] describe the shortcomings of attempts by odontologists and other forensic experts to "age" skin injuries according to the degree of discoloration present in the mark. During the process of healing, or skin response to a sufficient force, the bruise will go through color changes before fading from visual recognition. A bruise is an "area of hemorrhage into soft tissue due to the rupture of blood vessels caused by blunt trauma."[3] Using appearance of bruises for the purpose of aging a wound has been judged to be invalid by numerous investigators. A review of research reporting controlled studies of these discolorations over time concluded that, "it would seem unlikely that a bruise could be reliably aged from appearance alone."[4]

The bitemark should be thoroughly analyzed *first*. That means measurements, angles, and other features should be exhaustively studied before the teeth of any suspect(s) are viewed.[5] This provides a modicum of control where the determinations of the forensic value of the bitemark are established prior to the dentist comparing the suspect's dental evidence. The realities of two-dimensional (i.e., bruises) bitemarks suggest that finding individualizing (i.e., unique) features in bitemarks is extremely rare. The details of intertooth spaces, rotations, and blank spaces between teeth are the principal features of this type of injury. A survey of nearly 50 actual bitemark cases indicates the predominate skin injury dentists testify about is limited to bruising features. The amount of information available in these injuries is well below the detail seen in experimentally produced bitemarks.[6]

§ 37:20 Introductory discussion of the scientific status of bitemark comparisons—The scientific limitations of bitemark testimony—The issue of individuality of human dentition

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[Section 37:19]

[1]Dailey & Bowers, Aging of Bitemarks, A Literature Review, 42 J. Forensic Sci. 791 (1997).

[2]Dailey & Bowers, Aging of Bitemarks, A Literature Review, 42 J. Forensic Sci. 791 (1997).

[3]Dominick J. DiMaio & Vincent J.M. DiMaio, Forensic Pathology (1993).

[4]Langlois & Gresham, The Aging of Bruises: A Review and Study of the Colour Changes with Time, 50 Forensic Sci. Int'l 227 (1991).

[5]Reidar F. Sognnaes, Forensic Bitemark Measurements, 55 Dental Survey 34 (1979).

[6]C.M. Bowers and I.A. Pretty, Expert Disagreement in Bitemark Cases, ___ J. Forensic Sci. _____ (in press, 2009).

Another foundation of bitemark analysis is the belief that the total arrangement of a person's dentition creates a dental "profile" of sorts. Attempts to determine, or demonstrate, the uniqueness of human dentition has a history in bitemark analysis that stretches over four decades. The demonstration of uniqueness is a blend of art and opinion. The probability of more than one person producing a similar or identical bitemark in a specific case is the challenge in every bitemark case.[1]

Most bitemark experts consider the human dentition to be unique to each living being.[2] A large majority of ABFO diplomates consider the dental uniqueness issue settled and the capacity of these features to be accurately reflected in human skin to be confirmed (91% support dental uniqueness and 78% believe that uniqueness transfers faithfully to human skin).[3] Over the last 30 years, only a few papers asserting dental uniqueness (and reviewed elsewhere in this chapter) have been published.[4] They do not establish dental uniqueness or its replication onto human skin. In fact, until quite recently, no studies of this aspect of the subject of bitemarks were published in any peer reviewed journals. The assumptions of uniqueness and accurate transfer existed simply because they were convenient for court admission of bitemark analysis.

Two recent articles have added a more realistic understanding of the limits of transferability and dental uniqueness. The first article determined from other evidence that only two suspects had the opportunity to bite an assault victim.[5] The comparison of the two dentitions to the injury produced no findings that allowed either one to be excluded as the biter. The second article was a university-based project that introduced 3D laser scanning of a population of 42 study models and experimentally produced bitemarks in wax. The study's results indicated the following:

> The results of this study indicated that 15% of combinations of dentitions and bite models in this sample were categorised as a match when they were in fact a non-match, i.e. 15% of non-matching combinations were indistinguishable from the true match. This translates to six out of the 42 people in this sample at risk of being false positives, or wrongly convicted. This figure is only indicative of this particular sample and may be lower in actual casework,

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[Section 37:20]

[1]Beckstead et al., Review of Bitemark Evidence, 99 J. Am. Dental Assoc. 69 (1979).

[2]Pretty and Sweet, The Scientific Basis for Human Bitemark Analysis—A Critical Review, 41 Sci. & Justice 85 (2001).

[3]Pretty, A Web-based Survey of Odontologist's Opinions Concerning Bitemark Analysis, 48 J. Forensic Sci. 117 (2003).

[4]MacFarlane, MacDonald and Sutherland, Statistical Problems in Dental Identifications, 14 J. Forensic Sci. Soc. 247 (1974). Sognnaes et al., Computer Comparison of Bitemark Patterns in Identical Twins, 105 J. Am. Dent. Ass'n 449 (1982). Rawson et al., Statistical Evidence for the Individuality of the Human Dentition, 29 J. Forensic Sci. 245 (1982).

[5]Pretty and Turnbull, Lack of Dental uniqueness Between Two Bitemark Suspects, 46 J. Forensic Sci. 1487 (2001).

but this is not certain.[6]

Although this study used wax as a biting substrate, the false positive rate appears to be in agreement with the empirical study performed on cadavers.[7]

If, however, it can be said that no two humans have the same dentition, the task is made easier, because (putting aside technical problems of the registration and reading of the bitemark[8]) the theoretical probability of a coincidental match becomes zero, and then no probability need be worried about, much less calculated. Legal commentaries from the 1970s and 80s attacked bitemark analysis as a "new and unfounded science of identification"[9] and pointed out that the "uniqueness of the human dentition hasn't been established."[10] The odontology response then and now has been to base its assertion of uniqueness on a small number of journal articles which are less than persuasive in their efforts to prove uniqueness scientifically.[11] One such recent paper used geometric morphometric analysis as a means of measuring and comparing the anterior dentitions of 33 maxillas and 49 mandibles. Based on the small differences shown between the dentitions in this study the author asserted that his results supported the notion of uniqueness of the dentition, while acknowledging these small differences may not transfer to the skin. When viewed in the light of the results of the empirical studies by Bush et al. and Miller et al., the uniqueness of the dentition as described by Kieser seems overshadowed by the significant distortion rates in human skin.[12]

One approach to trying to prove uniqueness has been the comparison of identical twins.[13] The notion is that if "even" identical twins show differences, then every individual on earth "must therefore" be different from every other individual on earth. The logic that goes from the evidence to the conclusion is not especially clear, but we can understand why, as a

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[6]Blackwell et al., 3-D Imaging and Quantitative Comparison of Human Dentition and Simulated Bite Marks, 4 Int. J. Legal Med. 1, 8 (2006).

[7]Raymond G. Miller et al., Uniqueness of the Dentition as Impressed in Human Skin: A Cadaver Model, 54 J. Forensic Sci. (in press 2009).

[8]For example, Rawson & Ommen, Statistical Evidence for the Individuality of the Human Dentition, 29 J. Forensic Sci. 245 (1984), utilized teeth impressions in wax which were then hand traced and computer analyzed. Because bitemarks in skin were not the target of the 397 sets of wax teeth marks he choose to investigate out of a larger cohort of 1200, the generalizability of the findings to actual bitemarks is questionable.

[9]Wilkinson & Gerughty, Bitemark Evidence: Its Admissibility is Hard to Swallow, 12 W. St. U. L. Rev. 519 (1985).

[10]Hales, Admissibility of Bitemark Evidence, 51 S. Cal. L. Rev. 309 (1978).

[11]Sognnaes & Rawson, Computer Comparison of Bitemark Patterns in Identical Twins, 105 J. Am. Dental Assoc. 449 (1982); Rawson & Ommen, Statistical Evidence for the Individuality of the Human Dentition, 29 J. Forensic Sci. 245 (1984).

[12]J.A. Keiser et al., The Uniqueness of the Human Anterior Dentition: A Geometric Morphometric Analysis, 52 J Forensic Sci. 671 (2007).

[13]See discussion, § 37:23.

means of proving uniqueness, it is fundamentally unsound. When it is shown that identical twins do not have identical dentition (or fingerprints, or hair, or anything else), what that establishes is that the genotype for these traits is not isomorphic with the phenotype. Thus, genetics cannot be relied upon as a basis for concluding that these forensically relevant traits vary in accord with all that we know about genetics. Rather, it means that non-genetic, presumably random, factors introduce some disconnection between the genes and their physical expression. Rather than proving that, because identical twins show differences, everyone else must also, it proves that even the attributes of identical twins reflect these random factors and those random factors must be taken into account in determining the probability of a coincidental match. Rather than obviating the need for objective calculations, it brings us right back to the need to calculate probabilities of coincidental matches.

The heavy use of probability theory is seen in the seminal bitemark articles of the last four decades.[14] Their implication is that so much variation exists in the morphology and position of teeth that, when the product rule is applied, the probability of two being alike approaches the vanishing point. For example, some authors point to hypothetical frequencies of occurrence of more rare or "uncharacteristic" features, multiply them according to the product rule per Keiser-Neilsen, based on the assumption that these features of higher value are independent of one another, and arrive at vanishingly small probabilities.[15] Keiser-Neilsen was not, however, talking about bitemarks (far more limited representations of dentition) when he introduced the use of the "product-rule"[16] in 1960. He was offering a purely theoretical application of basic notions of probability, assuming that each dental feature was independent of the next and that the product of each frequency of occurrence could be used to establish the frequency of all the features occurring at once. He was actually talking about missing and filled teeth, not bitemarks. Thus, because bitemarks involve many fewer attributes than full sets of teeth, the probabilities can never get as small as Keiser-Nielsen's and the identifications can never be as individuating.

Another problem is that the use of the product rule requires that the separate attributes going into the calculation be independent of each other, otherwise the probability arrived at understates the improbability of the joint occurrence of the attributes. None of the studies taking the prob-

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[14]Keiser-Nielsen, Person Identification by Means of the Teeth (1980); Vale, Sognnaes & Noguchi, Unusual Three-Dimensional Bitemark Evidence in a Homicide Case, 21 J. Forensic Sci. 642 (1976); Rawson & Ommen, Statistical Evidence for the Individuality of the Human Dentition, 29 J. Forensic Sci. 245 (1984).

[15]Rawson & Ommen, Statistical Evidence for the Individuality of the Human Dentition, 29 J. Forensic Sci. 245 (1984).

[16]The product rule applied to dentition states that the probability of the joint occurrence of several attributes is the product of each separate attribute's frequency in the relevant population. This assumes each component occurs independently, something which is not yet known to be true.

ability approach to uniqueness of dentition have achieved, or even attempted, to determine whether the attributes of dentition are uncorrelated with each other. To the contrary, some research indicates that the distribution of some tooth positions are less random than others.[17] Current research looking at 2 and 3 dimensional features of human teeth indicate dental profiles (of front teeth) can be quantified and compared. The comparison of results are similar. The similarities and dissimilarities collect into a normal distribution (i.e. bell shaped curve) of occurrence.[18] The patterns do not support any claim of "dental uniqueness."

The largest problem with using probability theory to prove unique individuality is that it is simply incapable of doing so, something that other forensic identification sciences realized some time ago.[19] Probability leads only to probabilities, never to unique, one-of-a-kind certainties. Though it may be the best route to uniqueness, it is incapable of arriving at the desired destination.[20]

What the mathematics of probability can be used for is to calculate the probability of a coincidental match, and that probability can be reported to the trial factfinder. A forensic dentist can never say that the apparent similarity between a bitemark and a suspect's dentition links the suspect with certainty to the crime scene, but the jury could be informed of the probability that a person selected at random would have so similar a match. This is exactly what DNA typing leads to: not assertions of unique matches but a probability of coincidental matches. And that is precisely what other forensic identification sciences such as odontology could do.[21] Unfortunately, forensic dentists have not yet gathered the data to perform these calculations and so their opinions and testimony cannot give such information to factfinders. Thus, while it is true that we could calculate the necessary probabilities based on "missing teeth, pattern of rotation, angulation or position of each tooth . . . if the frequency of certain positions is known for the general population,"[22] the unfortunate state of affairs is that obtaining those frequencies has not yet been accomplished by

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[17]Rawson & Ommen, Statistical Evidence for the Individuality of the Human Dentition, 29 J. Forensic Sci. 245 (1984).

