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CASE REPORT

The individualisation of a dog bite mark: a case study highlighting the bite mark analysis, with emphasis on differences between dog and human bite marks

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Abstract A person who keeps or controls a dog in his own interest is liable "*without fault*" should that dog cause harm to any person. By owning a dog, man welcomes into his home a beast that preserves much of its primordial self, and is capable of inflicting a fatal bite wound. The courts may require the forensic expert to identify which specific dog caused the damage or fatal bite in an effort to establish the owner/controller of the animal. Very little has been published on the individualisation of dog bite marks, the procedures to be followed when confronted with usable bite marks and the range of analysis techniques available. The authors advocate a multidisciplinary approach, and utilise a case study to demonstrate the protocol to be followed when analysing a dog bite mark. The paper also highlights differences between human and dog inflicted bites. The authors warn against over interpretation of poor quality bite marks and a final conclusion of absolute certainty.

Keywords Forensic science · Forensic odontology · Dog bite marks · Delictually liable · Multidisciplinary approach

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Introduction

In the legal dogma of the previous century, it was inconceivable that a person could be held delictually liable in the "absence of fault". A re-evaluation of delictual liability has become necessary in the twenty-first century. In terms of South African legislature, a person who keeps or controls an animal in his own interest is liable "without fault" because he creates an increased risk of harm to the community [1]. In dog bite cases, the court may require the forensic expert to identify which specific dog caused the damage or the fatal bite in an effort to establish the owner/controller of the animal.

In 1993, the Smithsonian Institution's *Mammal Species of the World* included the domestic dog only as a subspecies of the wolf *Canis lupus*. As *C. lupus familiaris*, it joins the American wolf, *C. lupus occidentalis*, and the European wolf, *C. lupus lupus*; they are so much alike as to be ranked as mere subspecies of the same animal. One must therefore bear in mind that dogs are still *wolves beneath the skin* [2]. By owning a dog, any dog, man welcomes into his home a beast that preserves much of its primordial self [3–5]. In general, fatalities due to dog bites are rare. From 1979 to 1998, only 238 deaths were reported in the USA [3]. Figures for South Africa are not available, but the keeping of fierce guard dogs due to high crime levels will inevitably

lead to increased dog bites. Like wolves, dogs attack the weak and the young [4]. Usually, pet dogs are involved in attacks, and only recently has public awareness of this health problem increased [2]. Seventy percent of fatal dog bite attacks are committed by a pet dog within the owner's yard or its proximity [3].

Although fatal attacks on humans ostensibly appear to be a breed-specific problem (Pit Bull-type dogs, German Shepherds and Rottweilers, for example), other breeds may bite and cause fatalities at higher rates [6]. Because of difficulties in determining a dog's breed with certainty, enforcement of breed-specific ordinances raises constitutional and practical issues [6]. Fatal attacks represent a small proportion of dog bite injuries to humans and, therefore, should not be the primary factor driving public policy concerning dangerous dogs [2, 6]. The involvement of more than one dog may account for the severity of the injuries due to pack behaviour. Deaths are typically due to exsanguination, asphyxia, air embolism and decapitation [7]. Six categories of canine aggression have been described: territorial, possessive, fearful, intrasexual, parental and dominance [8]. The additional category of medical illness (e.g., rabies, brain neoplasm, encephalitis, encephalopathies, diabetes mellitus, deafness and blindness) has been described by several other authors [3, 9].

Diagnosis of a wound as a bite mark is generally not difficult considering the rather pathognomonic wound pattern of "a hole-and-a-tear" together with skin abrasions and claw marks [4]. An unusual concentration of severe injuries to the head and neck regions is typically reported in the literature [2, 4, 10, 11], and the cause of death is usually haemorrhage and/or asphyxia. Bites to the forearms are also common as the limbs are generally raised in an attempt to protect the face.

A complete forensic investigation can help reconstruct the event to identify the biter, to exclude criminal intention, to identify a pathological condition in the dog or human or to elucidate alternative explanations. It should involve a forensic scene investigation, an examination of the victim and lastly an examination of the dog [4]. Munnynck and Van De Voorde give a detailed description of the steps to be followed in such an investigation but only mention bite marks as a point to consider when examining the victim [4].

