



Review article

## Medico-legal implications of dog bite injuries: A systematic review

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### ABSTRACT

Dog bites pose a significant global public health issue and are the most common type of injury caused by animals. While most dog bites result in minor harm, they can also lead to severe or even fatal consequences. In cases involving serious injury or death, forensic pathologists investigate various aspects, including the crime scene, the injuries sustained by the victim, and the characteristics of the dog suspected to have caused the bite. The aim of this study is to provide a systematic review of the literature on the medical-legal implications of dog bites in forensic practice, in order to recognize the dog bite victim features, the injuries and their consequences related to, and to identify the offending dogs. The literature search was performed using PubMed, Scopus and Web of Science from January 1980 to March 2023. Eligible studies have investigated issues of interest to forensic medicine about dog bites to humans. A total of 116 studies met the inclusion criteria and were included in the review and they were organized and discussed by issue of interest (biting dog features, dog bite victim features, anatomical distribution of dog bites, injuries related to dog bites, cause of death, bite features, dog identification and post-mortem dog depredation). The findings of this systematic review highlight the importance of bite mark analysis in reconstructing the events leading to the attack and identifying the dog responsible. In medical forensic evaluations of dog bite cases, a multidisciplinary approach is crucial. This approach involves thorough analysis of the crime scene, identification of risk factors, examination of dog characteristics, and assessment of the victim's injuries. By combining expertise from both human and veterinary forensic fields, a comprehensive understanding can be achieved in dog bite cases.

### 1. Introduction

Dog bites are a significant global public health concern and represent the most common animal-related injury [1–3]. Dog bites are responsible for tens of millions of injuries per year. In the United States of America, about 4.5 million people are bitten each year and of these about 885000 seek medical treatment, while 20 of them die [4]. Other high-income countries have comparable incidence and mortality rates. The Australian National Injury Surveillance Unit has recorded that approximately 11.3 per 100,000 people are hospitalized annually due to dog-related injuries [5]. In Europe, there has been a significant increase in the number of fatalities associated with dog attacks between 1995 and 2016 [6]. In low- and middle-income countries, mortality rates from dog bites are higher due to rabies infection [7,8].

While most dog bites result in minor injuries, serious and even fatal

consequences may occur [9,10]. In cases of fatal or serious injury, forensic pathologists conduct a thorough investigation of the crime scene, the victim's injuries, and the characteristics of the suspected dog [11].

The purpose of this study is to provide a systematic review of the literature on the medical-legal implications of dog bites in forensic practice, in order to recognize the dog bite victim features, the injuries and their consequences related to, and to identify the offending dogs.

### 2. Materials and methods

An electronic search was performed in 3 databases: PubMed, Scopus and Web of Science. Keywords related to the study aim and included in the search string were: (*dog bite*) AND (*forensic OR post mortem OR legal OR autopsy OR genetic*) AND (*injury OR wound OR infection*). The

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Preferred Reporting Items for Systematic reviews and Meta-analyses (PRISMA) guidelines were used [12].

The English language and time interval of publication, from January 1980 to March 2023, were applied as filters and inclusion criteria. Eligible studies have investigated issues of interest to forensic medicine about dog bites to humans. Articles focusing only on the diagnostic and therapeutic implications of dog bites were not considered in this review.

Titles and abstracts were screened initially for inclusion criteria, and full texts were examined for articles that were unclear. References of the selected articles were further screened, and related papers were included as a source of additional data. To minimize selection bias, two authors independently conducted the review and reached a consensus in case of disagreement. Authors, title, journal, and year of publication were extracted, and papers were considered for the issue of interest.

### 3. Results

The results of the literature search are summarized in Fig. 1. A total of 116 studies met the inclusion criteria and were included in the review [5,6,9–11,13–124]. The papers were organized by issue of interest, as shown in Fig. 2.