[18]Mary Bush and Peter Bush (personal communication).

[19]Harold Cummins & Charles Midlo, Finger Prints, Palms and Soles: An Introduction to Dermatoglyphics (1943); 0Stoney, What Made Us Ever Think We Could Individualize Using Statistics, 31 J. Forensic Sci. Soc'y 197 (1991).

[20]"It is unfortunate that this approach carries the implication that a complete correspondence of two patterns might occur . . ." "it is impossible to offer decisive proof that no two fingerprints bear identical patterns." Harold Cummins & Charles Midlo, Finger Prints, Palms and Soles: An Introduction to Dermatoglyphics (1943).

[21]Saks & Koehler, What DNA "Fingerprinting" Can Teach the Law About the Rest of Forensic Science, 13 Cardozo L. Rev. 361 (1991).

[22]David L. Faigman, David H. Kaye, Michael J. Saks & Joseph Sanders, Modern Scientific Evidence: The Law and Science of Expert Testimony, Identification from Bitemarks: The Scientific Questions: Uniqueness of the Human Dentition, § 24-2.1.1[1], 168 (1997).

the field of forensic odontology.

In practice, then, forensic dentists have no choice but to fall back on intuition about frequencies and leaps of inference to reach their conclusions. The forensic dentist intuits the forensic weight (value) that various characteristics possess. The ABFO Workshop #4 data indicating a high false positive error rate may reflect an over-estimation of the individualizing value of various features. Not all bitemarks have the level of forensic value necessary to identify just one individual. Toolmark terminology was adopted early on by odontologists for discussing the types of dental features seen in bitemarks and the human dentition. A characteristic within a bitemark or in a person's dentition is a distinguishing feature, trait, or pattern. A class characteristic reflects a feature of generic value to a large population. Each human tooth has shape and position features common to the human species. Determining whether an injury is a human bitemark depends on these class characteristics being present in the injury.

Individual dental characteristics are said to be features that are unique to an individual variation within a defined group. The presence of worn, fractured or restored teeth is valued as unique features. If a bitemark possesses the reflection of such a feature, the degree of confidence in a match increases.[23] The odontological literature is silent regarding the frequency of these traits.[24] It is actually rather counter-intuitive to assume enamel chips, fractures, and dental restorations are inherently unique. The shape of human teeth is quite constant in nature and their changes over time is based on common events. The chance occurrence of more than one person having a crooked front tooth is quite large. That is why orthodontists have such large practices.

A frequent refuge for the experienced bitemark expert is the belief that "[t]he controversy seems to hinge on how closely we look at the teeth and teeth marks."[25] This describes the odontologist's rule of thumb protection against false positive bitemark identifications. The weight given to a conclusion is based on the number of characteristics seen in the injury. Probability of a positive match is how many tooth marks are seen, not in the uniqueness value of each individual characteristic of either the defendant or the bitemark injury. Proof of uniqueness is unavailable in the scientific literature.

At the end of the day, the reliability of dental opinion historically is

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[23]David L. Faigman, David H. Kaye, Michael J. Saks & Joseph Sanders, Modern Scientific Evidence: The Law and Science of Expert Testimony, Identification from Bitemarks: The Scientific Questions: Uniqueness of the Human Dentition, § 24-2.1.1[1], at 167 (1997).

[24]R.F. Kouble and G.T. Craig, A Survey of the Incidence of Missing Anterior Teeth: Potential Value in Bite Mark Analysis, 4 Science & Justice 19 (2007).

[25]David L. Faigman, David H. Kaye, Michael J. Saks & Joseph Sanders, Modern Scientific Evidence: The Law and Science of Expert Testimony, Identification from Bitemarks: The Scientific Questions: Uniqueness of the Human Dentition, § 24-2.1.1[1], at 167 (1997).

based on intuition derived from the expert's "experience," not scientific data. Likewise the forensic dentist's credibility with the judge or jury generally is based on factors present in the dentist's testimony other than underlying science. These factors include years of experience, demeanor on the witness stand, proper use of terminology, meticulous adherence to procedures (e.g., not forgetting to bring his/her notes), and the like.

§ 37:21 Introductory discussion of the scientific status of bitemark comparisons—Scientific literature on bitemark identification

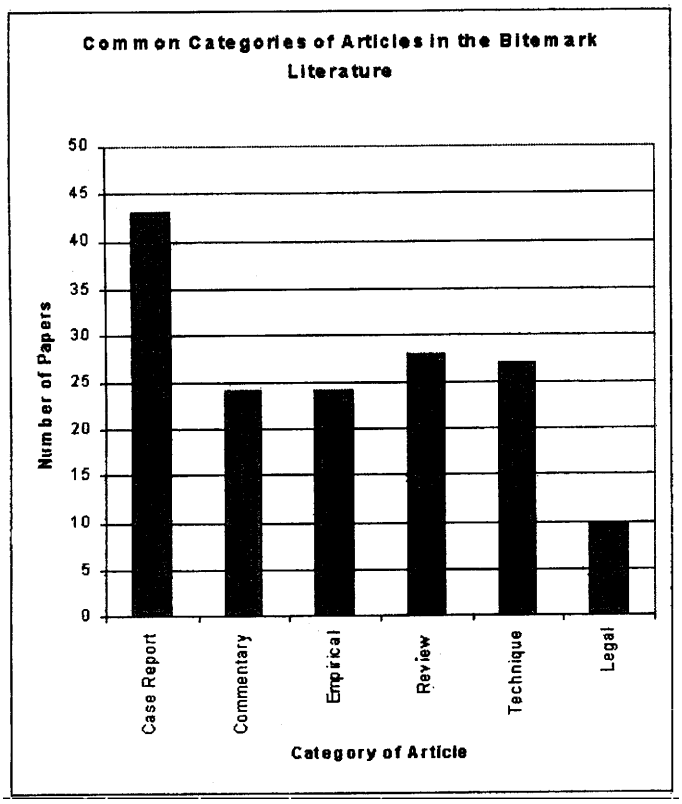
A literature review on the subject of bitemark analysis was presented at the 2000 meeting of the American Academy of Forensic Science in Reno, Nevada.[1] This section gives an overview of the characteristics of and comments on certain seminal articles.

The material was derived from English language publications from 1960 to 1999. The total number of articles was 120, which contained studies of empirical testing (15%), case reports (40%), technique studies (23%), commentaries (20%), and legal and literature reviews (32%). The 1970s brought out initial articles about bitemarks that were later used in the judicial system to justify the conclusion that bitemark analysis was scientific. The 1980s were the decade of greatest activity. The 90s should be considered the period where biochemical analysis of salivary DNA evidence arrived as the first independent means of confirming or invalidating bitemark opinions. Figure 4 shows the distribution of these papers by general type.

[Section 37:21]

[1]C. Michael Bowers & Iain A. Pretty, Critique of the Knowledge Base for Bitemark Analysis During the '60's, '70's and Early 80's, Invited address presented at Annual Meeting of the American Academy of Forensic Sciences, Odontology Section (2000).

Figure 4
The Bitemark Literature: Number of Publications in Various Categories (1960–1999).



The first thing to note is the limited number of studies,[2] and the second is that only a small subset of these studies report scientific research.

The three scientific limitations and areas of controversy of bitemark analysis have been described earlier in §§ 37:15 to 37:18. The following subsections revisit these issues in relation to the literature obtained by this review.

Recent followup database searches were conducted using MedLine, ISI Web of Science, and Forensic Abstracts. The search, performed in 2003, produced a total of 1703 papers with 151 of these specifically related to bitemarks.

The earlier findings, that the vast majority of the articles were case reports, have not changed.

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[2]As a contrast, there were 1457 papers on forensic DNA during the same period of time.

Aside from the human cadaver studies by Bush et al. and Miller et al., discussed supra, very little empirical evidence has been developed in the past several years.[3] This reflects the solo practice nature of the profession, limited training for scientific inquiry, and limited access to scientific equipment. The use of authentic forensic materials for research is also limited, as the average bitemark caseload for individual practitioners has been found to be minimal. A recent study of 37 respondents with forensic training found that only one conducted more than 11 bitemark cases per year.[4]

The recent publications of note in peer reviewed journals have been discussed supra. The most recent published textbooks on forensic odontology and some of its methods are:

1. Digital Analysis of Bitemark Evidence Using Adobe Photoshop.[5]
   This CD-based technique book is the continuation of the 1st edition published in 2000. Simple digital methods are explained and the CD contains practice images for the reader to develop computer imaging skills.
2. C.M. Bowers, Forensic Dental Evidence: An Investigator's Handbook.[6]
   This 200 page book was written for non-dental readers. The contents outline the principles of recognition, collection and preservation of dental evidence seen in criminal and mass disaster investigations.
3. Robert Dorion, Bitemark Analysis.[7]
   This 600 page book is a compilation of contributors who discuss the history and forensic science basis of odontology, human identification from teeth, bitemark analysis, and legal issues in odontology.

§ 37:22 Introductory discussion of the scientific status of bitemark comparisons—Scientific literature on bitemark identification—The accuracy of skin as a record of bitemarks

The bulk of bitemark cases involve injuries on skin. This is not considered a good material on which to record the impression of the biter.[1] The literature shows, however, that the bulk of studies involve bitemarks

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[3]Pretty & Sweet, The Scientific Basis for Human Bitemark Analyses—A Critical Review, 41 Sci. & Justice 85 (2001).

[4]McNamee & Sweet, Adherence of Forensic Odontologists to the ABFO Guidelines for Victim Evidence Collection, 48 J. Forensic Sci. 382 (2003).

[5]Raymond J. Johansen and C. Michael Bowers, Digital Analysis of Bitemark Evidence Using Adobe Photoshop, 2nd edition (2003) [Available from cmbowers@aol.com.]

[6]C. Michael Bowers, Forensic Dental Evidence (2004).

[7]Robert Dorion (ed.), Bitemark Evidence (2004).

[Section 37:22]

[1]Atsu, Gokdemir, Kedici & Ikyaz, Bite Marks in Forensic Odontology, 16 J. Forensic Odontostomatololgy 30 (1998); Stoddart, Bitemarks in Perishable Substances, 135 Brit. Dental J. 85 (1973).

in inanimate materials. Skin has considerable anatomical variation (e.g. breast tissue versus other locations) and also is affected by posture and movement at the time of biting. The 1971 study by DeVore[2] was the first to describe and measure these factors. Figure 2 shows a replication of his simple test where inked stamps were applied at various body locations. In the figure, the lower stamp has been distorted by pressure applied at the bottom of the picture.

DeVore found both shrinkage and expansion of the skin at various positions on the body. The maximum distortion found was 60% expansion at one location. Such variability was seen that the author cautioned about the need to know the exact position of the body at the time of biting before attempting an analysis. This has been generally bypassed in actual practice due to the obvious difficulties in duplicating the dynamics of bitemarks occurring during homicides.

The second article on the mechanics of skin distortion appeared in 1974.[3] It reiterated the variable influence body position had on bitemarks in skin. An additional revelation was the effect of healing over time on the shape of bitemarks. The researchers concluded that the changes in bitemark appearance are likely to become greater as the injury grows older. The article ended with the observation that because odontologists were "still ignorant . . . of the conditions during normal biting . . . considerable research is required" to fill that gap in knowledge.

