Forensic dentistry and human bite marks: issues for doctors

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The human dentition can be used as a weapon of attack or defence. Bite mark injuries are common in cases of sexual assault, child abuse and homicide. Many bite injuries are first seen in casualty departments where quick and proper recovery of evidence can assist in analysing these injuries. This article describes different bite injuries, collection of evidence and comparative analysis methods.

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Forensic dentistry, or odontology (the terms are synonymous), can be described as that portion of dentistry that interfaces with the law at both the criminal and civil levels (Pretty and Sweet, 2001c). In reality, most forensic dentists concern themselves with aspects of criminal law, and as such there are five main areas of expertise:

1. Human identification
2. Mass disasters (three or more individuals dying simultaneously)
3. Bite marks
4. Abuse (child, elder and spousal)
5. Medicolegal issues.

There is a degree of overlap among these areas; for example the main duty of a forensic dentist within the mass disaster response is the identification of the found human remains, but the added logistical complications of a large number of victims requires additional training (Pretty et al, 2001). The recognition, collection and analysis of bite mark evidence is one of the most interesting but contentious areas of forensic dentistry and this article will discuss some of the issues surrounding these injuries.

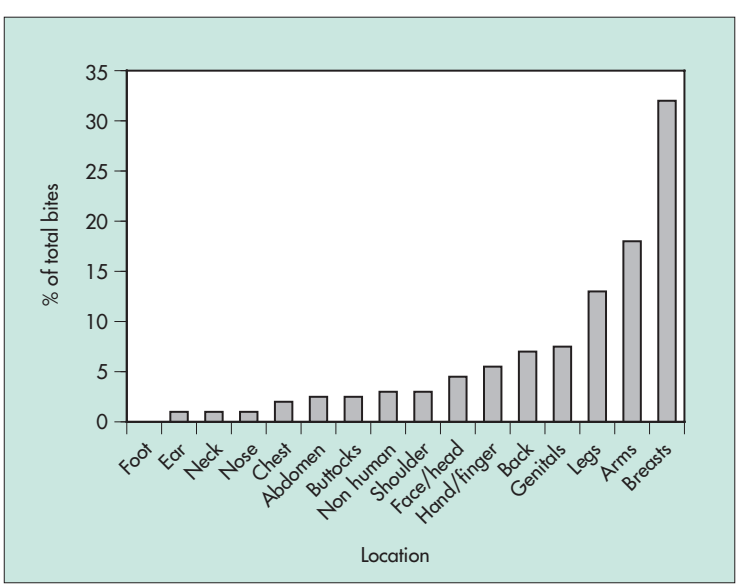


Figure 1. Location of 148 bite marks from 101 American cases.

HUMAN BITE MARKS

Crimes and location

Bite marks are found in some of the most serious types of crimes: bite marks were found in murders, rapes, assaults, child abuse and robberies (Pretty and Sweet, 2000). It is important to remember that bite marks can occur on both victims (as attack injuries) and assailants (as defensive injuries), indeed 50% of all males bitten in a American study were suspects in the offence (Pretty and Sweet, 2000). Bite marks can occur in a variety of anatomical locations, and police officers, medical personnel and forensic dentists must ensure that a thorough external exanimation is performed to ensure that such evidence is not missed in both living and deceased victims and suspects (Pretty and Sweet, 2001d). Common anatomical locations for bites to be found are shown in *Figure 1*.

Appearance

A typical presentation of a human bite mark can be described as an elliptical or circular injury that records the specific characteristics of the biter's dentition (Rothwell, 1995) (*Figure 2*). Most often, it is composed of two 'U' shaped marks (upper and lower teeth) that are separated at their bases by an open space. The diameter of such injuries vary, but is typically between 25 and 40 mm with this representing the intercanine distance (Sweet and Pretty, 2001). There is frequently a central area of bruising within the

arches. This extravascular bleeding is thought to be caused by pressure from the teeth as they compress the tissue inward from the perimeter of the mark. Bite marks may exhibit dynamic striations as the teeth (normally the lower arch) are dragged across the teeth (Sweet and Pretty, 2001). It is usual for the anterior six teeth to be seen on bite marks, i.e. from canine to canine. However, it is possible for premolar or even molar teeth to be present.