There are several papers which describe the procedures to be followed when examining bite marks [2, 12–16], but they do not include protocols to be followed when examining tooth puncture wounds and claw scratch marks commonly experienced in dog attacks. Very little has been published on the individualisation of dog bite marks, distinguishing bite marks from claw marks and the methodologies involved in the above procedures.

Presenting dog bite mark evidence in a court of law will require the expertise in the various fields of forensic science. The authors believe that dog bite mark analysis should follow a multidisciplinary approach involving forensic pathologists, forensic odontologists, veterinarians, police officers and other forensic scientists. This case study demonstrates such a multidisciplinary approach to bite mark analysis. The paper does not attempt to address in detail the case histories, DNA analysis, bacterial analyses, culpability of the dogs, motivation leading to dog attacks or the ultimate cause of death. The recommended protocol to be followed at the forensic scene and in the examination of the dog/s is included.

General principles in forensic scene analysis of dog bite mark cases

This generalised protocol is based on two recommended protocols for bite mark collection at the crime scene with modifications [2, 13].

The following steps should be followed in all dog bite mark cases.

Investigation of the victim:

a. Fulfil all the relevant legal requirements pertaining to the investigation of the crime scene, the victim and the dog.
b. Photograph all puncture wounds thought to be either bite or claw marks.
c. Collect DNA swabs of all puncture wounds. Specific profiling kits are available for the individualisation of dogs.
d. Collect bacterial swabs from the puncture wounds. *Capnocytophaga canimorsus* is a commensal bacterium of dog and cat saliva which can be transmitted to man [17]. Kampimga et al., using fluorescent in situ hybridisation with specific DNA probes, isolated identical strains of *C. canimorsus* from dog and victim [18]. A similar principle can be applied to other oral flora.
e. Take impressions of puncture wounds thought to be bite marks.
f. Excise puncture wounds thought to be bite marks (only performed in exceptional cases).
g. Correctly store the evidence.
h. Document all actions.

Investigation of dog or dogs:

a. Establish which dog or dogs could be involved; all dogs possibly involved should be examined.
b. Decide if a criminal case is going to be opened or not.
c. Decide whether the dogs are going to be euthanased or anaesthetised. The dog should be euthanased to take brain samples unless it is fully vaccinated against rabies. Personal protective measures should be taken during processing of the dogs.
d. Photograph the dog's dentition.

e. Collect DNA and bacterial swabs.
f. Take impressions of dogs' teeth and claws. This will be performed under general anaesthesia in the case of living dogs.
g. Check claws for the presence of human tissue.
h. Examine gut contents. Necropsy examination of the stomach content of the attacking dogs usually reveals tissues from the victim. This can be confirmed by DNA analysis of recovered tissue. Tissue from the victim or fibres of clothing can also be present between the teeth of the dog. It is not essential to euthanase the dog: dogs can be induced to vomit by early administration of emetics. Resulting stomach contents can be stored until a decision is made as to the fate of the dogs. Faecal matter can also be examined for the presence of human DNA.
i. Store the evidence and document all actions.

The analysis/individualisation of dog bite marks

The description of the analysis and individualisation for bite marks is based on the analysis technique described by Bernitz et al. [14]. For purposes of this paper, a *dog bite mark* will be defined as any break in the skin caused by a dog's teeth, regardless of the intention [19]. Only skin bite mark analysis will be discussed as inanimate objects are seldom involved. This case study highlights the procedures followed.

Selected items of the crime scene investigation of the victim and the dogs will be briefly discussed as this is primarily the task of the forensic pathologist, veterinarian and investigating police officers.

Stage 1. Determination of the mark as a dog bite mark

The general impression shape and size (GISS) must conform to that of a dog bite mark. The maxillary and mandibular tooth formulae are similar in all breeds of dogs and are different to that seen in a human bite mark. Dogs have six anterior incisors followed by a large canine at varying distances behind the last incisor. The incisal edges of the anterior six teeth are tri-tuberculate, with the central prominence being much the largest. The lateral tubercle is slightly nearer the neck of the tooth than the medial one. The incisors increase in size from 1 to 3. The crown of the canine tooth is large, conical and curved distally. The two large canines will generally leave puncture wounds, while the incisors will leave marks varying from scratch marks to skin puncture wounds. A clear distinction needs to be made between claw marks and bite marks. The claw pattern of most dogs is a symmetrical pattern. This should be interpreted in light of the anatomy of the canine forepaw. There are four weight bearing digits, digits 2–5. Digit 1 is either absent or reduced. Digit 3 and 4 are longest and equal and are flanked on either side by digits 3 and 5, which are shorter and equal. The marks left by the claws on the skin of the victim will reflect the length and the sharpness of the dog claws, which in turn will be affected by the surface on which the dog generally walks, and the size and breed of the dog.