A 1984 article by Rawson and Brooks[4] delineated a classification of breast shapes but provided no additional investigation of the actual distortion values associated with skin. They opined that "the nature of skin and its underlying structures are still of some concern and will probably be a major source of research interest during the next decade."[5]

The biomechanics of skin was addressed in some detail in the 2009 article by Bush. Skin properties including nonlinearity, visco-elasticity, anisotropy and hysteresis were discussed in relation to how skin responds to applied stress. It was concluded that no two bitemarks from a single dentition were identical and that each bite should be viewed as a unique event due to distortion from the skin. In a subsequent publication, loss of resolution in pattern transfer was demonstrated empirically with a sequence of bitemarks in human cadaver skin.[6] Research in bitemark analysis is hampered by the fact that it is not possible to replicate conditions from actual biting situations. It is hard to imagine Institutional Review

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[2]§§ 37:12 to 37:13.

[3]Barbanel & Evans, Bitemarks in Skin—Mechanical Factors, 14 J. Forensic Sci. Soc'y 235 (1974).

[4]§ 37:9.

[5]Barbanel & Evans, Bitemarks in Skin—Mechanical Factors, 14 J. Forensic Sci. Soc'y at 19 (1974).

[6]Raymond G. Miller et al., Uniqueness of the Dentition as Impressed in Human Skin: A Cadaver Model, 54 J. Forensic Sci. (in press 2009); and Mary A. Bush et al., Biomechanical Factors in Human Dermal Bitemarks in a Cadaver Model, 54 J. Forensic Sci.167 (2009).

Boards approving experimentation on living subjects in which the pain level is excessive, and the dynamics of violent altercation are not reproducible. Thus, human cadaver skin may be the best available model, and the studies mentioned supra represent the current state of science. It remains to be seen whether the 2009 research will affect the prevalent judicial acceptance of bitemark evidence. The cautions expressed in the 1970s have been reiterated and empirically confirmed by this more recent current research.

§ 37:23 Introductory discussion of the scientific status of bitemark comparisons—Scientific literature on bitemark identification—Uniqueness of the human dentition

The introduction to this chapter indicated the context of dental identification of human remains, which uses the shape, type, and placement of dental restorations, root canals, and skeletal landmarks as features with individual characteristics. This identification technique has been validated and consistently produces accurate results as evidenced in mass disasters where even highly fragmented human remains may be identified dentally and later confirmed by other methods.[1]

Identification from bitemarks, however, is more problematic. It is founded on two postulates: (a) the dental features of the biting teeth (six upper and six lower teeth) are unique, and (b) these dental details can be transferred and recorded in the actual bitemark. These two postulates form the basis for bitemark admissibility as a forensic identification discipline. The overall "uniqueness" of dental characteristics is a common statement in court and in the anecdotal forensic literature. This conclusion is generally accepted though it has not been well tested by research, and it has been subject to considerable criticism.

As discussed earlier, it is impossible to prove uniqueness. It is also unnecessary. Most forensic dentists, however, rely on the unproved and unprovable assumption of uniqueness. The advantage of assuming uniqueness is that it excuses the field from quantitatively analyzing objective dental features seen in bitemarks and human teeth. Such analysis would permit the derivation of probabilities of coincidental matches in actual cases. The "probability of a match" choices now used by dentists in court are offered with no consideration of this vitally important determination, but instead are subjective estimates. Some day, forensic dentistry will follow the lead of DNA typing, forget about "uniqueness," and instead gather the necessary data and calculate the probabilities necessary to inform the factfinder. Indeed, the topic of uniqueness has to advance into the more

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[Section 37:23]

[1]The January 31, 2000, Alaska Air crash in Ventura, California, produced multiple positive identifications of victims via dental status, medical status, personal effects, tattoos, fingerprints, and DNA methods.

useful question of coincidental matches, false positive identifications, and scientific proof of conclusions.

Still, the debate over the uniqueness of human teeth is an enduring forensic topic, fueled by a very few articles in the literature. The research that attempted to prove it (the four articles discussed below) explores this path to nowhere. The second and third of the articles are the most often cited as support for the uniqueness claim that forms the foundation of most bitemark opinions.

The first article to consider the statistical treatment of dental features appeared in 1974.[2] MacFarlane et al. studied plaster casts of 200 clinic patients. They developed two categories of features: (a) positive traits were physical shapes and rotations of teeth and (b) negative traits were an absence of teeth. The researchers subjectively inspected the plaster casts and attempted to establish base rates of occurrence of four positive dental features. These features are commonly seen in humans and consisted of (1) the number of teeth and their shapes, (2) any restorations in a front tooth, (3) shape of the jaw, and (4) rotated teeth.

The authors failed to indicate if any of these four features occurred independently of one another, and did not publish their table of results. They used the product rule to establish the likelihood of all four features occurring together and arrived at the value of eight in 100,000 people having teeth who could match a particular dental profile—an over-estimation of improbability due to the apparent violation of the product rule's assumption of independence. This figure was introduced in a later trial to much debate and eventual judicial rejection of this statistical method.[3]

The authors evidently reviewed their data and commented that some dental traits appeared to occur randomly in their study while tooth rotation and other traits were dependent. They edited their final conclusions because of this and reduced the frequency values by a factor of four for the dependent dental traits.[4] They did not claim to have confirmed the individuality of human teeth and did not relate bitemarks to their findings.

A study of five sets of identical twins was published in 1982.[5] Although the article stated that efforts were taken to standardize the production of the test bite exemplars, no details are provided. The paper concluded that the dentitions of each pair of twins could be distinguished. The authors went on to extrapolate these findings to the general human population. The fundamental flaw in the essential logic of this approach has been

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[2]§§ 37:12 to 37:13.

[3]*State v. Garrison*, 120 Ariz. 255, 585 P.2d 563 (1978).

[4]This important limitation was overlooked by Rawson & Ommen, Statistical Evidence for the Individuality of the Human Dentition, 29 J. Forensic Sci. 245 (1984).

[5]Sognnaes & Rawson, Computer Comparison of Bitemark Patterns in Identical Twins, 105 J. Am. Dental Assoc. 449 (1982).

discussed earlier.[6] From a more practical bitemark casework viewpoint, the study is irrelevant to bitemark analysis on skin.

Rawson and Ommen's 1984 study[7] accepted 384 bitemarks in wax from 1200 submitted by contributing dentists. Selection criteria for this subset of the larger sample were not reported. Radiographic prints of the bites were created and then hand traced to produce the outline of the original teeth. This method is not the most accurate, according to a later comparison study.[8]

Several elements of tooth position were then established. It was determined that the minimum number of positions that a tooth can occupy is 150 and the greatest is 239.9. Each tooth's (x, y) coordinate on a graph was multiplied to obtain these values.[9] The authors commented that only five teeth would be necessary for a positive identification (match) of one person from the entire world's population.

Present in this study was the notable use of the product rule. Again, the independence of the dental features examined was not established. But, even if the calculations were correctly based on independent attributes, the notion that if the world population is smaller than the denominator of the fraction produced by the product rule it is thereby proved that no two people on earth can have the same dental profile, is mistaken. This misconstrues the nature of probability. To believe such a conclusion requires us to assume that God (or Mother Nature)—for some unfathomable reason—gives out only one combination of traits to a customer. The error of this assumption is most easily explained with an illustration.[10] Suppose we have a lottery ticket machine that can produce 1000 differently numbered tickets. On any given push of the button it will print a ticket numbered at random somewhere between 000 and 999. And suppose we print out 10 tickets. There are, therefore, one hundred times as many numbers that can be printed as there are tickets actually printed. What law of nature or mathematics requires that each of those 10 tickets has to be different? The fact is that there is no reason the machine could not print duplicates when drawing at random from its pool of numerical possibilities. The probability of duplication is certainly low (and we can calculate how low), but it is by no means impossible. Consider a different example: There is one chance in 600 billion of any given bridge hand being

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[6] § 37:20.

[7] § 37:14.

[8] Sweet & Bowers, Accuracy of Bitemark Overlays: A Comparison of Five Common Methods to Produce Exemplars from a Suspect's Dentition, 43 J. Forensic Sci. at 366 (1998). Resolution of the radiographic and hand traced methods are not optimal methods for reproducing images of teeth.

[9] Although the article as published actually gives this value as 1.4×10^{14}, and in fact gives similar values for all of its reported probabilities, because probability can take on values only between 0 and 1, we are surmising that the quoted number is actually intended to be raised to a negative power.

[10] See Saks, Merlin and Solomon: Lesson's from the Law's Formative Encounters with Forensic Identification Science, 49 Hastings L.J. 1069 (1998).

dealt. Is there any reason to believe that a given hand cannot be dealt again in the next game? Or that it must wait to happen until the other 599,999,999,999 other hands have been dealt? Of course not. Decks of cards, lottery machines and gene pools have no memory for what they did a moment ago.[11]

In present light, this study does confirm that significant variability exists in the human dentition, but not that every person's dentition is distinguishable from every other person's. Although the article argued only that the human population is unique, the paper often is cited as standing for the more dubious proposition of uniqueness of *bitemarks*. But as Rawson & Ommen commented in their article: "[The question is] whether there is a representation of that uniqueness in the mark found on the skin or other inanimate object."[12]

The 2007 paper by Keiser et al. used landmark placement and subsequent geometric morphometric analysis to analyze the six anterior teeth in 33 maxillas and 49 mandibles in orthodontically treated subjects.[13] Geometric morphometric analysis is a well-established branch of science and is used to study biological form. The landmark data are extracted and plotted in Procrustres space resulting in removal of size and rotation effects. Kieser shows plots of the two most similar and most different maxillas and mandibles in his data set. Only small differences were noted in the two most similar plots. Bowers questioned the sample size as being insufficient to support Kieser's claim that his data support uniqueness of the dentition.[14] Bowers' point is that as more dentitions are added to a dataset the greater the chance of a coincidental match. Since we belong to a single species, the human dentition fits within defined boundaries that allow us to function. As the dataset increases, the probability that each additional biter will find a match among the dataset increases. Rather than attempt to prove uniqueness, a more appropriate question would be to determine the match rate in a given population. See, e.g., Figure 5 to consider the similarities of the dental outlines of three of four different adults.

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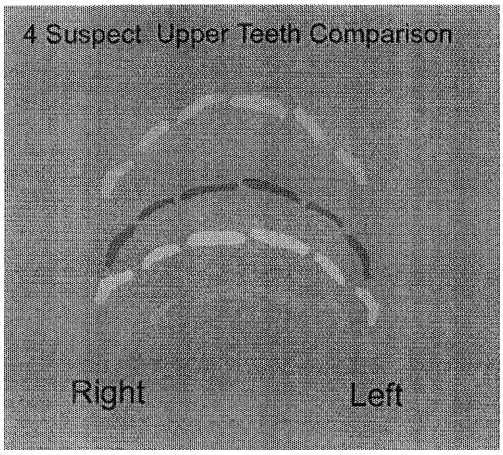
[11]So long as the deck is kept complete throughout the process (sampling with replacement).

[12]Rawson & Ommen, Statistical Evidence for the Individuality of the Human Dentition, 29 J. Forensic Sci. at 252 (1984).

[13]J.A. Keiser et al., The Uniqueness of the Human Anterior Dentition: A Geometric and Morphometric Analysis, 52 J. Forensic Sci. ____ (2007).

[14]C.M. Bowers, Letter, 52 J. Forensic Sci. ____(2007).

Figure 5



The survey of dentists[15] asked respondents a number of questions relating to the question of dental uniqueness. Ninety-one percent of the forensic dentists questioned believed that the human dentition was unique, with only 1% stating that it was not, and 8% were unsure. No evidence from well-designed studies can be found to support such a belief. Seventy-eight percent believed that this uniqueness was replicated on human skin during the biting process. Eleven percent believed not, and 11% were unsure. Ninety-six percent of ABFO Diplomates in this survey stated that the human dentition was both unique and accurately registered on human skin during the biting process. When questioned about the product rule[16] and its application in the determination of dental uniqueness, 60% of the respondents did not know what the product rule was, 22% thought that its use was justified, 9% believed that it should not be used, and 9% were unsure.