Apart from this gross description there is a huge range of bite mark presentations, ranging from mild bruising, through to abrasion, laceration/incision, and even avulsion (Whatmough and Nuckles, 1992; Barry, 1994; Vale, 1996) (*Figure 3*). The degree of force used, the anatomical location and the nature of the biter's teeth will determine the extent of the injury and also its forensic significance. Bite marks with high forensic value will exhibit accurately recorded traits of the biter's dentition. Anecdotally, it is most often the lower teeth that will leave the clearest impression and offer the most evidentiary value. Characteristics recorded in a bite mark can be separated into class and unique characteristics.

Class characteristics are aspects of the bite mark that will enable the identification of individual teeth. For example, lower incisor teeth produce rectangular injuries, while canines will produce more triangular wounds. However, for a bite mark to be of use in identifying the individual responsible for causing it, it is necessary for one or more unique characteristics to be present (Wright and Dailey, 2001). The use, misuse and abuse of our teeth throughout life create unique features (*Figure 4*). This is in addition to any unusual angulations, spacing or crowding that may be present. Unique characteristics include enamel fractures, attritional wear patterns, congenital malformations, trauma, restorations, occupational changes and disease (Pretty and Addy, 2001).

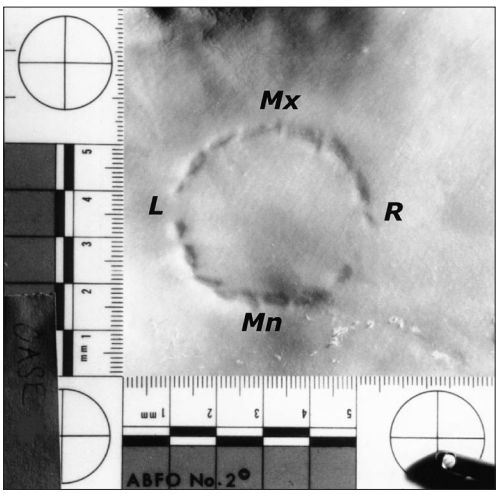


Figure 2. An example of a classic bite mark created on postmortem pigskin. The upper teeth (maxillary = Mx) and the lower teeth (mandibular = Mn) are seen clearly. Note that the American Board of Forensic Odontology ruler is in plane with the bite mark and the photograph has been taken perpendicular to the injury. As this injury has been created postmortem, there is no bruising present. This injury would represent a bite mark of high forensic significance.

