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REVIEW PAPER

Maxillofacial Injuries Due to Animal Bites

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Abstract
Introduction Animal bites are a significant public health problem, with the majority of bites coming from dogs, cats and humans. These may present as punctures, abrasions, tears, or avulsions. The force and relative bluntness of the teeth also increases the possibility of a crush injury with devitalized tissue .The clinical presentation and appropriate treatment of infected bite wounds vary according to the animal and causative organisms. These wounds have always been considered complex injuries contaminated with a unique polymicrobial inoculum.
Materials This article reviews animal bite wound incidence, bacteriology, risk factors for complications, evaluation components, recommended treatment and prevention based on advanced PUBMED search of the English language literature from the years 1970 to present.
Conclusion As the bite wounds are frequently located on the face, an oral and maxillofacial surgeon needs to be familiar with the treatment of animal bites, pitfalls in management and to educate patients on ways to avoid future bite injuries. The management of animal bites is an evidence poor area and most recommendations are based on small case series, microbiological data and expert opinion. The main controversies include whether wounds should or should not undergo primary closure and the use of prophylactic antimicrobials.

Keywords Animal bites · Facial wounds · Bite wounds · Maxillofacial injuries · Human bites · Soft tissue injuries

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Introduction

Facial bites are complex injuries due to the functional and cosmetic nature of the area, as well as the unique polymicrobial infection potential that exists. The face is third in a raw localization of bites following the upper and lower limbs [1]. Within the face, the nose and lips are injured the most often. In addition to the severe physical trauma and potentially permanent disfiguring wounds sustained by an animal attack, bite victims are often burdened with emotional and psychological trauma [2]. Bites are also a potential source of zoonotic infections particularly rabies and tetanus.

Since great percentage of animal and human bites is located on the face [3], oral and maxillofacial surgeons have remained in the forefront of the surgical treatment of these injuries and determining treatment protocol. This series of articles aims at reviewing the incidence, microbiology, wound characteristics, and current guidelines for the effective management of facial bite wounds. This review searched the National Library of Medicine (PUBMED). Keywords used in the search were 'facial wound', 'bite wound', 'animal bite', 'mammalian bite' and 'human bite'. Results were limited to English language and human studies. A manual search was performed of the references of each article from 1970 to present. All information was sorted and analysed for suitability for inclusion and relevant articles were retained.

Incidence

Bite wounds are mainly caused by dogs, cats and humans in decreasing order of frequency. They include superficial abrasions (30–43 %), lacerations (31–45 %), and puncture

wounds (13–34 %). Bite wounds account for about 1–2 % of all emergency department visits annually in the USA, costing over US $100 million annually [4].

Dog bites account for more than 70 % of the total animal bites incidence [5]. A survey conducted during 2001–2003 in the USA estimated 4.5 million dog bites each year with an incidence rate of 16.6/1,000 in adults and 13.1/1,000 in children [6]. There have been similar reports of human dog bites in the United Kingdom [7], Belgium, Spain, Switzerland, Australia, United Republic of Tanzania [8] and India [9–13]. Pit bulls are associated with higher morbidity rates and a higher risk of death than other breeds of dogs [14]. Besides pit bulls, Rottweilers and German Shepherds constitute the majority of canines implicated in fatalities [15, 16].

Females are most likely to be bitten by cats as compared to men [17]. According to studies, cat bites (8–13 %) [8, 18] and human bites to (2–3 %) [19, 20] come second after dog bites. It has been estimated that approximately 150,000 human bites occur annually but go unreported and roughly account for around 0.1 % of attendance to Emergency Medicine departments [21, 22]. More than 50 % human bites occur on the hands and are clenched fist injuries [23, 24]. Other less commonly encountered bites are monkey bites (3.2 % in India, 0.7 % in Israel) [25, 26] bear bites injuries ($\sim$2 attacks per year in U.S.) [27, 28] horse bites (3.8 % in all horse-related injuries in England, 17 % of animal bite injuries in eastern Turkey) [29, 30] and camel bites (25.0 % in United Arab Emirates) [31]. Camel bites are more common during the rutting season (November to February). In a comprehensive review of 153 cases of camel bites, 84 % victims were males, and the upper limbs were involved in 94 % of cases [32]. Fracture-dislocation of the temporomandibular joint was also present in one case series [33]. It has been reported that an average of five deaths occur from reptile bites each year in the U.S. [34].