Responses regarding the validity of biter identification revealed that the mainstream opinions varied. Seventy percent believed one person alone (to the exclusion of all others) could be identified via a bitemark comparison with teeth. Five percent said it was not possible to identify a biter. Twenty-five percent said it could be done in certain circumstances.

§ 37:24 Introductory discussion of the scientific status of bitemark comparisons—Scientific literature on bitemark identification—Analytical techniques

Empirical testing of methods is an essential basis for confidence in forensic procedures. Bitemark analysis is no exception. The wide variety of comparison techniques allowed by the ABFO is not based on thorough testing to find which are the most accurate. The array of photographic methods, bitemark and suspect exemplar production, and comparison methods are largely unsupported by individual testing and validity testing. The common ground for most dentists, however, is the placement of transparent overlays of the suspect's teeth onto the image of the bitemark. The typical odontologist uses methods that are readily accessible in a dental office. This is mirrored by the technique descriptions and case reports seen in the literature. Occasionally, complex imaging systems are used (e.g., a CT scan to reproduce cross sections of dental casts that give the dentist a look at tooth shape along the length of teeth, or a scanning electron

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[15]McNamee & Sweet, Adherence of Forensic Odontologists to the ABFO Guidelines for Victim Evidence Collection, 48 J. Forensic Sci. 382 (2003). This online survey received responses from forensic odontologists (experienced in actual casework). Fifty-four additional respondents had no bitemark experience. Thirty-eight percent of the respondents were ABFO Diplomates; 3% Fellows (senior level) of the American Academy of Forensic Sciences (AAFS); 33% were AAFS Members (middle level); 24% were American Society of Forensic Odontology members.

[16]See § 37:20 for a dscussion of the erroneous use of probability theory in the bitemark literature.

microscope to magnify a single tooth mark), but these are used relatively rarely.

The article by Sweet and Bowers,[1] discussed previously, is the sole example of testing the relative accuracy of different transparent overlay methods. See Table 3. Xerographic and radiographic methods are the ones most commonly used in the literature. This study concluded that the fabrication methods that utilized the subjective process of hand tracing should be discontinued as being the least accurate. It did not correlate any method's advantage or disadvantage in actual bitemark comparisons.

As a number of legal commentators have observed, bitemark analysis has never passed through the rigorous scientific examination that is common to most normal sciences.[2] The literature does not go far in disputing that claim. Definitive research in these areas remains for the future.

What method of comparison is most accurate remains an unanswered question. Although the American Board of Forensic Odontology (ABFO) has reported advice and guidance on many aspects of collecting bitemark evidence and terminology, the underlying question of what is the best comparison technique to use has not been addressed. This reluctance to establish a stricter protocol persists. The sole validity study of the most commonly used procedures recommended digital analysis.[3] Despite those findings, a review of the proceedings of the American Academy of Forensic Sciences since 1998 suggests that different techniques remain in use.

A recent review by the ABFO produced slight modification of the ABFO Bitemark Methodology Guidelines (see Appendices A, B, and C). The removal of the ability to identify just one person as the source of a bitemark was not supported by the Bitemark Committee tasked with summarizing suggested changes to the Guidelines. Apparently, only a minority of the review committee members agreed to this admonition. The determination of the "weight" of a bitemark comparison or how to support an analytical result using the ABFO approved methods is not discussed. The suggested methods section to the Guidelines was changed from the previous version in the following ways:[4]

DNA Swabs from Skin. DNA collection from a victim's skin was amplified with more scientific explanations.

Dental Cast Exemplars. No change was made to the section involving methods of creating dental exemplars of suspects. The current recommendations disregard primary research that shows computer generated

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[Section 37:24]

[1]§ 37:10.

[2]Zarkowski, Bite Mark Evidence: Its Worth in the Eyes of the Expert, 1 J. L. & Ethics in Dentistry 17 (1988).

[3]Sweet & Bowers, Accuracy of Bitemark Overlays: A Comparison of Five Common Methods to Produce Exemplars from a Suspect's Dentition, 43 J. Forensic Sci. 43 (1998).

[4]ABFO Bitemark Guidelines and Standards, 2006. [Available from www.abfo.org].

overlays to be the most accurate method.[5] Dental exemplars may be made by the following means:[6]

a. Computer generated overlays.
b. Tracings from dental casts.
c. Radiographs created from radio-opaque material applied to the wax bite.
d. Images of casts printed on transparency film.

Comparison of Dental Exemplars to Bitemark Injuries. These methods continue to stress the use of dental exemplars (overlays) which are superimposed onto life-size images of the skin injury. Bitemark and dental comparison methods considered reliable by the ABFO notably show the absence of the "direct" comparison of dental study models onto the skin of a victim. This method was in vogue for decades and was utilized in a number of cases where DNA later exonerated the defendants after conviction. The methods recommended are as follows:

1. Exemplars of the dentition are compared to corresponding-sized photos of the bite pattern.

2. Dental casts to life-sized photographs, casts of the bite patterns, reproductions of the pattern when in inanimate objects, or resected tissue.

The methods to achieve a final determination using the ABFO accepted five levels of certainty (i.e. medical certainty, probable certainty, possible certainty, exclude, or insufficient data) regarding a bitemark/suspect "match" or "mismatch" are not discussed in the document.

§ 37:25 Introductory discussion of the scientific status of bitemark comparisons—Technical advancements

As explained earlier, the basis of many dental opinions (both in the identification of bodies and in bitemark analysis) is the direct superimposition of Questioned (Q) and Known (K) samples that have sufficient identification value to demonstrate features of common origin or establish an exclusionary result. These direct analysis methods demand rigorous attention to scale dimensions and the detection of photographic distortion, be they radiographs, photographic slides, negatives, or prints, or digital images. These dental techniques are generally analogous to the physical comparison of Q and K evidence in fingerprint, firearms, and toolmark studies.

The process of comparing the Questioned (Q) evidence to the Known (K) evidence is controlled by the ABFO Bitemark Standards and Guidelines. What is evident in the literature and in court is that dentists tend to adopt

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[5]Sweet and Bowers, Accuracy of Bite Mark Overlays: A Comparison of Five Common Methods To Produce Exemplars From a Suspect's Dentition, 43 J. Forensic Sci. 1050 (1998).

[6]ABFO Bitemark Guidelines and Standards, 2006.

a method that their professional acquaintances use. Previous articles had talked about the use of digital methods. Sweet and Bowers used a desktop computer and an imaging program called Adobe® Photoshop® to create a transparent *overlay* of the biting perimeters of the teeth (obtained by scanning the dental casts). To review, the older methods included handtracing the tooth perimeters on clear acetate, Xeroxing the dental casts and then tracing the perimeters onto acetate, pushing the dental cast teeth into wax, and the use of X-ray film to capture the teeth impression which had been filled with metallic powder. The following section explains a computer method for bitemark comparison that contains tools which allow for greater control of the bitemark evidence and comparison analysis.

§ 37:26 Introductory discussion of the scientific status of bitemark comparisons—Technical advancements—Digital analysis

Identification disciplines often have the criminalist using a comparison microscope to place the Q and K evidence samples side by side. The loops, whorls, striations, indentations, accidental, and class characteristics present in the evidence samples may then be visually compared. What are difficult to assess, however, in both the crime laboratory and the dental laboratory, are the dimensional parameters of the evidence samples. In dentistry, the traditional ruler and protractor measurements and shape comparison processes are manually derived from evidence photographs and plaster casts of a suspect's teeth. These methods can vary among examiners and are therefore somewhat subjective in nature. Alternatively, some crime lab analysts ignore size comparisons and focus on similarities in class and individual features. In both situations, the possibility of error arises from examiner-subjective methods and partial selection of the total physical information available. Additional tools and protocols clearly are needed. The advent of digital technology has provided an opportunity to greatly improve the quality of comparative analyses. Working in digital format has become commonplace due to its many advantages:

- speed with which digital information can be sent (almost instantaneously)
- large amounts of digital information can be stored in a very small space
- digital images can be enhanced quickly and easily
- chain of custody issues are easily handled with digitization
- digital information can easily be duplicated and shared worldwide
- handling of digital information has proven to be very reliable
- standardization of procedures is simplified

There is no reason why forensic evaluation of dental evidence cannot avail itself of these same advantages.

The recent development of readily available digital imaging software (e.g., Adobe® Photoshop®) and image capture devices such as scanners

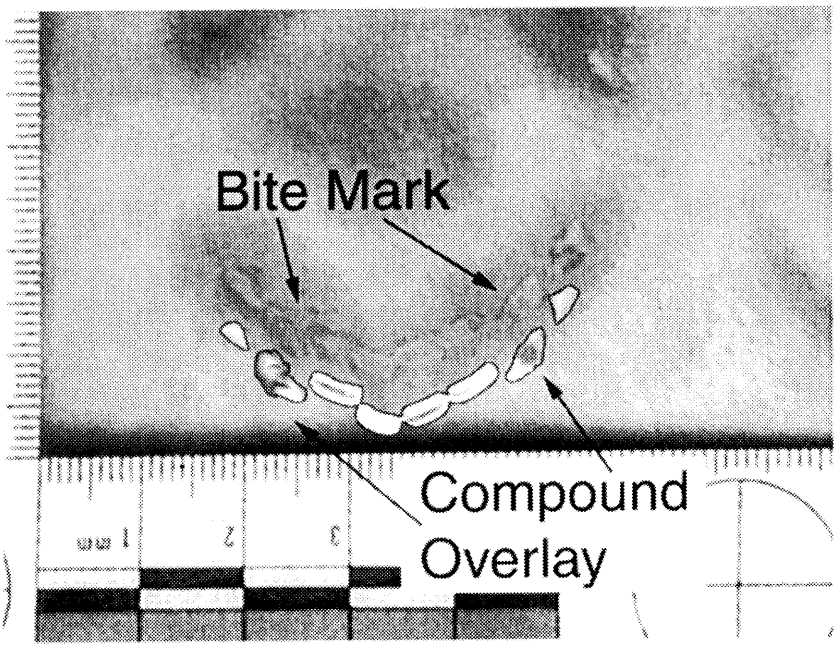
and digital cameras have created an opportunity to allow the dentist to turn the computer monitor into a comparison microscope with the added benefit of the following functions:

- accurate means of measuring physical parameters of crime scene evidence
- correction of common photographic distortion and size discrepancies
- help eliminate examiner subjectivity—better control of image visualization—standardization of comparison procedures
- reproducibility of results between separate examiners
- electronic transmission and archiving of image data
- fabricate exemplars of the evidence and comparison techniques
- accurately demonstrate these exemplars to the trier of fact

Figure 5 shows the background image of a bitemark on pig skin. The "compound overlay" is a digitally captured exemplar of the biter's lower front teeth. The detail present in this experimentally produced comparison shows a high degree of concordance between the exemplars and the injury.

Figure 5

Digital Image Showing Relationship Between Underlying Bite Mark and Computer Generated Exemplar of the Biter's Lower Six Teeth.



§ 37:27 Introductory discussion of the scientific status of bitemark comparisons—Technical advancements—DNA and bitemark analysis

Bitemarks have been considered possible sources of serological information since the 1970s. Swabbing of the bitemark area is considered a primary step in evidence collection, and the availability of DNA profiling of the biter's saliva has created a connection between these two areas of forensic identification.

The use of salivary DNA to analyze bitemarks is a highly objective system and offers a solution to some of the difficulties surrounding physical comparisons. However, the techniques are expensive and are subject to a number of variables: (1) failure to collect DNA; (2) ability to recover sufficient DNA; and (3) degradation of DNA from environmental factors.

An audit[1] of bitemark cases of practicing dentists found that: (1) only 18% of cases involved more than one bitemark suspect; (2) in 73% of cases the only physical evidence available was the bitemark; (3) 84% of the crimes were rated as serious assaults or higher; and (4) DNA was not involved in any of these actual cases.