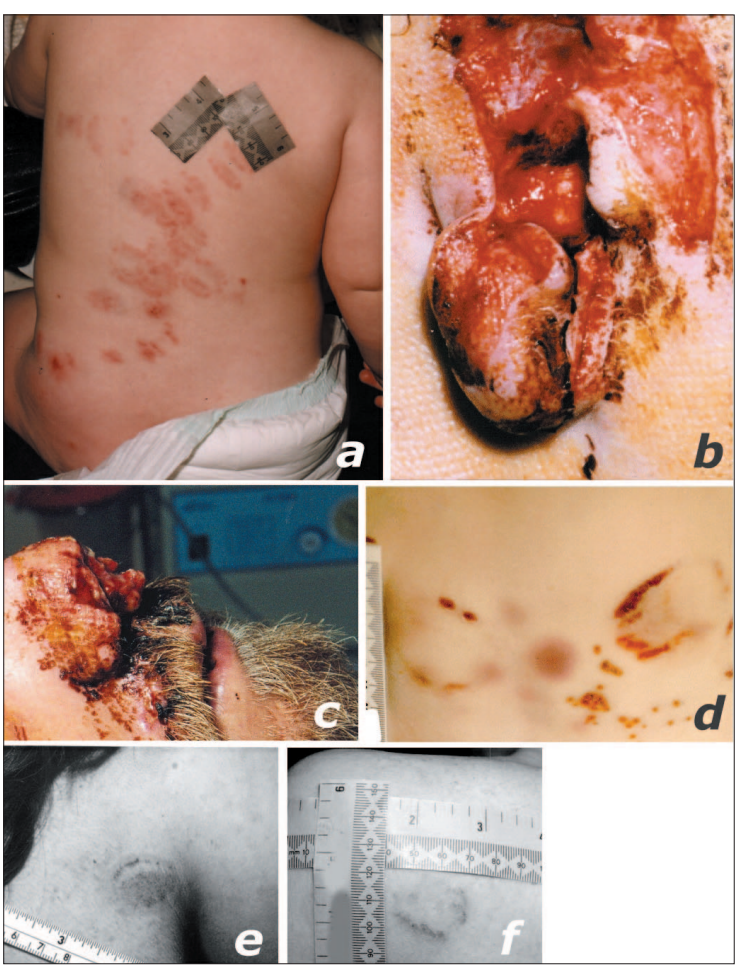


Figure 3. a. Multiple bite marks on the back of a child abuse victim. Divisions between upper and lower teeth are visible. Close-up photographs of each bite mark, with the American Board of Forensic Odontology scale, would be required to analyse these injuries. Examples of bruising with slight abrasion. b. Example of an avulsive injury in which a portion of the left ear has been bitten, such injuries are usually not amenable to analysis. c. A further example of an avulsive injury, this time on the nose. Again, this bite mark left little forensically valuable evidence. d. Multiple bite marks with moderate forensic significance. The injury to the right of the photograph demonstrates the dynamic process of biting with drag marks from the lower teeth. e. Example of a bite mark showing classical central bruising separating the upper and lower arches. The anatomical location of this injury may complicate its analysis, i.e. highly mobile skin, and the position of the arm when photographed may differ from that when bitten. f. Example of a forensically significant bite mark, showing clear details of the lower teeth, but a forensically less significant impression from the upper teeth.

It is also important to remember that a number of other mechanisms can cause injuries similar to bite marks, and these must be considered when assessing such wounds (Whittaker and MacDonald, 1989). A classic example of such an artefact is an electrocardiogram electrode placed by emergency personnel and subsequently removed in the mortuary. Further examples include knife marks, shoe prints, burns from hair curling irons, lead pipe, screwdrivers and many others (Sweet and Pretty, 2001). While not considered within this article, animal bite marks can also have forensic significance. An example would be a suspect bitten by a police dog who escapes arrest. Subsequently located, it may be possible to link the bite injury to the dog and thus prove that the individual was at the crime scene.

Figure 4. a. Example of an adult dentition lacking many unique features. With the decrease in dental caries and an increase in patient interest in aesthetic elective dental procedures (especially orthodontics) an increase in such individuals is likely. b. An example of a large diastema between the two central incisors, this feature is likely to be represented on a bite mark and may be of value in a comparative analysis between a suspect's dentition and a bite injury. c. Fractures will create not only an unusual pattern, but are often sharp, creating individual areas of more severe injury within a bite mark. d. Congenital absence of the maxillary lateral incisors is not rare, but may be a unique feature among a group of possible suspects. This is often the case in child abuse cases when only a small defined number of individuals have access to the victim, e.g. mother, father, sibling, baby-sitter. e. Examples of dental wear causing, on the upper left central incisor, a broad incisal edge unlikely to cause a well defined mark, on the upper right incisor, the wear has extended into the softer dentine of the tooth were preferential wear has created sharp enamel edges likely to leave an unusual and unique pattern on bitten skin. f. Dental neglect with periodontal disease and missing teeth. The drifting and rotation of teeth make this a unique dentition likely to produce several unique features of a bite of sufficient force. g. Megadonts, in which supplemental teeth have become fused to the maxillary central incisors, creating a crowding problem and likely to produce a bite of unusual appearance. h. Gross dental neglect with plaque and calculus extending over the incisal edges of lower teeth. It is unlikely that such an individual could make a bite mark featuring both upper and lower arcades, which may of use when excluding a suspect of causing a bite injury.