Age and Sex Predilection

Animal bites are more prevalent in males. They are more likely to be bitten by dogs, monkeys [35], horses and camels and are also more frequently involved in fight injuries, whereas females are more likely to be bitten by cats [36]. In a study held in Kashmir, a total of 203 attacks (26 deaths and 177 near-fatal injuries) were recorded in a period of 2 years, involving 145 (71.5 %) male and 58 (28.5 %) female victims [37]. Unlike adults, in whom only 10 % of bites involve the head and neck, most bites in children are to the head or face, with 76 % affecting lips, nose, or cheek [38]. According to studies [36, 39, 40] children less than 5 years are the highest risk group. This can be attributed to: (1) They are almost unable to recognize the emotional behavior of animals (2) Their face and hands are exposed on the same level as the dog's jaw (3) The undeveloped motor skills (4) Relatively larger size of the head in comparison with the body [41]. Summer months are found important, when children are on holidays [42]. The population of human bite victims is most frequent between 20 and 30 years of age [20].

Microbiology of Facial Bites

The microbiology of animal bite wound infections in humans is often *polymicrobial*, with a broad mixture of aerobic and anaerobic microorganisms. Bacteria recovered from infected bite wounds are most often reflective of the oral flora of the biting animal, which can also be influenced by the microbiome of their ingested prey and other foods. Bacteria may also originate from the victim's own skin or the physical environment at the time of injury [43]. Bites by aquatic animals have a bacteriology that is reflective of their water environment. Anaerobes are isolated from more than two-thirds of human and animal bite wound infections, especially those associated with abscess formation [44, 45]. It should be appreciated, however, that almost any organism can become a potential pathogen under the right circumstances [46].

A majority of the animal bite wounds are polymicrobial, with a mix of aerobic and anaerobic organisms [45, 47–50]. *Pasteurella* species are the most common isolates with *Pasteurella canis* (50 %) predominating among the dog bites and *Pasteurella multocida* (54 %) in cat bites. *P. multocida* is a gram-negative organism categorized morphologically as a coccobacillus [49]. *It* has also been reported for numerous human infections following bites of larger cats such as tigers and lions [51]. In human bite wounds α-streptococci and *Staphylococcus aureus* are identified as the most frequent pathogens.

Commonly isolated aerobic species from almost all mammalian bites are *Streptococcus* and *Staphylococcus* species. *Neisseria*, *Corynebacterium* and *Moraxella* species are also commonly found in samples from bite wounds [49, 52]. The most common anaerobic organisms include *Fusobacterium*, *Bacteroides*, *Prevotella*, *Propionibacterium*, *Peptostreptococcus* and *Porphyromonas*. β-Lactamase production is a common feature among anaerobes isolated from infected bites.

Capnocytophaga canimorsus has been implicated as a pathogenic agent in a variety of clinical conditions such as septicemia, purpura fulminans, peripheral gangrene, endocarditis, and meningitis following dog bites mainly in the immunocompromised patients [53]. Cats are the main reservoir of *Bartonella henselae*, the causative agent of cat scratch disease [54]. The transmission of *B. henselae* to

cats is vector mediated through the cat flea, *Ctenocephalides felis*. Another *Bartonella* species recently implicated in the development of cat scratch disease due to a cat bite is *Bartonella clarridgeiae* [55]. *Eikenella corrodens* has been found in 17–25 % of human bite infections [56]. *Candida* species (8 %) have also been found in human bites, always along with bacteria [56]. Human bites can also be a source of the hepatitis B and C virus and possibly, HIV transmission as well as syphilis [57].