But when DNA results are pending in a bitemark case, the optimum protocol is to maintain a separation between the two efforts (physical matching and DNA analysis). The literature suggests that the investigation of evidence be independent of extraneous information to prevent either intentional or expectational bias.[2] Knowing that the suspect was caught crawling through the window should not add weight to an otherwise inconclusive bitemark (or an ambiguous autorad). Knowing that the suspect's DNA matched should not add weight to an otherwise inconclusive bitemark (or vice versa). The judicial consumer of expert testimony and opinion has a right to expect odontological testing to be independent and blind to other expert conclusions.

Recent odontological studies indicate that the methods currently in use are most reliable either to exclude (exonerate) or to include (e.g., one of a group of persons who all would match the questioned bite about equally well) suspects.[3]

However, the odontological community sets no limits that restrict bitemark evidence to these two opinions. Seventy-two U.S. odontologists,

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[Section 37:27]

[1]Pretty, A Web-based Survey of Odontologists' Opinions Concerning Bitemark Analyses, 48 J. Forensic Sci. 1117 (2003).

[2]Nordby, Can We Believe What We See, If We See What We Believe?—Expert Disagreement, 37 J. Forensic Sci. 1115 (1992).

[3]Pretty & Sweet, Digital bitemark Overlays—An Analysis of Effectiveness, 46 J. Forensic Sci. 1385 (2001). This statistical analysis of four different dentist groups indicated "weak inter-examiner reliability" as an explanation to the contradictory opinions of bitemark experts. See also, Arheart & Pretty, Results of the 4th ABFO Workshop—1999, 124 Forensic Sci. Int'l 104 (2001).

38% of whom were ABFO Diplomates, were asked if bitemarks should be used only to exclude suspects. Twenty-two percent of all respondents stated "yes," though only 6% of diplomates expressed this view.[4]

§ 37:28 Introductory discussion of the scientific status of bitemark comparisons—Technical advancements—Casework involving both DNA and bitemark evidence

Casework involving both forensic dentistry and molecular biology is increasing. Biological and toothmark evidence, when recovered from the same crime scene, will result in parallel analyses. This section reviews three recently reported instances where both forensic dentistry and molecular biology became intertwined due to the nature of evidence found at the crime scenes. This evidence may be derived from a common origin such as a bitemark on skin which possesses trace amounts of saliva, blood, or semen from the perpetrator. Similarly, an inanimate object connected to the scene might possess toothmarks and biological material that will be compared to physical and genetic data developed from a suspect.

In *State v. White*,[1] a murder victim had been bound and gagged with commercially available duct tape. Marks of five upper teeth were clearly evident on the surface of the duct tape along with the impressions of the lower front teeth showing on the inner cardboard spool. They were presumably made by the assailant using his teeth to tear the tape. A forensic odontologist was retained by the prosecution to compare the pattern in the tape to a suspect's teeth. The suspect had two fractured upper front teeth that compared favorably in size and position to the marks on the tape. Direct physical comparison and a video superimposition of the suspect's dental models were made with a duplicated model of the marks on the tape. The odontology report concluded, with a high degree of confidence, that the suspect's teeth made the indentations in the tape. Prior to the odontologist's analysis, the questioned tape had been swabbed and genomic DNA was obtained and profiled. A DNA report was submitted after the odontological result had been established. The DNA analysis confirmed the odontological findings by concluding that the suspect's salivary DNA was on the duct tape. The odontologist did not become aware of the availability of DNA evidence until after the trial.

In *Regina v. Driver*,[2] a murder victim had been sexually assaulted and bitten on her right breast. The body was recovered after being submerged for approximately eight hours in fresh water. A forensic odontologist recorded the bitemark injury and collected salivary DNA from the injury. Additional swabs were taken according to the normal sexual assault

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[4] § 37:6.

[Section 37:28]

[1] *State v. Wesley White*, No. 5941815-3 (Contra Costa County, Cal., Sup. Ct., 1998) (suspect convicted of second degree murder).

[2] *Regina v. Terry Grant Michael Driver* (Provincial Court, Abbotsford, BC. Canada, Oct. 14, 1995) (defendant convicted of second degree murder).

protocol established by the pathologist. Once a suspect had been apprehended, the odontologist performed a detailed physical comparison of the bitemark and the suspect's dentition. His conclusion indicated a probable connection between the suspect and the victim's bitemark injury. Later, PCR analysis of genomic DNA obtained from the saliva swabs was performed at a separate laboratory. The results indicated the suspect was the source of the questioned DNA.

The impact of DNA analysis in all three cases underscores the persuasiveness of results when both techniques agree. The possibility of a conflict of results also exists.

§ 37:29 Areas of scientific agreement

Although the field of forensic dentistry is continually at odds over the reliability of bitemark identification conclusions, it has reached consensus on important questions of evidence collection procedure. The areas of agreement regarding these methods are broadly outlined in the ABFO Guidelines and Standards.[1] Refer to Appendices for details regarding these topics.

§ 37:30 Areas of scientific agreement—Evidence collection

The American Board of Forensic Odontology has well accepted protocols on the collection of evidence from both bite suspects and victims. Prior to their inception in 1988, the literature and other forensic organizations had not produced comprehensive measures on these subjects. The American Society of Forensic Odontology has a 20-year history of publishing manuals that were collaborative collections of articles on the breadth of odontology. It should be noted that the 33 contributors to the most recent version[1] all are diplomates of the ABFO. The creative process has been by agreement of the parties and, with the exception of photographic methods and techniques involving dental materials, has not been supported by extensive experimental testing. The process of judicial acceptance of this evidence, however, has developed an appellate history that supports these published ABFO protocols and even unaffiliated forensic dentists follow the concepts.

The collection of bitemark evidence is not solely the realm of dentists. This is particularly the case regarding photographic documentation. Police technicians and forensic pathologists may initially collect the evidence for later evaluation by an odontologist. Errors or omissions of certain procedures, such as specialized casting of a three dimensional bitemark,

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[Section 37:29]

[1]C. Michael Bowers & Gary Bell (eds.), Manual of Forensic Odontology at 337 (3rd ed.2001).

[Section 37:30]

[1]C. Michael Bowers & Gary Bell (eds.), Manual of Forensic Odontology at 337 (3rd ed.2001).

the proper excision and preservation of tissue, and collection of DNA evidence, generally result in the permanent loss of information. The weight of these transgressions are commonly debated in court.

§ 37:31 Areas of scientific agreement—Evidence collection—From the victim

The collection of bitemark evidence starts with photographic documentation.[1] This may just be a preliminary recording of the general anatomical location of the bitemark. The collection of possible DNA evidence from deposited saliva or blood must take place before any attempts are made to make the bitemark "cleaner" or otherwise more photographically acceptable. The swabbing done for salivary DNA is simple and should always be performed. The opportunity may never occur again.

Photography continues afterwards. Bitemark analysis demands that a scale or linear measuring device be placed adjacent to the bitemark[2] and parallel to the skin surface and the camera. Color film and black and white film are considered usual modes of photography. Adjunctive modes of digital, videotape, ultraviolet and alternative photography also are permitted.

The impression or casting of the bitemark completes the process. This is omitted if there are no discernible three-dimensional features seen in the bitemark. Dental materials are used throughout this process, which is both time consuming and demands particular attention to distortion control. The impressions are then used to create dental stone casts of the tissue surface. The availability of these models allows the odontologist to discern indentations created by specific teeth. Tissue removal may then occur in special circumstances and through specific methods that create a rigid framework to minimize later shrinkage of the skin. The sub-surface tissue may contain bruising that reveals additional information. The decision to dissect is made by the pathologist or medico-legal authorities.

§ 37:32 Areas of scientific agreement—Evidence collection—From the suspect

Properly written and signed consent of the individual suspect or an explicit warrant must be obtained prior to collection.[1] This aspect of evidence collection focuses on the visual dental examination, intraoral photography

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[Section 37:31]

[1]On the general subject of obtaining evidence from victims, see Appendix 37A to this chapter, ABFO Guidelines on Methods to Preserve Bitemark Evidence.

[2]The ABFO No. 2 (Lightning Powder Co., Salem, Oregon) ruler is preferred due to its L-shape and circular reference targets that indicate the proper alignment of the camera to the evidence. These targets allow the image to be rectified and then properly resized to 1:1 (life-size) if there is off-angle distortion present in the original photograph.

[Section 37:32]

[1]On the general subject of obtaining

and dental impressions. The use of a scale in appropriate photographs is also expected. It is prudent, but not an ABFO requirement, to examine the suspect for loose teeth, limited jaw opening, or abnormal chewing function. This last commonly is omitted in many odontology reports. The determination of jaw function is mandatory since the physical relationship of the upper and lower teeth in a bitemark must be determined to be anatomically possible.

The suspect's DNA may be obtained during this exam. Swabbing of the oral tissues (inside of the cheek) derives a significant amount of cellular material.

§ 37:33 Areas of scientific agreement—Analysis and comparison of bitemarks

The general expectations are that odontologists see all the available evidence that is relevant to the bitemark case. Quite often this involves pretrial discovery challenges to ascertain: (1) just how much evidence (usually photographic) is available; and (2) full disclosure of the methods and overlay materials from the opposing expert.

The comparison methods that occur follow a standard pattern.[1] The bitemark is the background image that has a properly sized exemplar of the suspect's teeth placed over it. Attempts to standardize terminology are meant to control the variations seen in expert expressions regarding the identification value of bitemarks. This being said, there are many versions of "acceptable" analyses and comparison methods. The attendant accuracy of each is up to the examiner to decide. The overlays showing the defendant's teeth can range from wax wafers to MRI images.

Agreement exists regarding the "exclusionary value" of bitemark evidence. If the dental characteristics in a bitemark do not have a spatial and/or shape similarity to a suspect, the expected result is an exclusion of the suspect. The other end of the spectrum is also seen, when odontolgists state that only one individual could have made a particular bitemark.

§ 37:34 Areas of scientific disagreement

The center point of disagreement amongst odontologists is the issue, "what is necessary to support a positive identification from a bitemark?" The odontological literature is silent on the sufficiency of evidence necessary to accomplish this task, yet this positive opinion is permitted to any

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evidence from suspects, see Appendix 37B. ABFO Guidelines on Methods for the Collection of Suspect Dentition.

[Section 37:33]

[1]See Appendix 37C, ABFO Guidelines on Methods of Comparing Bitemark Evidence.

dentist. Those odontologists who doubt the statement that "bitemarks are as powerful as fingerprints"[1] consider the positive identification of just one person to be quite rare and possible only when remarkable physical detail is present in a bitemark (usually *not* in skin).

The availability of probability theory as a bolster to bitemark identifications is a decades long practice. This flies in the face of aforementioned limitations to "uniqueness" determinations. This continues to be a highly controversial issue among forensic dentists.

The final, and most telling, major disagreement concerns the reliability of bitemark opinions. The proficiency results from the ABFO 4th Bitemark Workshop[2] seriously conflict with decades of assurances by odontologists that scientific reliability is possible and is in effect with bitemark analysis.

§ 37:35 Unresolved issues

What is the threshold quantum of information necessary to diagnose a skin injury as a human bitemark? The bitemark literature considers dental features seen in skin injuries or foodstuffs as "points," or uses synonyms to describe a physical finding pertaining to a tooth. This effort is rather vague since this "point" may be a complete tooth shape, a deeper bite injury showing more three-dimensional information, or only a portion of a tooth that is seen in the injury. The forensic identification value of each "point" is up to the individual dentist. It must be emphasized that many bitemark cases involve nothing more than bruising. The dental examiner must acknowledge that bruising generally creates an area of discoloration that exceeds the dimensions of the compared suspect teeth. The number of "points" necessary to conclude a human bitemark exists is not mandated in the ABFO Guidelines, and in fact is unknown. It is left to the subjective judgment of each examiner. This makes each bitemark case a potential argument between opposing dentists from the very beginning. In unfortunate cases, the question of "whether it is a human bitemark" can take place with the bitemark having been made by just one tooth—if it is a bitemark.