Collection of bite mark evidence

Collection of evidence from the bite victim: Bite marks represent two main evidence types; physical and biological. The physical appearance of the injury, and the presence of unique features can be employed in metric and comparative analyses with a suspect's dentition. Saliva deposited during the biting process has been shown to contain sufficient DNA to provide identification of biters in forensic cases. The use of this biological evidence offers a more objective method of bite mark analyses (American Board of Forensic Odontology (ABFO), 1986).

The physician working within a hospital environment will often be in a position to identify a bite mark, and to assist in recovering evidence that will be of great value in future investigations. It can be difficult to obtain a forensic dentist to attend and therefore the physician, either alone or with the assistance of a medical photographer or scenes of crime officer (SOCO), will be required to collect such evidence. The collection of high quality evidence at the time of presentation can be crucial to the success of subsequent analyses and therefore physicians should make every effort to accurately and precisely preserve evidence as soon as it is discovered (Pretty and Sweet, 2001a). This applies only to living victims, with the collection of evidence from deceased individuals being handled by the pathologist and forensic dentist within the mortuary environment. Clearly emergency treatment takes precedence over the collection of forensic evidence, but non-emergency procedures likely to disrupt bite mark evidence collection (such as debridement, suturing or placement of local anaesthetic) should be delayed until the evidence has been secured (ABFO, 1986).

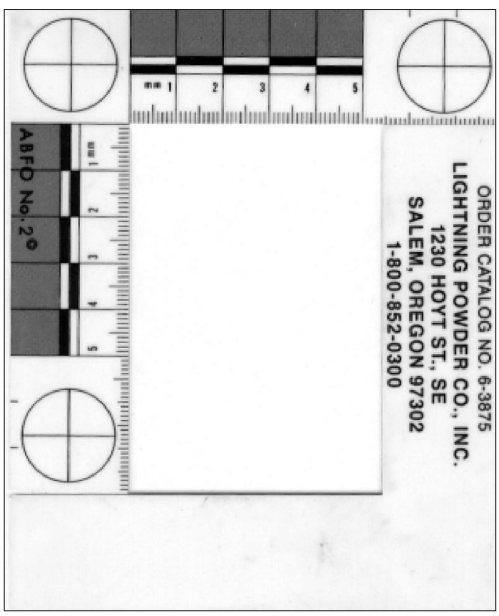
Documentation: A written record of the injury should be made including descriptive notes that clearly document the injury's location, appearance, colour, size and orientation. Describe the anatomical location – is the skin mobile? Is the surface countered or elastic? Does the injury show individual teeth? Note the severity of the bite.

Photographs: Arguably high quality, correctly exposed photographs are the most important method of documenting a bite injury and are usually crucial to any subsequently comparison between bite mark and suspect dentition. Extensive orientation and close-up shots, in both black and white and colour, should be taken. A reference scale, ideally the ABFO scale (*Figure 5*), should be used, but if not available a regular ruler can be used (Hyzer and Krauss, 1988). The scale should be placed in the same plane as the injury and be visible in the photographs. Identical images should be taken without the scale in place to ensure that it can be shown that no details were covered by the scale's placement. The camera should be placed directly over the bite mark, with the long axis of the camera lens perpendicular to the skin, to prevent angular distortion (*Figure 6*). The use of flash photography is useful, with the flash placed both on and off the camera in an oblique fashion. If available ultraviolet photography can provide additional details. A SOCO should be able to assist with this type of photography, which is particularly useful if the injury is older (*Figure 7*).