Stage 2. Pattern association analysis of the bite mark on the victim and the canine dentition

The pattern association analysis of dog bite marks/tooth marks can be defined as the three-dimensional analysis and the comparison of the dental arch forms, arch relationships and individual tooth features within the described canine dental arches. Arch shapes (upper and lower) are compared with the bite mark, followed by the examination of each individual tooth mark present in the bite mark as well as each tooth's position relative to the surrounding teeth. Obvious features, which included the canine puncture marks, diastemas, missing teeth, rotated teeth and teeth out of the dental arch, help with the orientation while matching the patterns. In dog bite marks, the canines play a pivotal role in the orientation of single or multiple bite wounds. As bite marks are often inflicted by more than one dog, several differing intercanine distances may be observed. This can give an indication of the number of dogs involved.

A pattern association analysis of the dog's dentition with a plaster cast of the bite mark from the victim is often problematic because of the length of the canines. To circumvent the problem, the indentations caused by the canines can be lengthened in one of duplicate models of the bite to accommodate the canines when analysing the bite marks. This will allow the incisors from the dog's dentition to be matched to the marks on the plaster models. Making duplicate models of the dog's dentition, and then shortening the large canine teeth on one of the models, will achieve the same result. The first method better represents the dynamics of the biting process and will be simpler to explain to a court of law. It is important to note that tissue distortion will not affect the pattern association comparison of the features in the bite mark.

Acetate sheeting can also be used to match the bite mark patterns to the dentition, but the resulting representation will be two-dimensional and unreliable.

Stage 3. Metric analysis as a quality control measure

A metric analysis of selected dental features present in the bite mark should be performed as a quality control measure, and it must be born in mind that some distortion will always be present [20]. Intercanine distance will confidently separate small dogs with a small intercanine distance from larger dogs with a larger intercanine distance. The cylindrical shape of the victims' thigh will cause an increase in the intercanine distance because the straight distance will be shorter than the measured curve. Tooth width,

degrees of rotation and naturally occurring spacing (diastemas) can all be measured and compared to the dentitions of the dogs suspected to be involved in the biting. If a scale is included in the photograph, modern computer software programmes allow for the easy calibration of the image and the metric analysis of the individual features.

Stage 4. Test the match using affine transformations

This can be achieved by importing images of the bite mark and the dentitions of the suspected dogs into GeoGebra (open source) as described by Stols and Bernitz [21].

Case study

A case study will be used to illustrate the procedures to be followed. All personal data of the victim in this case have been removed to ensure confidentiality of the victim. The consent from the Director of Public Prosecution in the relevant magisterial district was obtained.

A body was found with possible bite marks on the lateral aspect of the thigh. Two large dogs, one a Bullmastiff and the other a Labrador retriever, were observed in the vicinity of the attack. The possibility of individualising the bite marks present was investigated. Although many marks were present on the victim's body, only one was regarded as clear enough for any form of positive bite mark identification.

Stage 1. Determination of the mark as a dog bite mark

A clear bite mark, with individualising features, was present on the lateral aspect of the victim's thighs, see Fig. 1. The GISS was consistent with that of a dog bite mark. The tooth formula clearly showed five small anterior incisors flanked on either side by the large puncture wounds caused by the larger and longer canines. A sixth faint marking, believed to represent the remaining incisor, was also visible. The incisal edges of the anterior teeth clearly demonstrate the tri-tuberculate pattern of the anterior incisors. Bite marks from more than one dentition were visible. An EDR scale is visible in the photograph.