What is the probability that a random match has occurred between a suspect's teeth and a bitemark? The prosecution usually would like to argue that the risk of a coincidental match is so small that it can safely be ignored. The defense usually would like to argue that the risk of a coincidental match is too great not to be taken into account. But at present no one can answer this question in a scientific manner. Any assertion of a small chance is the realm of dentist judgment, even speculation.

How much detail is necessary in a bitemark analysis report? Many experienced odonotologists prepare reports that contain limited and vague

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[Section 37:34]

[1]Ira A. Gladfelter, Dental Evidence: A Handbook for Police 23 (1975).

[2]§§ 37:12 to 37:13.

information, and which might later be modified at will by the odontologist, just before or even during trial.[1] The typical report contains a list of evidence (usually a single set of dental models of a suspect and bitemark photographs), possibly a copy of the overlay (if one has been used; it is not mandatory) of the suspect's teeth, and a statement regarding conclusions. Other odontologists are of the view that reports must contain specific details of the analyses, indicating exactly what the observations are and how they lead to the examiner's conclusions.

Proper documentation of image enhancements and color changes performed to evidence photographs. The permitted use of video and digital imaging creates the necessity for the examiner to quantify changes or "improvements" done to an image's color balance, brightness, contrast, and levels of hue and saturation. The lack of "before" and "after" values makes the duplication of another examiner's efforts problematic at best.

The amount of photographic distortion that precludes a bitemark analysis. It is common for dentists to receive evidence photographs from a bitemark case. This presents problems if the pictures have been taken improperly. A threshold requirement is that the bitemark be photographically reproduced in a manner that is free of controllable distortion. The literature well documents examples of less than accurate bitemark photographs. Among the common errors are: (1) the improper placement of a scale within the same plane of a bitemark, (2) the camera is not parallel to the plane of the bitemark and (3) the bitemark and the scale are not close enough to each other. The uncorrected acceptance of any of these factors means that the bitemark will not be properly sized and its shape will be distorted. This should preclude any final analysis with a suspect's teeth.

Estimates of the force necessary to create a particular injury. This is a common question from lawyers and an answer is unattainable. Another variation is "would this injury have caused pain?" Any answers are subjective as the literature is silent to both subjects.

Can a bitemark constitute "Deadly Force?" This is largely a legal question since the dental literature does not contain articles which describe someone dying from a bitemark. Communicable disease may be transmitted by a bite that breaks the skin.

The American Board of Forensic Odontology [ABFO] Guidelines and Standards for bitemark evidence were initiated in 1986[2] and have not been

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[Section 37:35]

[1]Modifying conclusions or reports before or after they have been written in order to make the findings and conclusions more consistent with other evidence in the case is a practice specifically condemned by the Inspector General in the investigation of misconduct at the FBI Crime Laboratory. Office of the Inspector General, United States Department of Justice, The FBI Laboratory: An Investigation into Laboratory Practices and Alleged Misconduct in Explosives—Related and Other Cases (1997).

[2]American Board of Forensic Odontology, Inc., Guidelines for Bitemark Analysis,

updated since 1995.[3] The Guidelines contain suggestions for the odontologist practicing bitemark analysis, but they lack science-based validation of suggested comparison protocols. Such validation, if achieved, would assure the accuracy of the permitted levels of confidence.[4] The intent of the document's originators was to promote uniformity of the investigative approach to bitemarks by odontologists. This has failed to materialize, since these guidelines are not sufficiently narrow in methodology to provide guidance in the analysis of bitemarks and suspect teeth. Recent discussion of the forensic dental community's adherence to certain Bitemark Guidelines and Standards has been favorable. This is limited, however, in that it related only to proper evidence collection methods.[5] The ABFO is silent about the best comparison method(s) that would improve accuracy in bitemark identification cases.

This lack of a standard protocol is an underlying reason that calibration of forensic dentists' methods and results is subject to continued debate and public contradiction.[6] The caveat given to dentists in recent bitemark testimonials is for the evidence to be "good" before initiating a comparison to a suspect. But this remains no more than an "in the eye of the beholder" opinion for the odontologist rather than a substantive threshold having biological meaning and forensic identification value. Recent authors have confirmed the discipline's rationale that bitemark analysis is a qualitative process. They argue that it cannot be reinforced or restrained by statistical assurances of accuracy.[7]

Argument, pro and con, regarding the scientific underpinnings of

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112 J. Am. Dent. Ass'n 383 (1986).

[3]C. Michael Bowers & G. L. Bell, eds. Manual of Forensic Odontology (1995), at 334–357. The addition was report writing guidelines which were published in this technique manual for aspiring odontologists. They are purely voluntary in nature and are frequently ignored by practitioners.

[4]§ 37:12. Degrees of bitemark identification allowed are: virtual certainty, probable, possible, improbable, incompatible (exclusionary) and inconclusive.

[5]Pretty & Sweet, Adherence of Forensic Odontologits to the ABFO Bitemark Guidelines for Suspect Evidence Collection, 46 J. Forensic Sci. 1152 (2001). Two groups of forensic dentists (41 ABFO Diplomates and 28 non-ABFO dentists) were surveyed regarding types of dental impression materials they used and what forensic dental exam protocols they performed. There was little variation between the groups. It is notable that the original evidence collection was done by non-dentists in most active cases reported by these groups. This reflects law enforcement's role in recognizing, documenting and preserving this type of forensic evidence.

[6]*People v. Harold Hill*, Superior Court of Cook County (Illinois), PC 92CR8344 (post-conviction). This 1994 case resulted in conviction of two defendants for the sexual assault and homicide of a teenage girl. There were two possible bitemarks on the girl's body. The prosecution was heavily reinforced by an ABFO past president who stated he could positively (with medical/dental certainty) identify one defendant as a biter. He considered the other defendant as a possible biter. Appellate Counsel obtained DNA evidence in 2002 that exonerated both men. Also see *State v. Krone*, at § 37:7. Misidentification errors such as these have not yet been taken heed of by the forensic dentistry field.

[7]Kittleson, et al., Weighing Evidence: Quantitative Measures of the Importance of Bitemark Evidence, 20 J. Forensic Odontostomatol. 31–37 (December 2002).

bitemark identifications occasionally are superficially addressed in some trial courts. The commonly contested issue by opposing dentists, which then is typically given to the jury to resolve, is what denotes "good bitemark evidence"? The basis of this expert disagreement is, considering this author's casework, that some odontologists discuss tooth class characteristics seen in bitemarks as if they were individualizing (read: unique; one of a kind) characteristics.

Notwithstanding the occurrence of cases where DNA has shown flawed bitemark opinions leading to false convictions, the majority of the profession feels a positive identification of a given individual as a biter can be made with "reasonable doubt" not being an issue.

Research findings supporting pinpoint bitemark identification do not yet exist. This field of human identification can be considered to be in a state of flux. The recent bitemark literature contains two studies[8] that support limiting bitemark identification opinions to the more conservative categories. According to the survey mentioned above, the practitioners of the discipline (ABFO members) who adhere to the view of bitemark identification reliability outnumber the skeptics by about 3 to 1. Notable is that the non-ABFO dentists were of the view that bitemarks' usefulness is limited to including or excluding outnumber their ABFO brethren by 22% to 6%.[9]

§ 37:36 Future directions

A significant improvement of forensic education is mandatory. The bulk of U.S. forensic odontologists are self-trained products of seminars and week-long meetings. The interface between odontologists and academic programs involving pathology, criminalistics and forensic biology needs to deepen. The availability of forensic "cross-training" in these disciplines and the law would develop clearer understanding of law enforcement and the judiciary's slowly growing requirement of stringently validated protocols for methods and conclusions.

The future work of forensic odontology must focus on reliability testing of procedures, methods, and examiners. Testing the validity of such propositions as "everyone's teeth are unique" and "this bitemark shares the dental characteristics of one person in all the world" also are at the top of the list of future work the field must do. Population studies on the lines of what was accomplished in DNA typing would start to distinguish what is commonly seen in a dental profile and what features are seen less often. The assessment of independence among these features must also be

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[8]See, Arheart & Pretty, Results of the 4th ABFO Bitemark Workshop—1999, 124 Forensic Sci. Int'l 104 (2001). Pretty & Sweet, The Scientific Basis for Human Bitemark Analysis—A Critical Review, 41 Sci.& Justice 85 (2001).

[9]Pretty, A Web-based Survey of Odontologists' Opinions Concerning Bitemark Analyses, 48 J. Forensic Sci. 1117 (2003).

undertaken.

The question of coincidental matches between a bitemark and an innocent person must be satisfied. The determinations of "likelihood ratios" to calculate the probability that one set of teeth in a bitemark could randomly match more than one person is an oft quoted wish. The confounding variables found in most bitemark patterns make experimental control that is necessary for these findings very difficult to achieve. The reality is that individualizing (only one person) dental characteristics seldom are seen in bitemarks.

A current belief exists that "the forensic dentist of today often is able to see matching characteristics that are difficult to demonstrate to other less experienced observers or jury member."[1] This axiom has apparently been gored by the ABFO Bitemark Workshop No. 4 where the findings suggest that experience has no relationship to the accuracy of bitemark opinions.

The following are several additional issues in bitemark analysis that are of some importance.

What is the threshold quantum of information necessary to diagnose a skin injury as a human bitemark? The bitemark literature considers dental features seen in skin injuries or foodstuffs as "points," or uses synonyms to describe a physical finding pertaining to a tooth mark. This effort is rather vague since this "point" may be a complete tooth shape, a deeper bite injury, or only a portion of a tooth. The forensic value of each "point" is up to the individual dentist. The number of "points" necessary to identify a human's bitemark is not mandated in the ABFO Guidelines and, in fact, is unknown. It is left to the subjective judgment of each examiner.

Considering the enormity of all these limitations, the future may contain a forensic revamping of bitemark analysis testimony where a positive identification is not allowed, but, rather, only a lesser opinion is admissible. On the other hand, if the testing methods of the forensic DNA community (the ability to calculate coincidental matches) can be imported into the odontological context, the future will be brighter.

[Section 37:36]

[1]David L. Faigman, David H. Kaye, Michael J. Saks & Joseph Sanders, Modern Scientific Evidence: The Law and Science of Expert Testimony, Identification from Bitemarks: Bite Mark Guidelines and Studies § 24-2.4.1, 181 (1997).

APPENDIX 37A

ABFO Bitemark Methodology Guidelines

July 2006 Updated ABFO Bitemark Standards and Guidelines

History

This project is an update of the efforts begun at the first Bitemark workshop in 1984. This set of guidelines is not intended to invalidate the document generated as a result of previous workshops.

Please read Bitemark Methodology with the following perspective:

There is a need for forensic dentists to agree on basic methodology used in bitemark cases so as to maximize the quality, completeness, and validity of the collection and analysis of bitemark evidence. It is not expected that this document is ideal to all forensic dentists. However, it represents majority opinions and has the highest level of acceptance to the largest number of odontologists. All Diplomates (and other forensic odontologists) will have to make some compromises if the science of forensic odontology is to achieve the higher objective of universally agreeable methodology. There is no intention for the ABFO to mandate methods but instead to provide a list of generally accepted valid methods for this point in the development of our science. This document is not meant to stifle the development of new valid techniques that meet the criteria of the scientific method. There is every intention for the ABFO, as a credible body of experts, to present a clear and unified message as to what its members use and accept as valid methods for the collection and analysis of bitemark evidence. This document will present methods that have been agreed upon and approved as valid preservation and analysis procedures. In keeping with the commitment not to stifle the development of new methods, individuals should continue to develop new and possibly better techniques. These new techniques should be backed up by the use of accepted techniques and should satisfy the basic concepts of the scientific method.