Salivary swabs: It is likely that saliva will have been deposited during the biting process and this should be recovered. A double-swab technique is recommend for this procedure (Sweet et al, 1997). First a cotton wool swab is moistened with distilled water and is used to wash the bitten surface using light, circular motions. A second, dry swab is then used to collect the remaining moisture. Both swabs should be allowed to dry at room temperature. A control swab should be taken from the victim (usually from the buccal mucosa). Store the swabs in a paper rather than plastic container and give these to the police as soon as possible. The procedure is worthwhile even if the skin has been washed, as DNA has been recovered from a bite mark on a body left in a fast-flowing river for 5 hours using the polymerase chain reaction (PCR) technique (Sweet and Shutler, 1999).

Impression of the bite injury: The equipment to do this is unlikely to be present in accident and emergency departments, although hospitals with maxillofacial units may have access to it.

Figure 5. The American Board of Forensic Odontology (ABFO) No. 2. scale. Used extensively by forensic photographers it incorporates a number of features to ensure bite mark photographs of high quality. The lateral nature of the rule enables photographs to be scaled correctly in both horizontal and vertical dimensions. The transected circles are used to detect, and correct, distortion. Each of the lines within the circles should be the same size, should discrepancies be noted then the photograph is distorted. Using digital image software, such distortion can be corrected. The ABFO scale also features an 18% grey box that can be used during photographic developing to ensure that the colour reproduction is accurate. Made of plastic, a case name and number can be easily written and removed from the scale.



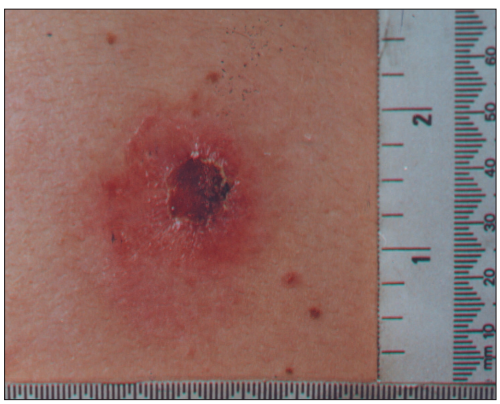


Figure 6. Example of a bite mark photograph. A lateral scale has been used and is in the same plane as the injury. The scale obscures no part of the injury and the exposure is correct.

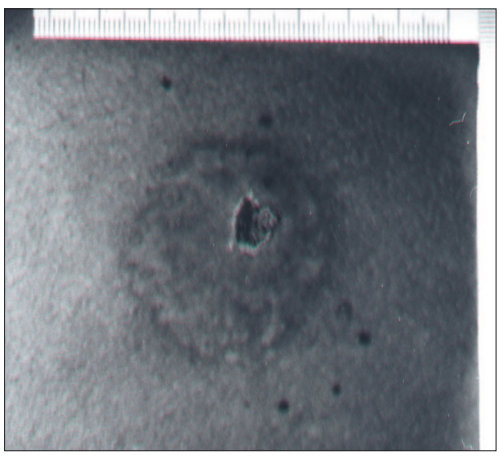


Figure 7. A photograph of the same injury as shown in Figure 6 *under ultraviolet conditions. Taken some time after the colour photographs, additional details of individual teeth can be seen.*

Personnel on call from such a department will be familiar with the handling of such materials and should be called upon to help. The fabrication of an accurate impression of the bitten surface will permit the registration of any irregularities produced by the teeth such as cuts and abrasions. Vinyl polysiloxane impression materials are most suited to this and should be backed using orthopaedic mesh or similar to ensure that there is no dimensional change. These impressions can be subsequently cast in plaster and will provide an enduring record of the injury.