The spectrum of isolates from humans bitten by monkeys is similar to that of isolates from human bite wounds [58]. A major concern with monkey bites is the transmission of viral diseases [59]. Organisms isolated from grizzly or black bear bites have included *Streptococcus* (61 %), *Staphylococcus* (48 %), *Escherichia* (40 %), *Enterobacter* (25 %), *Citrobacter* (10 %), *Hafnia* (10 %), *Proteus* (6 %) [60]. Most reports of the bacteriology of horse bite wounds in humans have revealed infections to be polymicrobial, which include *Actinobacillus*, *Bacteroides*, *Campylobacter*, *Neisseria*, *Pasteurella*, *Staphylococcus Streptococcus* and *Yesinia* species [61]. Bacterial cultures of specimens taken from camel bite wounds revealed *S. aureus*, *Pseudomonas aeruginosa*, and *Bacillus* species as the prominent organisms [62].

Causes

Animal bites are either provoked or unprovoked. This type of information is very important to the person taking care of the bite beside in certain animal species "unprovoked" bites can be a sign or indicator that the animal has rabies and needs to be captured, quarantined or very closely monitored. According to studies [16, 63–66] 85 % of dog bites and 80 % of cat bites/scratches were from an animal belonging to the victim and happen at or near the victims' home [63, 64, 66]. In a review by Griego et al. [65] approximately 1 in 20 dogs will bite a human being during the dog's lifetime and the pet is known to the victim in approximately 90 % of such cases. Although bites of owned cats are less frequent than those of strays, owned cats deliver more severe bites with a higher percentage of bites delivered to the face [13, 67]. Curtin and Greeley [68] found that human bites occurred most frequently in adolescents and young adults who are most likely to become involved in physical altercations.

Wound Characteristics

An animal bite wound can be characterized by various types of injuries like abrasions, puncture wounds, avulsions, lacerations, and crush injuries along with underlying fractures, foreign bodies and tendon and nerve injuries. Patients either present with a fresh wound soon after the injury or after developing painful signs of infection. As a result, bite wounds result in morbidity and mortality through both physical trauma and infection.

Table 1 Classification of facial bite injuries [69]

Type	Clinical findings
I	Superficial injury without muscle involvement
IIA	Deep injury with muscle involvement
IIB	Full-thickness injury of the cheek or lip with oral mucosal involvement (through and through wound)
IIIA	Deep injury with tissue defect (complete avulsion)
IIIB	Deep avulsive injury exposing nasal or auricular cartilage
IVA	Deep injury with severed facial nerve and/or parotid duct
IVB	Deep injury with concomitant bone fracture

The severity of the animal bite wounds is assessed by modified Lackmann's classification for facial wounds (Table 1).

Dogs are more likely to inflict superficial abrasions and lacerations [3, 70]. The typical dog bite results in a combination of torn tissues and adjacent punctures, the so-called ''hole-and-tear'' effect [47]. The force delivered by a dog's jaws while biting can be as high as 200–450 psi (pressure enough to perforate sheet metal) and results in the devitalization of the wound tissue with associated ripping and tearing motion [46, 71]. Additional injuries may include facial nerve damage, lacrimal duct damage and ptosis from levator transaction [72]. Although facial fractures are not commonly considered to be associated with dog bite injuries, the index of suspicion for a fracture should be raised when the injury occurs in a child. Only one study [72] reported six cases of facial fractures associated with dog bites and reviewed additional 10 cases reported in the literature. The thin and immature calvaria of a young child has little resistance to the pressure that can be exerted by animal bite, and a small, apparently minor cranial puncture can be associated with a breach in dural integrity, which carries with it a high risk of intracranial infection. The nose, lips, and cheeks have been designated the "central target area" and are the most common structures that are damaged [7].

In contrast cats, because of their long, slender and sharp teeth almost always inflict deep puncture wounds [67, 70, 73]. These wounds may appear minor at the skin surface but can penetrate deeply and puncture bone, joints and tendons. One should keep in mind that cat bite wounds are challenging, they appear to be less destructive but they can be life threatening. If occurring close to joints or bones, septic arthritis, deep abscesses (spread along fascial planes) and osteomyelitis may develop.