Please read Bitemark Terminology with the following perspective:

Forensic dentists need to agree on language and terminology used in bitemark cases so as to avoid miscommunicating facts and opinions to attorneys, judges, juries and other dentists. This document represents majority opinion of ABFO Diplomates, and has the highest level of acceptance to the largest number of odontologists. **ALL** Diplomates (and other forensic odontologists) will have to make some compromises if the science of forensic odontology is to achieve the higher objective of universally agree-

able communication.

There is no intention for the ABFO to mandate language as it is used within the body of a report or in testimony when responding to specific or hypothetical questions.

There is every intention for the ABFO, as a credible body of experts, to present a clear and unified message as to what its members mean when they state a conclusion. This document will present language that has been agreed upon and approved for communicating bitemark opinions.

Bite mark vs. Bitemark

It is the feeling of the ABFO that the meaning of the word in any of its forms is clear and there is no need for the ABFO to endorse a particular form.

Methods to Preserve Bitemark Evidence

General Considerations—It should be recognized that often the Forensic Odontologist is often involved in the initial examination and collection of the Bitemark evidence. This does not necessarily preclude the ability of the Forensic Odontologist to render a valid opinion. The below listed methods are not meant to be an all-encompassing list of preservation methods; however, it does list those methods that are used by the Diplomates of the ABFO. The use of other methods of documenting the Bitemark evidence should be in addition to these techniques.

Evidence collection will be done with appropriate authorization.

It should first be determined whether washing, contamination, lividity, embalming, decomposition, change of position, etc, have affected the bitemark.

A. Saliva Swabs of Bite Site
   - Aim — Acceptance of DNA evidence by the courts and the power of discrimination of current DNA testing has resulted in previous methods of salivary analysis, such as blood group antigens, being replaced by DNA methods. The aim of swabbing the bite site is now solely the collection of cells for DNA.
   - Jurisdiction — It is often unclear who is responsible to collect saliva evidence from the bite site. Since the odontologist is not usually the first to see the bite, others such as the medical examiner, coroner or police technologist might have already swabbed the area. It is the odontologist's responsibility to determine if swabs for DNA have been taken before he/she examines the site, and to take them if they were not previously recovered.
   - When — DNA degrades over time and in the presence of such things as UV light, seawater, extreme heat, acidic soil, skin decomposition, etc. Swabs should be taken as soon as possible after the bite is inflicted and before the area is cleaned or washed. If it can be determined that the bite was inflicted through cloth-

ing, attempts should be made to seize the clothing for DNA analysis.

- Method — The double swab method will maximize the amount of DNA recovered. One swab that is moistened with sterile distilled water is used with medium pressure to wash the dried saliva from the surface over a period of 7–10 seconds. Within a few seconds of finishing with the first swab, a second swab that is dry is used as a sponge with light pressure to collect the moisture left on the surface by the first swab. The two swabs must be air-dried at room temperature prior to submission to the laboratory, or inserted into a sterile container that will allow air to circulate during storage.
- Storage — The swabs should be submitted for analysis as soon as possible. They are kept at room temperature if submitted within 4–6 hours, or refrigerated (not frozen) if stored longer than 6 hours.
- DNA Control Sample — A sample of the bite victim's DNA is usually collected by others for investigative purposes. This sample, usually whole blood or tissue, is also used for interpretation of DNA mixtures from the bite swabs. No other form of control sample from the victim is required to be taken by the odontologist.

B. Photographic Documentation of the Bite Site

- The bite site should be photographed using digital and/or conventional photography. (Guidelines of the ABFO Digital Enhancement Committee will be followed)
- The photographic procedures should be performed by the forensic odontologist or under the odontologist's direction to insure accurate and complete documentation of the bite site.
- Orientation and close-up photographs should be taken.
- Photographic resolution should be of high quality.
- Color print, and/or slide film, and black and white film may be used. If color film is used, accuracy of color balance should be assured.
- Photographs of the mark should be taken with and without a scale in place.
- When the scale is used, it should be on the same plane and adjacent to the bitemark. It presently appears desirable to include a circular reference in addition to a linear scale. (An ABFO No. 2 or an equivalent right-angle scale should be utilized).
- The most critical photographs should be taken in a manner that will eliminate distortion
- In the case of a living victim, it may be beneficial to obtain serial photographs of the bitemark
- Photographic filters, specialty film, alternate methods of illumina-

tion may be used to record the bite site *in addition t*o unfiltered photographs.

- Video imaging may be used *in addition* to conventional and digital photography.

C. Impressions

- Impressions should be taken of the surface of the bitemark whenever it appears that this may provide useful information.
- The impression materials used should meet American Dental Association specifications and should be identified by name in the report.
- Suitable support should be provided for the impression material to accurately reproduce body contour.
- The material used to produce the case should accurately represent the area of impression and should be prepared according to the manufacturer's instructions.
- When a self-inflicted bite is possible, impressions of the individual's teeth should be made.
- Impressions of the bite site should be made when indicated.

D. Tissue Samples

- In the deceased, tissue specimens of the bitemark should be retained whenever it appears this may provide useful information. The bite site may be excised and preserved following proper stabilization prior to removal with appropriate approval.

APPENDIX 37B

Evidence Collection of Suspected Dentition

Before collecting evidence from the suspect, the odontologist should ascertain that the necessary search warrant, court order, or legal consent has been obtained, and should make a copy of this document part of his records. The court document or consent should be adequate to permit collection of the evidence listed below:

A. Dental Records

Whenever possible the dental records of the individual should be obtained.

B. History

Obtain history of any dental treatment subsequent to, or in proximity to, the date of bitemark.

C. Photography

Whenever possible, good quality extraoral photographs should be taken, both full face and profile. Intraoral photographs preferably would include frontal view, two lateral views, occlusal view of each arch, and any additional photographs that may provide useful information. It is also useful to photograph the maximum interincisal opening with scale in place. If inanimate materials, such as foodstuffs, are used for test bites, the results should be preserved photographically.

- Photographs of the dentition should be made by the forensic dentist or under the odontologist's direction.
- A scale may be utilized during photography.
- Video imaging may be used to document the dentition *in addition* to conventional and/or digital photography.

D. Extraoral Examination

The extraoral examination should include observation and recording of significant soft and hard tissue factors that may influence biting dynamics, such as temporomandibular joint status, facial asymmetry, muscle tone and balance. Measurement of maximal opening of the mouth should be taken, noting any deviations in opening or closing, as well as any significant occlusal disharmonies. The presence of facial scars or evidence of surgery should be noted, as well as the presence of facial hair.

E. Intraoral Examination

- In cases in which saliva evidence has been taken from the victim, saliva evidence should also be taken from the suspect in accor-

dance with the specifications of the testing laboratory.

- The tongue should be examined in reference to size and function. Any abnormality such as ankyloglossia should be noted.
- The periodontal condition should be observed with particular reference to mobility and areas of inflammation or hypertrophy. In addition, if anterior teeth are missing or badly broken down it should be determined how long these conditions have existed.
- It is recommended that, when feasible, a dental chart of the suspect's teeth be prepared, in order to encourage thorough study of the dentition.

F. Impressions

Whenever feasible, at least two impressions should be taken of each arch, using materials that meet appropriate American Dental Association specifications and are prepared according to the manufacturer's recommendations, using accepted dental impression techniques. The interocclusal relationship should be recorded.

- Dental impressions should be made by the forensic dentist or under their supervision.

G. Sample Bites

Whenever feasible, sample bites should be made into an appropriate material, simulating the type of bite under study.

H. Study Casts

- Master casts should be prepared using American Dental Association approved Type II stone prepared according to manufacturer's specifications, using accepted dental techniques.
- Additional casts may be fabricated in appropriate materials for special studies. When additional models are required, they should be duplicated from master casts using accepted duplication procedures. Labeling should make it clear which master cast was utilized to produce a duplicate.
- The teeth and adjacent soft tissue areas of the master casts should not be altered by carving, trimming, marking, or other alterations.

I. Saliva Samples

- A DNA sample from the suspect is needed to enable comparison to any biological evidence at the crime scene that is thought to originate from the suspect. The best source of DNA evidence is whole blood, so usually others recover this suspect DNA sample under the provision of a warrant. There is currently no need for the odontologist to collect a saliva sample at the time of examination of the suspect.

Standards for "Bitemark Analytical Methods"

1. All Diplomates of the American Board of Forensic Odontology are

responsible for being familiar with the most common analytical methods and should utilize appropriate analytical methods.

2. A list of all the evidence analyzed and the specific analytical procedures should be included in the body of the final report. All available evidence associated with the bitemark must be reviewed prior to rendering an expert opinion.

3. Any new analytical methods not listed in the previously described list of analytical methods should be explained in the body of the report. New analytical methods should be scientifically sound and verifiable by other forensic experts. New analytical methods should, if possible, be substantiated with the use of one or more of the accepted techniques listed in these guidelines.

Bitemark Analysis Guidelines

Description of Bitemark

The odontologist should record and describe:

1. Identification Data (case number, agency, name of examiner(s), etc.)
2. Location of Bitemark
   - anatomical location or object bitten
   - surface contour: (e.g., flat, curved or irregular)
   - tissue characteristics
3. Shape, color, and size
4. Type of Injury (e.g., abrasion, contusion, avulsion)
5. Other Information as indicated (e.g., three-dimensional characteristics, unusual conditions, derived from excised tissue, transillumination).

APPENDIX 37C

Methods of Comparing Exemplars to Bitemarks

1. **Types of Overlays:**
   - Computer generated
   - Tracing from dental casts
   - Radiographs created from radiopaque material applied to the wax bite.
   - Images of casts printed on transparency film.
2. **Test Bites (wax, Styrofoam, clay, skin, etc.)**
3. **Comparison Techniques**
   - Exemplars of the dentition are compared to corresponding-sized photos of the bite pattern.
   - Dental casts to life-sized photographs, casts of the bite patterns, reproductions of the pattern when in inanimate objects, or resected tissue.
4. **Other Methods Employed For Analysis**
   - Transillumination of tissue
   - Computer enhancement and/or digitization of mark and/or teeth
   - Stereomicroscopy and/or macroscopy
   - Scanning Electron Microscopy
   - Video superimposition
   - histology
   - Metric studies

ABFO Bitemark Terminology Guidelines

Component Injuries Seen in Bitemarks

Abrasions (scrapes), contusions (bruises), lacerations (tears), ecchymosis, petechiae, avulsion, indentations (depressions), erythema (redness) and punctures might be seen in bitemarks. Their meaning and strict definitions are found in medical dictionaries and forensic medical texts and should not be altered. An incision is a cut made by a sharp instrument and, although mentioned in the bitemark literature, it is not an appropriate term to describe the lacerations made by incisors.

A Characteristic

A *characteristic,* as applied to a bitemark, is a distinguishing feature,

trait, or pattern within the mark. Characteristics are two types, *class characteristics* and *individual characteristics.*

Class characteristic: a feature, trait, or pattern that distinguishes a bitemark from other patterned injuries. For example, the finding of four approximating linear or rectangular contusions is a class characteristic of human incisors. Their dimensions vary in size depending upon what inflicted the injury: maxillary or mandibular teeth; and, whether primary or permanent teeth. Moreover, the overall size of the injury will vary depending on the contributor's arch dimension. Thus, a bitemark *class characteristic* identifies the group from which it originates: human, animal, fish, or other species.

Individual characteristic: a feature, trait, or pattern that represents an individual variation rather than an expected finding within a defined group. There are two types:

Arch characteristic: a pattern that represents tooth arrangement within a bitemark. For example, a combination of rotated teeth, buccal or lingual version, mesio-distal drifting, and horizontal alignment contribute to differentiation between individuals. The number, specificity, and accurate reproduction of these arch characteristics contribute to the overall assessment in determining the degree of confidence that a particular suspect made the bitemark (e.g., rotation, buccal or lingual version, mesial or distal drifting, horizontal alignment).