It is also important to take a dental impression of the bite victim in order to demonstrate that they did not bite themselves. This is not an immediate priority and is best performed by a forensic dentist if deemed necessary. If the bite is located in an area inaccessible to the victim, for example, on the back, then this evidence is not required.

It is important to note that the collection of evidence must take place with the victim's consent (ABFO, 1986). Should the bite victim be the suspect in the case, the regulations of the Police and Criminal Evidence Act 1984 come into play and written consent must be obtained. In such instances the advice of the police should be sought.

Evidence collection from the bite suspect: For legal and practical reasons it is unlikely that individuals within a hospital setting will be required to obtain evidence from a bite mark suspect, this normally being done by a forensic dentist within a practice or police station. For completeness, brief details of the evidence collected are presented here. A thorough intra-oral clinical examination should be conducted, in a similar manner to that of a normal dental review. Teeth present should be charted and any recent treatment, especially of the anterior teeth, should be noted. It should be noted that suspects in bite mark cases, famously Theodore Bundy, have been known to adjust their own teeth to confound analysis. Features such as tooth mobility, restoration, fractures, prostheses and caries should be noted. Following the clinical examination photographs should be taken of the suspect's dentition including views demonstrating the ability to open wide. Dental impressions should be taken of the suspect, generally in duplicate, and always closely following the manufacturer's instructions. Impressions should be cast in good quality dental stone as soon as possible to avoid any distortion or shrinkage.

A bite sample, for example in a piece of dental wax or silicone putty, should be taken and a reference DNA swab should be acquired. Photographs of these processes should be taken to demonstrate what was done, should this be questioned in the future.

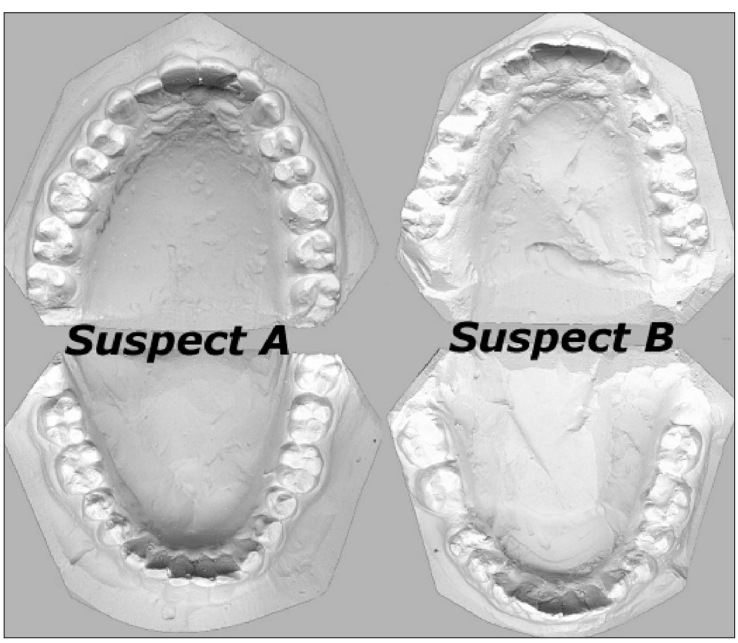


Figure 8. Dental study models produced from impressions taken from two suspects. This shows the casts after they have been scanned into the computer before the production of transparent overlays.

ANALYSES OF BITE MARK EVIDENCE

Forensic physical comparison of exhibits

The physical comparison of bite marks is divided into two main aspects: metric and comparative analyses. The metric component is the simple measurement of aspects of the bite injury and comparison with the equivalent features on the suspect's dental casts. Common measurements include the inter-canine distances, angulations, size of incisal edges and size of any spacing. In order to conduct a metric examination accurately, a high quality, correctly scaled image is required, emphasizing the importance of this aspect of the evidence collection.