Most human bites occur during fights whereas a substantial percentage is related to sexual activities. In addition to occlusional bites, human bites include a specific type of wound, the clenched-fist injury. Clenched-fist injuries are caused by a blow to the teeth from a clenched fist during a fight, with the blow resulting in a bite, usually to the dorsum of the hand or over an Meta-Carpo-Phalangeal (MCP) joint. According to some authors, clench-fist human bite wounds penetrate into the MCP joint in 52–62 % [74], resulting in tendon injuries in 20 %, cartilage injuries in 6 %, and bone injuries in 17–58 %. A case of osteomyelitis of the anterior skull resulting from a human bite has also been reported [75]. Human bite wounds have a very bad reputation for infection and subsequent severe complications [76].

Monkey and simian bites are becoming more common, occur more frequently in men, and often affect the upper extremity, especially the hand [46]. The complications of these bites include cellulitis, osteomyelitis, tenosynovitis, and flexion contractures [61]. Herbivores rarely cause bites but appear to be associated with a high infection rate [67]. Camels can cause severe injury with their large incisors and there are cases of camels biting their handlers to death [77, 78]. Horse and sheep bites have been reported mainly to the handlers of these animals in farms. Pig bites are not uncommon, can be severe and have a high risk of infection from multiple organisms [79, 80].

Bite wounds inflicted to the head and neck region by large animals like bears, camels and horses can present in a more serious fashion [81]. These animal attacks can result in life-threatening or even fatal injuries because of airway compromise, exsanguination or craniocerebral trauma.

Risk Factors for Wound Infection

Facial bite wounds generally display low infection rates, commonly attributed to the rich blood supply of the area [47, 82]. By contrast with other sites, 30–40 % of hand bites become infected [16]. Factors that increase the risk of infection can be divide into high risk and low risk wounds (Table 2).

Table 2 Infectious potential of animal bites [65, 67, 76, 83–86]

Factor	High risk	Low risk
Species	Domestic cat	Dog
	Large cat (deep punctures can penetrate joints, cranium),	Rodent
	Human (in hand wounds only),	
	Primate(anecdotal evidence only),	
	Pig, monkey	
Location of wound	Hand, feet, wrist	Face, scalp, ear and lip
	Scalp or face in infants (high risk of cranial perforation)	
	Below knee	
	Through-and-through oral	
	Penetration of underlying tissue (bone, joint, tendon, vascular)	
Wound type	Puncture (impossible to irrigate) 40 % of all bite infections)	Superficial, large clean lacerations that can be thoroughly cleansed; the larger the laceration and the better the cleansing, the lower the infection rate
	Extensive crush that cannot be debrided (typical of herbivores such as cows, horses)	
	Contaminated	
	Delayed presentation >12 h	Clean
		Recent
Patient	Elderly	
	Diabetic	
	Peripheral vascular insufficiency	
	Asplenic	
	Chronic alcoholic	
	Chronic corticosteroid therapy	
	Cytotoxic drugs	
	Altered immune status	
	Prosthetic or diseased cardiac valve (consider systemic prophylaxis)	
	Prosthetic or seriously diseased joint (consider systemic prophylaxis)	

Diagnosis of Infection

Infected bite wounds are usually manifested by pain and edema at the site of the injury frequently associated with a purulent discharge and possibly regional lymphadenitis. Fever greater than 38 °C has been recorded in less than 10 % of these patients [3]. When examining neglected bites of any kind, the clinician must distinguish the normal inflammatory response from the erythema and swelling of infection. The latency period between the bite and the appearance of first symptoms of infection appears to be significantly shorter for cat bites than for human and dog bites (median time 12 vs. 22 and 24 h, respectively) as wound infections due to *P. multocida* organisms tend to occur earlier (usually within 24 h from injury) [82]. Penetrating skull wounds may result in meningitis or a brain abscess. Septicemia occurs primarily in immunocompromised patients, particularly those who are

asplenic and therefore more susceptible to infection with encapsulated organisms [46, 73, 76].

There is no need to culture fresh or uninfected wounds as 83 % will show no growth [87]. Since the bacteriology of bite wound infection has been so extensively studied, cultures are probably helpful only in cases of treatment failure or severe or high-risk infections. When infection is present, both aerobic and anaerobic cultures should be obtained from deep within the wound, after removal of superficial crusts, but before debridement [16]. Methicillin resistant *S. aureus* (MRSA) appears to be emerging zoonotic pathogen in animal bites [70].