Dental characteristic is a feature or trait within a bitemark that represents an individual tooth variation. The number, specificity, and accurate reproduction of these dental characteristics in combination with the *arch characteristics* contribute to the overall assessment in determining the degree of confidence that a particular suspect made the bitemark (e.g., unusual wear pattern, notching, angulations, fracture).

Distinctive — This term is variably defined as either rare or unusual.

- variation from normal, unusual, infrequent.
- not one of a kind but serves to differentiate from most others.
- highly specific, individualized.
- lesser degree of specificity than unique.

Bitemark Definitions

Bitemark:

- A physical alteration in a medium caused by the contact of teeth.
- A representative pattern left in an object or tissue by the dental structures of an animal or human.

Describing the Bitemark

A circular or oval (doughnut) (ring-shaped) patterned injury consisting of two opposing (facing) symmetrical, U-shaped arches separated at their bases by open spaces. Following the periphery of the arches are a series of

individual abrasions, contusions, and/or lacerations reflecting the size, shape, arrangement, and distribution of the class characteristics of the contacting surfaces of the human dentition.

Variations:

1. Additional features:
   - Central Ecchymosis (central contusion).
   - Linear Abrasions, Contusions or Striations
   - Double Bite—(bite within a bite)
   - Weave Patterns of interposed clothing.
   - Peripheral Ecchymosis
2. Partial Bitemarks
3. Indistinct/Faded Patterned Injury (e.g., fused or closed arches, solid ring pattern)
4. Multiple Bites.
5. Avulsive Bites.

Terms Indicating Degree of Confidence That an Injury is a Bitemark:

Bitemark — Teeth created the pattern; other possibilities were considered and excluded.

- *criteria*: pattern conclusively illustrates a) classic features. b) all the characteristics, or c) typical class characteristics of dental arches and human teeth in proper arrangement so that it is recognizable as an impression of the human dentition.

  Suggestive — The pattern is suggestive of a bitemark, but there is insufficient evidence to reach a definitive conclusion at this time.
- *criteria:* general shape and size are present but distinctive features such as tooth marks are missing, incomplete or distorted or a few marks resembling tooth marks are present but the arch configuration is missing.

  Not a bitemark — Teeth did not create the pattern.

Descriptions and Terms Used to Relate Bitemark to the Suspected Biter:

Descriptors to indicate similarities between a bitemark and a person's dentition:

Reasonable Dental/Medical Certainty — beyond a reasonable doubt.

Probable — more likely than not.

Exclusion — ruled out.

Inconclusive — insufficient evidence to relate the bitemark to the suspected biter.

ABFO Standards for "Bitemark Terminology"

The following list of Bitemark Terminology Standards has been accepted by the American Board of Forensic Odontology.

1. Terms assuring unconditional identification of a perpetrator, or without doubt, are not sanctioned as a final conclusion.

2. Terms used in a different manner from the recommended guidelines should be explained in the body of a report or in testimony.

3. All boarded forensic odontologists are responsible for being familiar with the standards set forth in this document.

APPENDIX 37D

ABFO Scoring Sheet for Bite Mark Analysis

(Important: Use only with scoring guide, score only reliable information.)

Case Name:

Features Analyzed Discrepancy (if any)	Nbr. of Points	Max.	Mand.
Gross			
All teeth in mark present in suspect's mouth	*One per arch		
Size of arches consistent (i.e. mark not larger than dental arch)	*One per arch		
Shape of arches consistent	*One per arch		
Tooth Position			
Tooth and tooth mark in same labiolingual position	*One per tooth		
Tooth and mark in same rotational position (whether rotated or normal)	*One per tooth		
Vertical position of tooth regarding occlusal plane matches depth of mark (use only in unusual case)	*One per matching tooth		
Spacing between adjacent marking edges	*One per space		

Case Name:

Features Analyzed Discrepancy (if any)	Nbr. of Points	Max.	Mand.
Intradental Features			
Mesiodistal width of tooth matches mark (use only if individual tooth is clearly marked)	*One per tooth		
Labiolingual width of tooth matches mark OR attrition of edge matches mark	**Three per tooth		
Distinctive curvature of tooth incisal edge matches mark (use only in unusual case)	**Three per tooth		
Other distinctive features (fractured teeth, unusual anatomy)	Three per tooth		
Miscellaneous			
Suspect has one edentulous arch and this is reflected in bite mark	Three		
	Total, each arch:		
	Grand Total:		

* Three points if feature is significantly distinctive.
** Only in case permitting accurate measurement.

Signature _____ Date _____
2/20/84 Committee on Bite Mark Guidelines

Note: Compilation of "points" was abandoned in January 1988.

APPENDIX 37E

National Research Council Comments

FORENSIC ODONTOLOGY

Forensic odontology, the application of the science of dentistry to the field of law, includes several distinct areas of focus: the identification of unknown remains, bite mark comparison, the interpretation of oral injury, and dental malpractice. Bite mark comparison is often used in criminal prosecutions and is the most controversial of the four areas just mentioned. Although the identification of human remains by their dental characteristics is well established in the forensic science disciplines, there is continuing dispute over the value and scientific validity of comparing and identifying bite marks.[1]

Many forensic odontologists providing criminal testimony concerning bite marks belong to the American Board of Forensic Odontology (ABFO), which was organized in 1976 and is recognized by the American Academy of Forensic Sciences as a forensic specialty. The ABFO offers board certification to its members.[2]

Sample Data and Collection

Bite marks are seen most often in cases of homicide, sexual assault, and child abuse. The ABFO has approved guidelines for the collection of evidence from bite mark victims and suspected biters.[3] The techniques for obtaining bite mark evidence from human skin—for example, various forms of photography, dental casts, clear overlays, computer enhancement, electron microscopy, and swabbing for serology or DNA—generally are well established and relatively noncontroversial. Unfortunately, bite marks on the skin will change over time and can be distorted by the elasticity of the skin, the unevenness of the surface bite, and swelling and healing. These features may severely limit the validity of forensic odontology. Also, some practical difficulties, such as distortions in photographs and changes over time in the dentition of suspects, may limit the accuracy of the results.[4]

Analyses

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[1] E.g., J.A. Kieser. 2005. Weighing bitemark evidence: A postmodern perspective. *Journal of Forensic Science, Medicine, and Pathology* 1(2):75-80.

[2] American Board of Forensic Odontology at www.abfo.org.

[3] American Board of Forensic Odontology at www.abfo.org.

[4] Rothwell, op. cit.

The guidelines of the ABFO for the analysis of bite marks list a large number of methods for analysis, including transillumination of tissue, computer enhancement and/or digitalization of the bite mark or teeth, stereomicroscopy, scanning electron microscopy, video superimposition, and histology.[5] The guidelines, however, do not indicate the criteria necessary for using each method to determine whether the bite mark can be related to a person's dentition and with what degree of probability. There is no science on the reproducibility of the different methods of analysis that lead to conclusions about the probability of a match. This includes reproducibility between experts and with the same expert over time. Even when using the guidelines, different experts provide widely differing results and a high percentage of false positive matches of bite marks using controlled comparison studies.[6]

No thorough study has been conducted of large populations to establish the uniqueness of bite marks; theoretical studies promoting the uniqueness theory include more teeth than are seen in most bite marks submitted for comparison. There is no central repository of bite marks and patterns. Most comparisons are made between the bite mark and dental casts of an individual or individuals of interest. Rarely are comparisons made between the bite mark and a number of models from other individuals in addition to those of the individual in question. If a bite mark is compared to a dental cast using the guidelines of the ABFO, and the suspect providing the dental cast cannot be eliminated as a person who could have made the bite, there is no established science indicating what percentage of the population or subgroup of the population could also have produced the bite. This follows from the basic problems inherent in bite mark analysis and interpretation.

As with other "experience-based" forensic methods, forensic odontology suffers from the potential for large bias among bite mark experts in evaluating a specific bite mark in cases in which police agencies provide the suspects for comparison and a limited number of models from which to choose from in comparing the evidence. Bite marks often are associated with highly sensationalized and prejudicial cases, and there can be a great deal of pressure on the examining expert to match a bite mark to a suspect. Blind comparisons and the use of a second expert are not widely used.

Scientific Interpretation and Reporting of Results

The ABFO has issued guidelines for reporting bite mark comparisons, including the use of terminology for conclusion levels, but there is no incentive or requirement that these guidelines be used in the criminal justice system. Testimony of experts generally is based on their experience and their particular method of analysis of the bite mark. Some convictions based mainly on testimony by experts indicating the identification of an in-

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[5]American Board of Forensic Odontology, op. cit.

[6]Bowers, op. cit.

dividual based on a bite mark have been overturned as a result of the provision of compelling evidence to the contrary (usually DNA evidence).[7]

More research is needed to confirm the fundamental basis for the science of bite mark comparison. Although forensic odontologists understand the anatomy of teeth and the mechanics of biting and can retrieve sufficient information from bite marks on skin to assist in criminal investigations and provide testimony at criminal trials, the scientific basis is insufficient to conclude that bite mark comparisons can result in a conclusive match. In fact, one of the standards of the ABFO for bite mark terminology is that, "Terms assuring unconditional identification of a perpetrator, or without doubt, are not sanctioned as a final conclusion."[8]

Some of the basic problems inherent in bite mark analysis and interpretation are as follows:

(1) The uniqueness of the human dentition has not been scientifically established.[9]

(2) The ability of the dentition, if unique, to transfer a unique pattern to human skin and the ability of the skin to maintain that uniqueness has not been scientifically established.[10]

   i. The ability to analyze and interpret the scope or extent of distortion of bite mark patterns on human skin has not been demonstrated.

   ii. The effect of distortion on different comparison techniques is not fully understood and therefore has not been quantified.

(3) A standard for the type, quality, and number of individual characteristics required to indicate that a bite mark has reached a threshold of evidentiary value has not been established.

Summary Assessment

Despite the inherent weaknesses involved in bite mark comparison, it is reasonable to assume that the process can sometimes reliably exclude suspects. Although the methods of collection of bite mark evidence are relatively noncontroversial, there is considerable dispute about the value and reliability of the collected data for interpretation. Some of the key areas of dispute include the accuracy of human skin as a reliable registration material for bite marks, the uniqueness of human dentition, the techniques used for analysis, and the role of examiner bias.[11] The ABFO has developed guidelines for the analysis of bite marks in an effort to standardize analysis,[12] but there is still no general agreement among practicing forensic odontologists about national or international standards for comparison.

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[7]Bowers, op. cit.

[8]American Board of Forensic Odontology, op. cit.

[9]Senn, op. cit.

[10]Senn, op. cit.

[11]Senn, op. cit.

[12]American Board of Forensic Odontology, op. cit.

Although the majority of forensic odontologists are satisfied that bite marks can demonstrate sufficient detail for positive identification,[13] no scientific studies support this assessment, and no large population studies have been conducted. In numerous instances, experts diverge widely in their evaluations of the same bite mark evidence,[14] which has led to questioning of the value and scientific objectivity of such evidence.

Bite mark testimony has been criticized basically on the same grounds as testimony by questioned document examiners and microscopic hair examiners. The committee received no evidence of an existing scientific basis for identifying an individual to the exclusion of all others. That same finding was reported in a 2001 review, which "revealed a lack of valid evidence to support many of the assumptions made by forensic dentists during bite mark comparisons."[15] Some research is warranted in order to identify the circumstances within which the methods of forensic odontology can provide probative value.

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[13]I.A. Pretty. 2003. A web-based survey of odontologists' opinions concerning bite mark analyses. Journal of Forensic Sciences 48(5):1-4.

[14]C.M. Bowers. 2006. Problem-based analysis of bite mark misidentifications: The role of DNA. Forensic Science International 159 Supplement 1:s104-s109.

[15]I.A. Pretty and D. Sweet. 2001. The scientific basis for human bitemark analyses—A critical review. Science and Justice 41(2):85-92. Quotation taken from the abstract.