### 4. Discussion

#### 4.1. Biting dog features

Dogs that are typically involved in attacks are large-sized breeds often trained to be watchdogs or for personal defense [9]. The United States insurance industry identifies six dog breeds as vicious: Akitas,

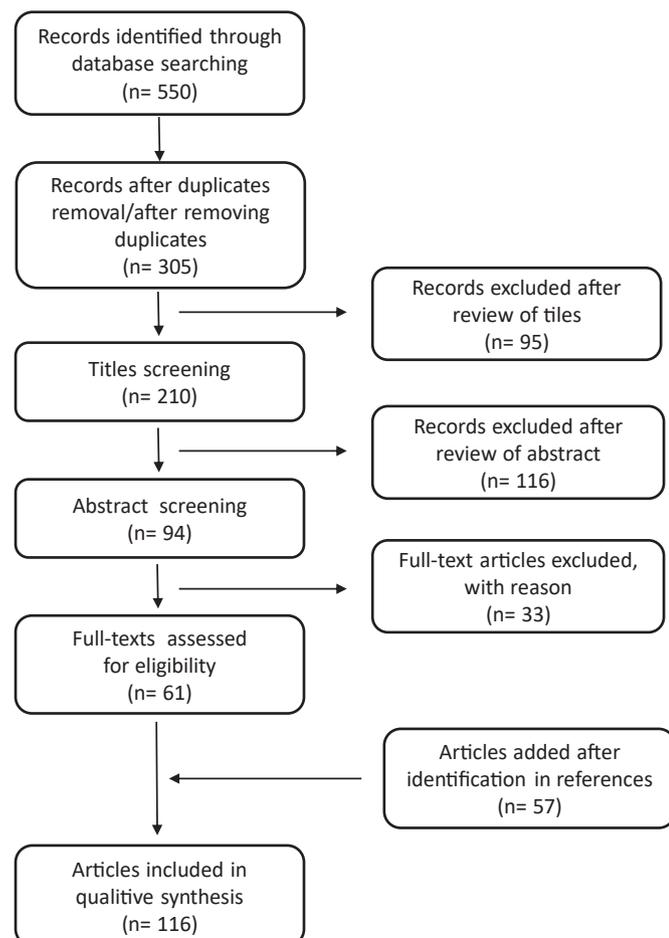


Fig. 1. PRISMA flowchart of systematic review.

Chow Chows, Dobermanns, Pit Bulls, Rottweilers, and Wolf-mixes [13]. Additionally, dog types that have been repeatedly identified as perpetrators in literature are Bull type terriers, Mastiff types, Nordic Sledge dogs, Asian Spitz, German Shepherd [14–19,97,116]. It should be noted that small-sized breeds, such as Pinschers, can frequently bite humans, resulting in minor injuries that rarely necessitate medical intervention. When dealing with a biting dog case, it is important to ensure correct breed identification, which can be also useful when there is a need to discriminate among multiple dogs allegedly responsible for the attack. It is therefore recommended to add photographs of the allegedly biting dog(s) to the case file whenever possible to aid the investigation.

Male dogs account for approximately 75% of all incidents and are reported to be more aggressive. Other factors believed to facilitate dog attacks on humans include possible genetic predisposition toward aggressiveness, intact reproductive status, poor health, late or inadequate training and socialization [20–23,120]. Most fatal attacks involve young male dogs that have previously shown aggression or bitten someone [24,25]. It is not uncommon that dog attacking humans had previously killed another dog or another animal [20].

Pack dog attacks are rare, but they are the most dangerous. Once an attack has started in a pack situation, other dogs will join in. Not only do packs inflict a greater number of wounds, but there is also a likelihood that social facilitation and pack instinct will prolong or escalate the attack until the victim is killed or the dogs are driven off [26,27,120].

Studies of dog behavior show that factors that make dogs view humans as prey include genetic predisposition towards aggressiveness, training, abuse, hunger, previous predation, group behavior, defense of territory, the behavior, age, and size of the victim, and the absence of other people nearby [23].