The second, arguably more important, physical comparison method uses a transparent overlay of the suspect's dentition to conduct a pattern association. Transparent overlays were traditionally hand drawn, by placing the acetate sheet over the suspect's cast and then tracing the biting edges. Studies found this to be a highly subjective process, depending more on artistic ability than objective science (Sweet and Bowers, 1998). In response to this, a number of more objective techniques were developed, including photocopying, radiographical and computer-based systems (West et al, 1990; Dailey, 1991; Robinson and Wentzel, 1992; Wood et al, 1994; Naru and Dykes, 1996; Sweet and Bowers, 1998; Sweet et

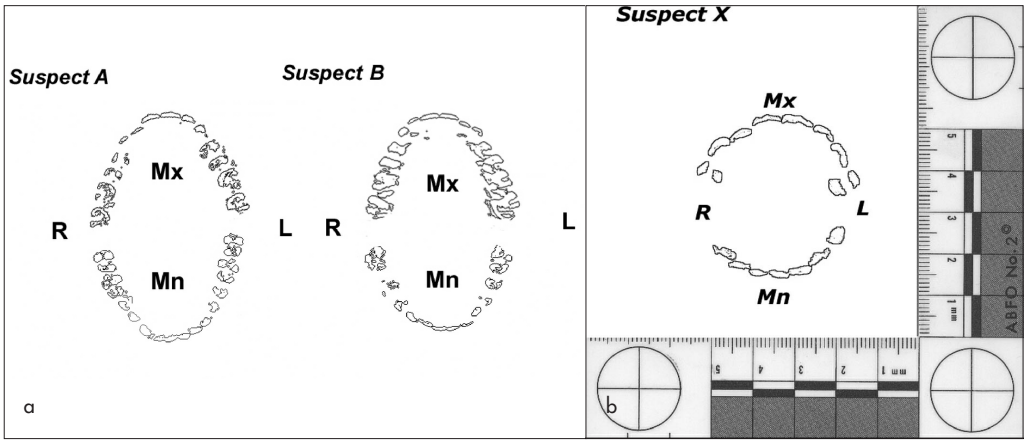


Figure 9. a. The two transparent overlays produced from the dental casts, with left (L), right (R), mandibular (Mn) and maxillary (Mx) indicators. These have been produced using the Naru technique. b. Another method of producing an overlay, this time using the Sweet method.

al, 1998; Pretty and Sweet, 2001b). The computer-generated overlays have proved to be the most accurate and least complex to produce, and they are regarded as the standard method for pattern comparison.

Overlay production

The dental casts of the suspect are scanned into a computer using a regular flat-bed scanner (*Figure 8*). The ABFO rule is included within the scan to ensure that the subsequent overlay is life sized. Once scanned into the computer the scans are manipulated in image analysis software, usually Adobe Photoshop. Using a number of special features within the software the biting edges of the suspect's dental cast are selected out and a hollow volume overlay is produced (*Figure 9*). Case details, left and right indicators are added, and then the overlay is printed using a high quality laser printer on to an acetate sheet (Sweet and Bowers, 1998; Sweet et al, 1998). The acetate sheet is then placed on to the photograph of the bite mark and a pattern analysis is conducted. Each of the marks present on the injury is compared with the hollow volume representations of the suspect's biting edges (*Figure 10*).

Unlike fingerprint analysis, there is not a minimum number of matches that are required in order to make a positive identification. Instead, the comparison is a somewhat subjective process in which the odontologist must consider, for example, the bitten surface type, any slippage, mobility, decomposition, putrefaction, tooth mobility and biting surface sharpness. A study determined that forensic dentists correctly identified the biter in 86% of cases presented to them (Arheart and Pretty, 2001). When assessing a bite injury there are a range of possible conclusions to indicate level of confidence afforded by the analysis. The conclusions are:

- Excluded – there are discrepancies between the bite mark and suspect's dentition that exclude the individual from making the mark
- Inconclusive – there is insufficient forensic detail or evidence to draw any conclusion on the link between the suspect's dentition and the bite mark injury
- Possible biter – teeth like the suspect's could be expected to create a mark like the one examined but so could other dentitions
- Probable biter – suspect most likely made the bite; most people in the population would not leave such a bite
- Reasonable medical certainty – suspect is identified for all practical and reasonable purposes by the bite mark – any expert with similar training and experience, evaluating the same evidence, should come to the same conclusion of certainty.