The use of Gram's stain as an indicator of the presence of pathogens in the wound can be of assistance [70]. *P. multocida* may be difficult to capture by swabbing an exposed wound surface because this organism dies in 10 min of exposure to sunlight [87]. Measurement of sedimentation rate or C-reactive protein can be helpful [7]. If the C reactive protein level continues to rise, then a clinical reappraisal is needed as a second debridement may be advisable, particularly with joint space infections. In severe cases, there may be a peripheral leukocytosis of 15,000–30,000 cells/cubic mm.

Management

The management of animal bite wounds should include the elements of history, physical examination, documentation, laboratory investigation, therapeutic intervention, and prophylactic measure [63]. The prompt implementation of such appropriate medical and surgical therapy for bite wounds may serve to prevent associated complications. Many of the specific therapies recommended for bite wounds are controversial with opinions on either side of most issues. Local standards of care should be followed, and appropriate consultation with other specialists should always be considered.

Prophylactic antibiotics should be considered in patients with factors that increase the likelihood of infection as infected animal bites may result in devastating consequences. It is equally essential to enquire about the status of tetanus immunization and to evaluate the risk of rabies and arranging appropriate immuno-prophylaxis. One must never forget to provide hepatitis prophylaxis for patients who have been bitten by known carriers of hepatitis B. So the overall goal of treatment is to manage wounds properly in order to prevent morbidity and mortality.

Emergency Management

As with any injury, priorities are given to any life-threatening conditions, according to advanced trauma life support (ATLS) resuscitation guidelines [3, 45, 88, 89]. Such injuries are usually associated with penetrating neck trauma following mauling by bears and large dogs. Penetrating wounds of the neck and thoracic inlet can cause exsanguination because of carotid trauma, and are the major cause of death in children aged less than 10 years. In these cases, resuscitation must be the priority and early angiography and exploration may be necessary. Close attention should also be paid to scalp lacerations of infants and young children because the thin and incompletely mineralized skulls of infants and young children are susceptible to puncture-type fractures, with resultant intracranial injury so evaluation with plain films or CT scan is important [71]. Victims need cervical immobilization until cervical lesions are excluded. Eyelid lacerations require careful evaluation to rule out penetrating injury to the globe or interruption of the lacrimal drainage system. Ultrasonography can be used for diagnosis of suspected soft tissue injury. One should always consider cervical spine evaluation if the child was shaken.

History

After the patient is considered "stable", a history and physical examination is performed with the comprehensive head-to-toe secondary survey. A focused history with attention to the specified features will serve to identify persons at highest risk for complications and to identify animal behavior suggestive of rabies infection. The points to be included in the history are summarized in Table 3.

Physical Examination

Wound type and measurements should be noted along with the injury to bone, vessels, airway, facial nerve, parotid and lacrimal duct [89]. This should include depth and extent of the wound and integrity of the neurovascular and motor systems. If infection is present, the extent of cellulitis,

Table 3 Points to be included in history [44, 88, 89]

Circumstances of attack (animal species, provocation, timing, mechanism of injury)
Current medications
Medical comorbidities (particularly immunosuppression)
H/o splenectomy, mastectomy, transplanted organs
Allergies
Immunization status (tetanus, hepatitis, rabies)
Occupation
Current health status and vaccination record of the animal (when available)
Determine if law enforcement has been notified
History of discharge, redness, or increasing pain at the site of injury

adenopathy, fever, systemic signs or abscess formation must be recorded. If cellulitis is present, drawing the extent on the patient's skin will frequently benefit follow-up. A procedure note should detail all therapeutic maneuvers [63, 90].

Patients who have a fight bite may hesitate to reveal the actual mechanism for fear of legal repercussions. Any wound occurring over the MCP joints should alert the physician for this type of mechanism [86]. All bite marks in a young child should raise suspicion of abuse. Any human bite marks with an intercanine distance greater than 3.0 cm are likely inflicted by an adult.