Different types of aggression that lead to attacks in different circumstances can be distinguished. Protective aggression occurs when the victim is perceived as a threat to the family. Conversely, territorial aggression arises when the victim invades the dog's territory or attempts to take something the dog considers its own, such as food or toys. In both situations, aggression intensifies as the approaching individual gets closer, regardless of any intervention, correction, or the individual's intention to interact. Redirected aggression can occur when a dog fight is interrupted. In this case, the dog redirects its aggression caused by excitement or arousal towards a nearby target. The redirected aggression may involve prolonged or repeated biting, and the dog may also exhibit behaviors like staring or growling at the human or another nearby target. In the case of newborn babies, dog attacks can occur without any apparent direct provocation, often manifesting as instances of opportunistic predation rather than overt aggression. It is worth noting that infants can be attacked even while they are asleep in their cribs or beds. Pain and fear, particularly in dogs that have experienced abuse, can also contribute to aggressive behavior. In addition, any pathological (e.g., rabies, encephalitis, brain tumors, diabetes mellitus) or toxicological conditions that could account for the dogs' aggressive behavior must be considered to identify drugs or stimulants that may have been used to precipitate aggression. An association between dog abuse and child abuse and the extent to which violent behaviors are learned and practiced have also been reported. Thus, in case of dog attack, the appropriateness of the situation, the extent to which a bite is provoked, the nature of the provocation, and the behavioral tendencies of the dog involved must be evaluated [6,24,28–31,125].

#### 4.2. Dog bite victim features

Most dog bites occur from domestic dogs towards their owners or relatives on their own property [15,30,32,33,100]. Moreover, Cornelissen et al. conducted a retrospective survey, wherein they observed that incidents targeting the owner occurred with greater frequency in non-public areas, accounting for 86% of cases. In contrast, when incidents involved someone other than the owner, intentional biting was reported more frequently at 77%, as opposed to incidents involving

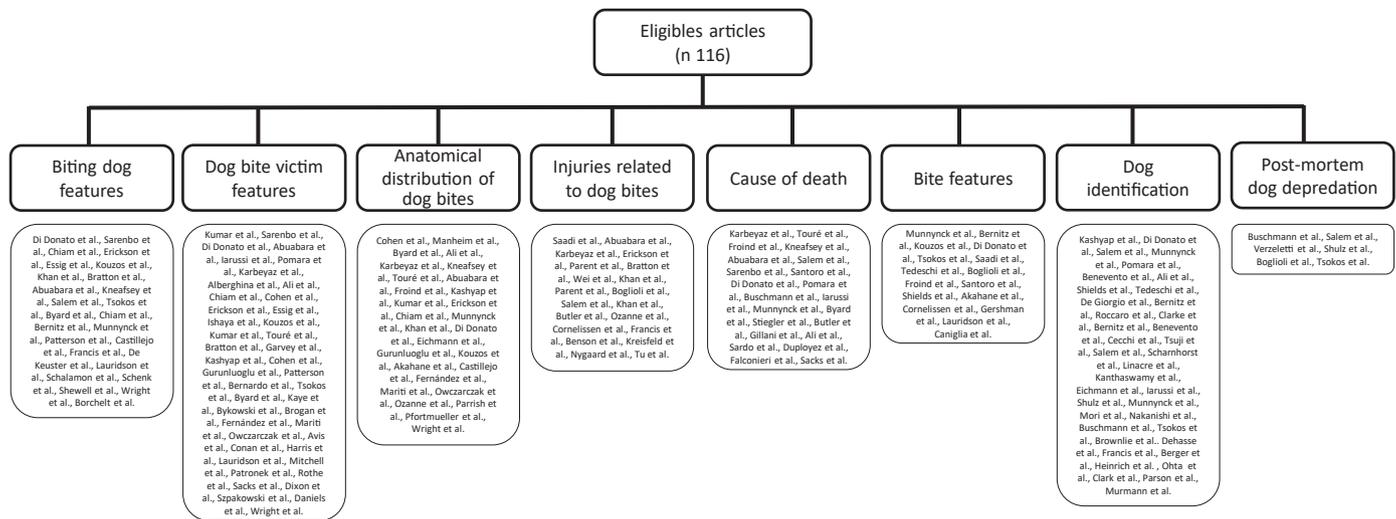


Fig. 2. Studies organized by issue of interest.

owners, where intentional biting was reported in only 51% of cases [123].