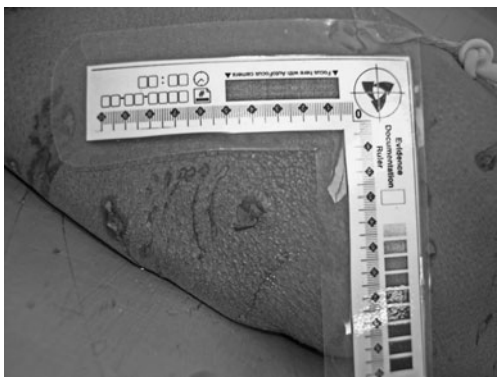

Fig. 1 High quality dog bite mark with individualising features

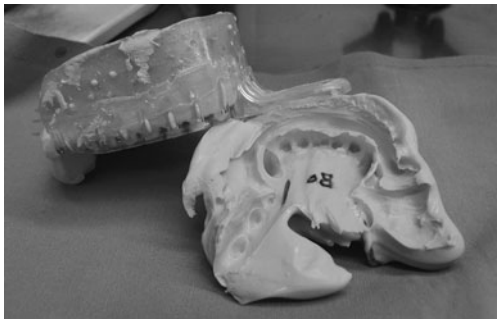

Fig. 2 Modified bite trays to accommodate the long canines

Stage 2. Pattern association analysis of the bite mark on the victim and the canine dentition

A pattern association analysis of the bite mark present on the victim's lateral thigh and the dentitions of the dogs suspected to have inflicted the bites was carried out. Models of the dogs' dentitions were cast after taking alginate impressions of the teeth with modified dental trays, while the dogs were under general anaesthesia, see Fig. 2. Stone models were then cast from the alginate impressions. Silicone impressions were taken of the bite mark present on the victim and plaster casts constructed [14].

Individual tooth features present in the bite mark were compared to the tooth features present in the dentitions of the dogs. The large intercanine distance present in the bite mark of this case excluded the Labrador retriever which had a considerably smaller intercanine distance, see Fig. 3. Individualizing features, which included the relative positions of the canine puncture marks and incisal tooth diastemas, assisted with the orientation and individualization of the marks. The pattern association analysis of the dog's dentition with a plaster cast of the bite mark was problematic because of the length of the canines, see Fig. 4. Several models of the dogs'

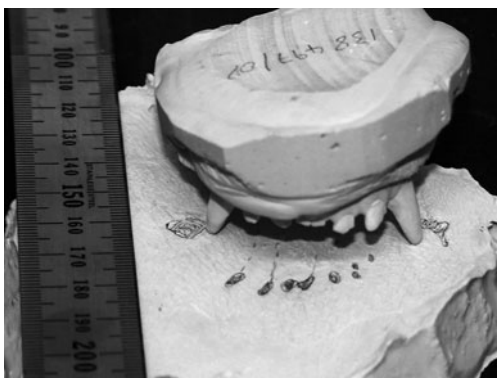

Fig. 3 Three-dimensional matching of bite mark with unmodified model of Labrador's upper dentition

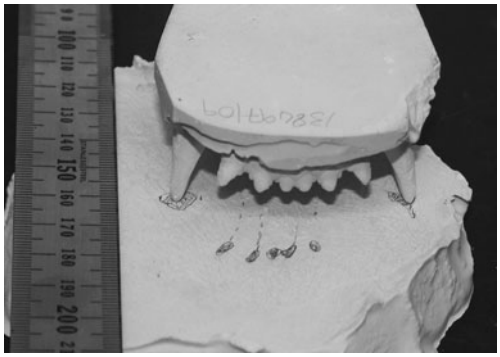

Fig. 4 Three-dimensional matching of bite mark with unmodified model of Bullmastiff's upper dentition

dentition were constructed, some of which were modified to assist in the pattern matching of the bites. To circumvent the problem, indentations were made in the bite mark cast to accommodate the canines. This allowed the incisors from the dog's dentition to be matched to the marks on the plaster models. In another model, canines were shortened to allow the incisors to be positioned relative to the models of the bite mark, see Fig. 5. This technique of adapting the models to allow better matching is a new and previously undescribed technique. The difference in size between puncture marks produced by the paired canines was used to determine the approximate angle at which the canines penetrated the skin.

Stage 3. Metric analysis as a quality control measure

Metric analysis of selected dental features present in the bite mark was performed. This included the intercanine space, the individual spacing between the anterior incisors and the spacing between the anterior incisors and the canine teeth.

Stage 4. Test the probability of a match using affine transformations

A mathematical analysis of the dental transformations was carried out using GeoGebra.

Results

Comparison of the bite marks on the victim and the dentition of Dog 2 (Bullmastiff) showed a high degree of concordance, see Fig. 4. The intercanine distances are similar. The relationship of each anterior incisor to the neighbouring incisor as well as the relationship of each incisor to the canines is similar. A distinctive concordant pattern of individual and paired incisors is clearly visible.