Wounds over joints or vascular structures should be examined throughout the complete range of motion to identify retracted injuries. It is important to recognize when a wound is at high risk of infection and when admission to hospital is required (Table 4).

Consultation

- Plastic surgery consultation is recommended for disfiguring injuries, especially those involving the face.
- Ophthalmologic consultation is indicated for the treatment of wounds involving the eye, orbit, or both.
- Surgical (vascular, general, hand, orthopedic) consultation is needed for wounds with involvement of major blood vessels, abscesses or deep tissue infections, or a potential for loss of hand function (clenched-fist wounds).
- An infectious disease specialist can provide advice regarding antibiotic choices, especially if the infection is not responding to initial antibiotic therapy.
- Neurosurgery should be consulted for penetrating wounds to the skull [88, 93].

Psychology services should be solicited as appropriate, especially when the event was particularly frightening or when there is concern for disfigurement.

Local Wound Care

According to traditional surgical dictum—"dilution is the solution to all pollution". The rules governing the management of any laceration also apply to animal bites: cleanse, explore, irrigate, debride, drain, and possibly suture [44, 45, 71]. According to Thompson and Svitek's [94] study wounds difficult to irrigate thoroughly such as punctures, are twice as likely to become infected.

Table 4 Indications for hospital admission [45, 91, 92]

Systemic manifestations of infection, severe cellulitis
Penetration of deeper tissues or central nervous system
Likelihood for noncompliance e.g. children requiring surgical care
Presence of peripheral vascular disease
Immunocompromised by disease or drugs
Injuries requiring reconstructive surgery
Head injuries
Infection refractory to oral or outpatient therapy

- A thorough examination under proper lighting conditions should be conducted. If the skin is penetrated, debridement and irrigation reduce the infection rate to 5–15 % for most mammalian bites [44, 45, 71]. Irrigation of these wounds can be accomplished to optimal by using a 19–20G gauge needle or plastic catheter or splash shield [81] on a 30- to 60-ml syringe which delivers a pressure range between 5 and 8 psi, using 250–500 ml of solution [71]. Continuous irrigation seems to be just as effective as pulsatile lavage [45]. However, sustained high-pressure irrigation should be avoided in areas containing loose areolar tissue, such as the eyelids or children's cheeks because such irrigation may cause tissue disruption and excessive edema [81]. When using a pressure irrigating system on facial tissue, one must use extreme caution and properly protect the eyes from direct contact with the pressurized stream [95].
- Incising the puncture to promote irrigation is not advised as it causes unnecessary scarring [57, 96]. The tip of the flexible angiocatheter can be readily positioned into the depth of the puncture wound and the irrigation solution can then be expressed through the syringe to irrigate the wound [71]. Care must be taken not to inflict additional trauma.
- Normal saline or 1 % providone–iodine solution (not the detergent scrub preparation) [81] can be used for irrigation, although normal saline is the most commonly recommended [45, 71, 97]. By no means should the use of prophylactic antibiotics replace adequate irrigation of these wounds [71]. Cleansing of the wound with soap and water followed by 1 or 2 % benzalkonium chloride, 1 % centrimonium bromide [71] or povidone–iodine [81, 86] has also been recommended to reduce viral contamination.
- Cautious debridement of devitalized or crushed tissue including probing for embedded teeth or fragments is crucial because it significantly decreases the likelihood of infection [44, 45, 63, 98]. 1–2 ml of tissue may need to be excised from around the perimeter to create a healthy, clean wound edge. However, debridement of facial wounds should be kept to a minimum (because facial tissue can survive on small pedicles);so as to avoid scarring and sacrifice of tissue that has a good chance to survive particularly in landmark areas such as the vermilion border of the lips, the nasolabial fold and eyebrows [90].

- Bites to the face, especially of children, require meticulous management. Nearly all facial bite patients do well with careful debridement, ample irrigation and cleansing and loose closure by suture.

Surgical Treatment

There has been a diversity of opinion with regard to the surgical management of human bite wounds of the orofacial region (Table 5). The treatment of each case depends on factors such as the nature of the injury, the expertise of the surgeon, the amount of time between injury and repair, and the location of the injury. It is universally agreed that these injuries must be treated early and that good wound cleansing must be achieved .