Dog attacks typically involve children or elderly [6,10,34,35]. The highest rate of serious injury from dog bites is among male children [24, 31,32,35–42,99,101,104,120,121]. There is a general lack of knowledge regarding dog behavior and safety practices for dog-child interactions [43,44]. Children do not possess the cognitive skills necessary to recognize and understand how to behave appropriately around dogs, as they may not know how to interpret the warning signs of aggression, such as growling, piloerection, and raising the ears and tail [15,45]. Furthermore, children are considered to be at greater risk of dog bites due to their innate curiosity, tendency to act in unpredictable ways, and lack of experience in handling animals roughly. Additionally, many activities that children and teenagers engage in, such as cycling, running, and other sports, may provoke dogs [27,46,104,120]. They may also be unable to escape from a predatory dog as they are not fast enough to outrun the animal and lack an understanding of the need to rapidly distance themselves from danger [24].

The second age group that experiences a high incidence of dog bites is people over the age of 70. The elderly are less able to defend themselves than younger individuals, may already suffer from health conditions that may worsen the clinical outcome and have a greater predisposition to lose their balance and fall [24,32].

In cases of attacks on middle-aged people, a significant proportion of adult victims could be explained by professional activities "at bite risk", such as canvassers, veterinarians, postal workers, and home delivery workers. To limit the damage done by dog bites it was suggested to ensure that staff should work in pairs during high-risk situations (e.g. in kennels, vet practices), and equipped with panic alarms and communication devices (walkie-talkies, mobile phones) which could help to alert others to attend the incident [47].

#### 4.3. Anatomical distribution of dog bites

The anatomical distribution of dog bite sites on humans has been linked to the age of the victim. Children are primarily bitten on the head region, while adults and the elderly are predominantly injured on the extremities. Several studies have reported that children up to about 5–8 years of age are most commonly injured in dog attacks to the face, head, and neck [7,24,35,38,39,101,120,121,124]. As children grow older, they are more likely to be bitten on the extremities, similar to adults and the elderly [15,39]. Although facial bite injuries are common, a recent court study of 245 patients with facial injuries showed that only 4–17% of animal bite injuries involve periocular and ocular tissues. These affect

various areas such as the eyelid margin, canaliculus, lacrimal gland, facial nerve, levator aponeurosis, rectus muscles, and trochlea. Globe injuries, on the other hand, are rare [48].

In a recent retrospective study, Kaye et al. evaluated 551 children and young people aged 5 months to 18 years treated in The Children's Hospital of Philadelphia Emergency Department after suffering a dog bite injury. The majority of dog bite injuries among infants and pre-schoolers affected the face (53.5%), whereas elder children mostly sustained injuries to the extremities (60.7%) [49].

It is believed that children are more likely to be bitten on the face and adults on the extremities due to height differences, as these body parts are at the level of the dog's teeth [9,37]. Facial involvement may be due to the fact that small children may frequently provoke dog bites by hugging, kissing, and petting, putting their face in close proximity to the dog's mouth [44].

The distribution of injuries on the extremities in adults and the elderly is assumed to be due to the use of hands and legs to ward off attacking dogs, the height of the dog in relation to the victim, and the extremities being a better surface for biting than the trunk [50]. Current literature suggests that elderly individuals may sustain more hand injuries when attempting to repel an attacking dog, while younger individuals may find themselves trying to separate a dog fight or may interact roughly with dogs in a way that may be perceived as aggressive, making them vulnerable to dog bites in their lower extremities [51]. The elderly may also experience head and neck injuries as they have a higher susceptibility to losing balance and falling to the ground, granting dogs access to these sensitive areas [32]. Bites within the occupational contexts similarly affect mainly hands, arms and legs [47].