Dog 1 (Labrador retriever) could be excluded.

GeoGebra could not confirm a match of the bite marks to any of the dentitions using affine transformation.

Discussion

The analysis of dog bite marks requires a multidisciplinary approach, and should include forensic pathologists, police officers, forensic dentists and veterinarians. All the said disciplines play a vital role from the initial recognition of the lacerations as dog bite marks observed by the forensic pathologist or crime scene investigator, the anaesthesia performed by the veterinarians to obtain dental casts of the dogs to the final matching of the bite marks by the forensic dentists.

The qualitative and quantitative theory of one as described by Vanderkolk is more applicable to dog bite marks than those inflicted by humans [22]. Vanderkolk goes to great lengths to emphasize the fact that in any comparison, there must be both quality and quantity in the material studied before a positive match can be made. In dog bite marks, we generally have quantity but lack the quality to individualise features to a point where a reliable comparison can be made. The authors therefore warn against over interpretation of marks with poor quality. Dog bite marks tend to be very distorted, and this is borne out by the unsuccessful attempts to show that distorted bite marks seen on the victim were in fact affine transformations of the dog's dentition. Affine transformations have been proven to cross match human bite marks to dentitions in cases where distortion is minimal: in dog attacks, distortion is extensive and beyond the resolution power of affine transformations. The authors postulate that in dog bite marks, the distortion is non-uniform and severe because of the deep penetration of the canines and the shallower penetration caused by the anterior incisors. This severe distortion can however be accommodated by a pattern association analysis, but not by a mathematical affine transformation which requires a uniform distortion of the features. The physical matching of the dog's dentition to a model of the bite mark is in fact a 3D analysis of the bite mark. The authors do not believe that a computer-generated

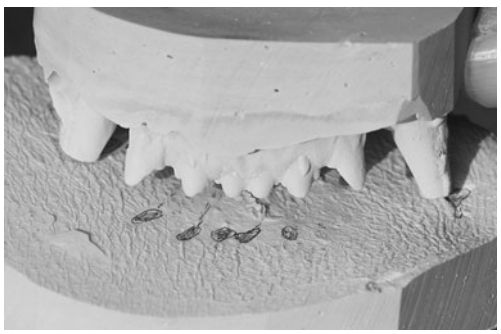

Fig. 5 Canines shortened to assist in the matching of the incisal teeth

3D analysis of the evidence would lead to a higher degree of certainty in this case.

Good quality dog bite marks can be analysed as demonstrated in the case study above. It is essential that the correct protocol be followed from the start, and that a multidisciplinary approach is followed. The canine anatomy necessitates certain modifications to the normal pattern associated analysis described for human bite mark analysis. The authors advocate the use of duplicate canine dental models, together with duplicate models of the bite marks present on the victim. This will allow the examiners to shorten the canine teeth on selected models in an effort to match the anterior incisors without the canines. The models of the bite marks can also be modified to accommodate the long canines present in dog dentitions. This previously undescribed technique whereby modifications are made to models, and which thus represent the manipulation of the respective models, will assist in showing a pattern associated concordance in a three-dimensional plane when giving evidence in court. The intercanine distance is of great value in eliminating dogs with obviously differing measurements. The metric analysis of canine puncture marks can assist in determining the angle at which the bite mark was inflicted. This is achieved by comparing the size of the lacerations caused by paired canines during the biting process. The larger laceration will generally indicate a deeper penetration, while the smaller laceration will generally indicate a shallower penetration. This fact can assist with the analysis of the anterior incisors where the pattern analysis could be affected by the angled incidence of the bite mark. The examiner can use the above principle to explain distortions present in the bite mark which could otherwise be seen as inexplicable discrepancies. The mechanics of dog bites will always induce the degrees of distortion which make a conclusion of absolute certainty undesirable and irresponsible. If there are multiple points of concordance with no unexplained discrepancies between the bite marks on the victim and the dentition of the suspected dog, the conclusion of a match with a high degree of certainty or high probability should be reached.

Conclusion

Dog bite marks, although similar to human bite marks in certain respects, need a modified analysis technique to accommodate the anatomical differences which exist in the canine dentition. Dog bite marks can be matched to a high degree of certainty, but as a consequence of varying degrees of distortion, a match with absolute certainty should never be declared.

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