The comparison shown in *Figure 10* is an example of a probable biter. Many forensic dentists believe that bite mark analysis should only be used to exclude individuals until a more objective analysis technique can be developed. DNA analysis of salivary deposits left during biting offers such a technique.

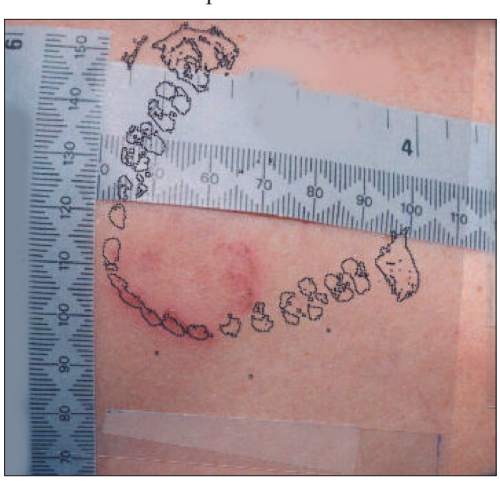


Figure 10. An example of a transparent overlay placed on a scaled (1:1) photograph of a bite mark injury. In this comparison the mandibular teeth are being compared. The suspect represented by the overlay in this case was determined to be a probable biter.

Human bites as forensic biological evidence

During the process of biting saliva is deposited on the skin's surface and it has been demonstrated that sufficient trace evidence is present to permit PCR-based typing of DNA. DNA present in saliva is from white blood cells and sloughed epithelial cells and can often be detected on the skin using alternate light sources and lasers. Following elucidation of the DNA profile of the suspect, the victim and the salivary sample can be compared to determine if any of them have a common source. The use of short tandem repeat analysis enables forensic scientists to use statistical tests to evaluate how rare or common any one profile is, and therefore the chance of the saliva on the bite being from the suspect.

DNA profiling is a far more objective method of bite mark analysis, however, it is not always possible to perform such comparisons. DNA suffers from degradation over time and it is possible for it to suffer a number of environmental assaults that render the PCR process ineffective. Washing of the skin can remove vital evidence, as can many medical procedures. However, the collection of this type of evidence is quick and cost effective (double swab technique) and therefore it is always worthwhile performing as part of an evidence collection protocol.

PROBLEMS WITH BITE MARK ANALYSIS

As described above, there are doubts over the scientific validity of physical bite mark comparisons. Such concerns centre around the uniqueness of human teeth and, more particularly, the registration of these unique features on the bitten substrate (Pretty and Turnbull, 2001). Concern has also been expressed over forensic dentists who have tried to introduce a statistical certainty to their conclusions, for example 'this individual who has a dental arrangement that would only be seen in 1 of 100 000 people'. There is no scientific evidence available to support such statements and they should be avoided (Pretty and Sweet, 2001d).

CONCLUSION

Despite some of the inherent problems of bite mark analysis, such injuries often represent the only physical evidence of a crime. As such, they are important to a successful investigation of crime. Careful, methodical collection of the evidence is crucial to the success of the ultimate analysis. Physicians within the hospital environment are in a prime position to assist in this process. Further information is accessible from www.forensicdentistryonline.org **HM**

KEY POINTS

- Bite marks are found in some of the most serious criminal assaults.
- Accident and emergency physicians are in a unique position to identify bite marks and to assist in the proper collection of evidence from them.
- Bite marks should be analysed by qualified forensic dentists.
- Bite marks are usually complex injuries and the analysis techniques are still somewhat subjective.

Conflict of interest: none.

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