#### 4.4. Injuries related to dog bites

Dog bites can result in a range of soft-tissue injuries in humans, from scratches and punctures to avulsions and fractures of varying severity [5].

Facial dog bites are most commonly found on the nose, lips, and cheeks, and can cause tissue loss that affects facial nerve, lacrimal duct, ocular, and periorbital structures. Head bites can lead to extensive scalp avulsions with areas of alopecia and cranial fractures, while the powerful jaws of a large dog can cause bilateral or multiple depressed fractures in an infant's relatively thin and incompletely mineralized skull [18,19,28,52–55].

In neck bites, the carotid and jugular vessels are the most commonly affected vascular structures, with vertebral artery injuries being infrequent. The most severe penetrating trauma can result in cervical spine

and laryngeal fractures [56,57,100]. Extremity bites can cause injuries to the vessels, tendons, muscles, and joints, with crush injuries sometimes involving bone fractures up to and including amputation of the extremity [18,58,59].

Lastly, biting dogs can transmit bacterial infections, such as several species of bacteria of the genus *Pasteurella* (e.g., *Pasteurella multocida*, *Pasteurella dagmatis*, *Pasteurella canis*, *Pasteurella stomatis*), *Actinomyces*, *Staphylococcus intermedius*, *Streptococcus* spp, *Proteus*, *Klebsiella*, *Enterobacter*, *Clostridium* spp, *Bartonella henselae*, *Capnocytophaga canimorsus*, *Leptospira* and *Bordetella bronchiseptica*). Biting dogs can also transmit viral infections, with Rabies virus being the most significant one. The virus causes inflammation of the brain and spinal cord, which can ultimately lead to the individual's death due to complications such as seizures and widespread muscle paralysis. Signs of infection such as skin redness, swelling, pus drainage can be detected at the bite site, and in severe cases, peripheral gangrene may develop [24,34,60–63].

Veterinary surgeon Dunbar developed a dog bite classification system to assess the severity of bite problems on the basis of objective wound assessment. Depending on the amount of injury caused, the bite is categorized to one of six levels, from mild lesions to the subject's death [126].

#### 4.5. Cause of death

In fatal attacks, dogs usually aim for the throat, neck, or head. They tend to drag their prey down or bite the limbs to disable them, before proceeding to attack the head and neck. Death is usually caused by exsanguination or air embolism due to vascular lacerations, asphyxiation from a compressed larynx, or brain damage from skull fractures. In rare cases, death can be caused by pulmonary embolism after calf cellulitis complicating a dog bite [24,56,64–69].

If no significant vascular or tissue injuries are found during an autopsy, an infectious cause of death should be investigated. The bacterium *Capnocytophaga canimorsus* has been reported to cause septicemia, meningitis, and endocarditis in immunosuppressed patients, those with a previous splenectomy, or those with other health problems such as alcoholism, cirrhosis, chronic lung disease, and neoplasms. Therefore, when asplenia or hyposplenia are detected during an autopsy, the possibility of a lethal infection should be seriously considered [60,70,114].

Rabies, caused by the Rabies lyssavirus of the *Rhabdoviridae* family, is fatal after the onset of clinical symptoms. It causes encephalitis characterized by psychomotor disturbances (e.g., loss of sense of direction, hyperactivity attacks), progressive muscle paralysis, leading to coma and death [38,71]. Rabies is estimated to result in approximately 59,000 human fatalities each year across more than 150 countries, with 95% of cases occurring in Africa and Asia [8].

#### 4.6. Bite features

Dogs have 42 permanent teeth, with 20 in the upper jaw consisting of 6 incisors, 2 canines, 8 premolars, and 4 molars, and 22 in the lower jaw consisting of 6 incisors, 2 canines, 8 premolars, and 6 molars. Depending on the function and shape of the involved teeth, specific types of injuries may occur. Canid incisors are relatively small and are used for nipping, producing small parallel grooves on bone. Canines are long and sharp with small serrations along one border, used to stab and tear, and can cause either punctures or gouges. The premolars are small, hook-like teeth used to hold onto prey and can cause striations on bone. The molars have small, round cusps and are used for crushing. The carnassial teeth, consisting of the maxillary fourth premolar and the mandibular first molar, allow a scissor-like action that can slice through tissues during mastication [24,29,31,65,67,72].

During attacks, dogs move their heads vigorously as they bite, compromising tissue integrity. The classical pattern of a wound produced by a bite is called "a hole-and-a-tear." The puncture injury occurs when one of the canine teeth, either from the upper or lower jaw, creates

a circular hole. This tooth acts as an anchor, while the remaining teeth slice through the flesh, resulting in elongated cuts when biting, shaking, and tearing. Under ideal circumstances, a complete impression of all the front teeth can be obtained. However, it is common to see only a prominent impression of the canine teeth. These specific injuries should be recognized as characteristic indicators of canine bites, particularly when they occur alongside tissue damage and claw marks. The claw marks, which are slender, surface-level scratches, are aligned in a parallel fashion, typically numbering four or five, and are commonly located near the site of the bite [29,73]. Indeed, in case of unwitnessed bite injuries, given the similarity of their bite patterns, wild canids should be included with domestic dogs as potential perpetrators [80]. However, despite the widespread fear of humans toward wolves, wolf attacks on people are far less common compared to dog attacks [116].

To establish the level of danger posed by a biting dog, it is important to evaluate the control and intensity of the bite, and whether the location of the bites was isolated or multiple. Indeed, the less controlled the bite, the more intense the wounds and the greater the danger for the victim. A controlled bite typically leads to a subcutaneous hematoma, while an held bite can cause an epidermal wound. However, if the bite is hard, it can result in muscle injury and even muscle laceration if the bite is prolonged. A dog that bites repetitively is more dangerous than a dog that bites once, and likewise, a dog that holds the bite is more dangerous than a dog that pinches and lets go of the person immediately [74].

#### 4.7. Dog identification

Currently, the most commonly used methods to identify a dog responsible for a bite are forensic odontology of bite marks and genetic analysis. Stomach content analysis can also be used in combination with these two techniques.

##### 4.7.1. Forensic odontology of bite marks

Bite mark analysis is based on the assumption that dentition is unique to each individual dog, and this uniqueness is replicated on the bitten surface. The shape of dental arches in dogs varies considerably depending on the dog's size, age, breed, and head morphology (i.e., brachycephalic, mesocephalic or dolichocephalic). Natural gaps exist between a dog's teeth, which may also be reflected in the bite mark impressions. Each dog may also have peculiar dental features, such as missing or fractured teeth, supplementary or abnormal teeth [31,66,72, 75–77].

The technique of whole dental arch three-dimensional comparison involves matching the whole dental cast with the bite marks on the skin. To do this, preformed acrylic trays are used to take dental replicas of the jaws after anesthetizing the dog. Hydrocolloid is a suitable impression material as it is soft and elastic and can spring without distortion around the flared canine teeth. Dental replicas of the jaws are compared with the bite mark, followed by the examination of each individual tooth mark, as well as each tooth's position relative to the surrounding teeth. The impressions of the anterior teeth are typically the most evident and likely to be measurable [65,75,77,78].

One of the primary parameters of investigation is the measurement of the inter-canine distance. The inter-canine distance varies with the animal's breed and weight, making it possible to confidently discriminate small dogs from larger dogs [65,75,76,78,79]. Murmann et al. reported that the inter-canine distance in domestic dogs ranges from 13.0 to 48.0 mm in the superior jaw, while for the inferior jaw, there is a range of 6.0–49.0 mm [80]. According to Tedeschi et al., it was found that the distance between the canines ranged from 22.0 to 65.3 mm in the upper jaw and from 18.0 to 45.1 mm in the lower jaw [76].

If bite marks are inflicted by more than one dog, several differing inter-canine distances may be observed, which can provide an indication of the number of dogs involved.

Moreover, given the similarity of bite patterns between wild canids and domestic dog and the latter's exceptional variability in terms of size

and morphology, dogs' inter-canine width ranges overlap those of smaller canids (e.g., red fox, coyote) but also larger ones (i.e., wolves) [80]. Therefore, further analyses might be necessary in order to identify the species involved. Genetic testing has already proven effective in unmasking false wolf aggressions on humans [115].

The analysis of canine 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. The mechanics of dog bites always induce degrees of distortion, which make a conclusion of absolute certainty undesirable and irresponsible. However, 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, a conclusion of a match with a high degree of certainty or high probability should be reached [79]. Bite mark analysis is still controversial but, performed according to the guidelines of the American Board of Forensic Odontology, may be helpful to identify the dog involved and DNA analysis can also be of value in dog identification [29].

#### 4.7.2. Genetic analysis

Genetic testing of animal biological material has become a valuable tool in criminal forensic investigations. Canine biological evidence can often be left behind on a victim or at the scene of an attack and may include dog saliva from bite marks on the skin or clothing, as well as dog blood, hair, and faeces [81]. Canine saliva can be recovered from the area directly surrounding the human wound, where the dog's gums and flews touched the skin of the bitten person [79]. Saliva samples need to be taken immediately as DNA can easily be removed and degraded by washing or medicating the wounds [75].

Genetic testing allows for individual animal identification through STR (short tandem repeat), SNP (single nucleotide polymorphism), and mitochondrial DNA (mtDNA) typing. Recently the forensic DNA phenotyping for predicting visible traits in dogs was studied to complement eyewitnesses' testimonies [82]. The LASSIE MPS Panel to predict externally visible traits in dogs is based on a total of 44 genetic markers to estimate the phenotypic appearance of the traits of coat color, coat pattern and coat structure, as well as tail morphology, ear shape, skull shape, eye color, and body height [83].

The most commonly used DNA-based method for identification from biological samples involves the extraction of DNA and amplification of STRs from saliva traces [11]. In DNA profiling, microsatellite markers are useful for estimating the genetic relatedness between individuals of unknown ancestry, which is especially important when there is no genealogical data available, unlike pure breeds where pedigree information is typically available to estimate relatedness from genealogies [84]. Multiplex PCR systems for canine STR typing have high specificity and sensitivity, similar to the commercially available STR kits used for human identification, and a dog population sample database is already available for the match probability statistical evaluation performed with the same statistics used for forensic human DNA identification [85–88]. While severe injuries will likely contain abundant canine biological evidence, they may also contain much blood and biological material from the victim. However, Eichmann et al. reported that high concentrations of human DNA do not seem to interfere with successful canine STR typing. Thus, severe injuries provide a better chance of obtaining a successful canine-specific DNA profile compared to more harmless dog bites [89].

SNPs and mtDNA analysis are usually performed when the biological material contains highly degraded or low quantity nuclear DNA. In particular, SNPs are a powerful complement to conventional STRs and SNP typing is mainly performed for species assignment and biogeographic ancestry and phenotype prediction [117].

MtDNA is primarily used for species identification by the analysis of the cytochrome *b* gene (*cyt b*), the most common locus on mtDNA used

in taxonomic and forensic studies. Other useful regions are the cytochrome *c* oxidase subunit I gene (COI), the 16 S ribosomal RNA gene, and the hypervariable regions (HV1 and HV2) in the D-loop [87,90,91].

Techniques for dog saliva identification by mRNA analysis are being investigated [92].

However, genetic analysis can also be conducted on biological material from the victim found on the dog. Blood and other biological samples from human victims can sometimes be found on a suspect dog after an attack, such as on a dog's collar [81]. A novel approach has been recently proposed to identify the victim's DNA from canine buccal swabs [11].

A molecular biological method using *Streptococcus oralis* and *Pasteurella canis* DNA markers for detecting human and canine saliva, was described that allows the analysis of indistinct bite marks although the results interpretation should be suggestive and considered with other evidence [93].

#### 4.7.3. Stomach content analysis

It may be possible to examine the dog's stomach content for human tissue remnants, depending on the time since ingestion. Gastric content analysis can be performed either by necropsy examination of the animal or by inducing dogs to vomit through early administration of emetics. Since dogs do not completely chew their food, intact fragments of the victim or pieces of the victim's clothing can potentially be found in their stomachs [24,68,79].

#### 4.8. Post-mortem dog depredation

The post-mortem timing of the injuries can be determined by the absence of vital reaction signs, such as haemorrhagic infiltration or marginal inflammation. Post-mortem damage can be caused by any dog and is typically observed in cases of sudden death from natural causes. Deceased individuals, particularly pet owners found in enclosed settings like apartments, often present post-mortem bites and claw injuries caused by domestic dogs. In cases of post-mortem dog depredation, damage patterns are usually limited to a specific area of the body, typically unclothed, such as the head and neck or the hands. If clothes are open or missing, the genital organs or other body sites may also be affected, raising suspicion of homicide or a sexually motivated crime. Post-mortem dog depredation may be a displacement activity in which the dog is confronted with unknown behavior of the reference person after death, and the well-known scent might be missing or changed. In this situation, the dog tries to attract the attention of its owner by bumping and licking unclothed body areas. When the usual reactions are not evoked, the dog begins to bite. Although food shortage has been suggested as a potential reason, domestic dogs are unlike wild animals in that hunger rarely seems to be their motive for post-mortem interference. Moreover, dog food is often readily available at the death scene [28,56,65,68,69,108].

## 5. Conclusion

Dog bites continue to be among the most common injuries inflicted by animals on humans. This review reveals that the characteristics of the biting dogs and their victims have not significantly changed over the past decades. In fact, the most severe or fatal attacks are typically perpetrated by young intact males in poor health conditions, inadequately trained, or lacking socialization. Furthermore, the most common victims are children, who sustain injuries to the face and head region. It is worth to mention that dogs can bite children, even newborns, without apparent provocation and such incidents are often categorized as opportunistic predation rather than overt aggression. Therefore, despite preventive measures and informational campaigns, children remain the most vulnerable group.

Conversely, dog identification methodologies have advanced over the past forty years. Forensic genetics have seen the development of

increasingly sensitive and specific methods, including techniques based on amplifying STRs from saliva traces. Additionally, the MPS Panel, which is still undergoing research for dog DNA phenotyping, represents a more recent advancement in this field. Another expanding area of research involves molecular biological methods for detecting salivary genetic markers of *Streptococcus oralis* and *Pasteurella canis*. Forensic odontology has evolved to incorporate synthetic materials that allow for three-dimensional comparisons of dental arches using replicas, eliminating the need to harm the animal. The materials used have become progressively softer and more elastic to better replicate tooth shapes. The primary parameter that has consistently been of interest over the years is the inter-canine distance, as canine teeth leave the most identifiable marks. However, it's important to note that this technique still carries limitations due to the degree of distortion, rendering conclusions of absolute certainty undesirable and irresponsible. Further studies, involving the experimental reproduction of bite marks on human skin, could help evaluate the skin's distortion factors and identify additional parameters.

Therefore, in medical forensic evaluations of dog bite cases, it is imperative to adopt a multidisciplinary approach that encompasses a comprehensive analysis of the crime scene, risk factors, dog and victim characteristics, as well as injury features. This approach allows for the sharing of expertise between human and veterinary forensics professionals.

#### CRedit authorship contribution statement

**Elena Giovannini** Conceptualization, Methodology, Writing  
**Mariana Roccaro** Data curation, Formal analysis, Writing  
**Angelo Peli** Data curation, Formal analysis, Writing  
**Simone Bianchini** Writing  
**Carla Bini** Data curation, Formal analysis, Writing  
**Susi Pelotti** Supervision, Writing  
**Paolo Fais** Supervision, Writing.

#### Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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