The proper means of bite wound closure remains controversial especially when cosmetic concerns are high [45, 81, 100, 101]. All types of mammalian bites to the face and head are frequently closed primarily to minimize scarring and disfigurement [38, 88, 93, 102, 103]. Good results are probably due to excellent blood supply, rarity of edema, meticulous irrigation, avoidance of multiple layered closure with buried sutures, and antibiotic prophylaxis. *Keeping these facts in mind many surgeons have a view that wound closure is the treatment of choice for all uninfected facial bite lacerations seen within 24 h, because this obtains the most favorable esthetic result* without significantly increasing wound infection rate (i.e., 1–6 %) [45, 81, 104–108]. But as bite wounds are essentially contaminated, meticulous debridement and delayed closure appear to be another choice. Supporters of this method claim that as long as the repair is performed before the wound reaches the proliferative phase of healing, cosmetic results are indistinguishable from those of primary repair. Successful immediate primary closure has also been reported after debridement with proteolytic agents. [71].

By contrast, deep puncture wounds should be left open, particularly when inflicted by cats [45, 63, 89, 98, 99, 109]. Most of the surgeons do not advocate closure of puncture wounds presumably because it is difficult to obtain adequately cleansed wounds. Callaham [76] recommends that wounds at high risk for infection such as: crush injuries, puncture wounds, wounds to the hands, dog bite wounds receiving initial care more than 8 h after the injury, all cat or human bites, and wounds in immunosuppressed patients, should be irrigated copiously and left open to drain.

For uncomplicated bite wounds presenting beyond the 'golden 24-hour period', primary closure is controversial [71]. *In these cases, delayed closure is a time-honored practice*. This implies a waiting period of 4–5 days before definitive wound closure, during which time the wound is kept open, usually with moist gauze dressings providing drainage, while edema is allowed to subside. Antibiotics can be administered to further diminish the risk of infection.

In crush avulsion injuries with associated skin loss, nonviable elements must be surgically excised because they predispose to infection and lead to excessive scarring [107]. Complicated tissue transfer techniques have no place in the acute treatment of facial wounds. Closure should be achieved in the simplest way possible and complex reconstructive efforts should be deferred until the scar has matured. It is problematic if large areas of soft tissue in the head region are lost or amputated [89, 110]. An optimal aesthetic result sometimes can only be achieved by extensive surgery such as local flaps or microsurgical replantation which has become the standard operation in some centers, yet it remains technically demanding. Musgrave and Garrett [111] have allowed avulsive wounds of the lips to heal by secondary intention, with revision at a later date if necessary. When dealing with wounds involving the periorbital soft tissues and nose, the surgeon must also remember to fully evaluate the nasolacrimal system and perform a dacryocystorrhinoscopy to determine if the duct is injured. Eyebrows provide a landmark for realignment of disrupted tissue edges and do not always grow back so they should not be shaved when facial lacerations are repaired.

Whenever suturing is chosen, only percutaneous nonabsorbable sutures are used [81]. Clean lacerations are treated with minimal, tension-free, fine monofilament suture placement and early suture removal (3–5 days) [107]. *N*-butyl-2-cyanoacrylate (Derma bond) or steri strips are preferably used to repair pediatric facial lacerations, particularly with low tension. Some surgeons avoid or minimize the use of deep sutures and rely on drains and pressure dressings to eliminate the dead space. They believe that deep sutures act as a nidus for infection and should be avoided. Other surgeons prefer to close the deep layers following vigorous wound irrigation and debridement [108, 112]. Suture placement to produce wound eversion and time of removal affect the final result. Contusion, infection, retained foreign body, improper orientation of laceration, pattern of laceration (e.g., ''U'' shaped), tension, and beveling of edges predict a poor outcome. Further management includes close patient monitoring because there remains a risk of developing infection at a

Table 5 Controversial topics in the management of facial bite wounds [45]

Selection of solution for wound irrigation
Irrigation of puncture wounds
Role of antibiotic prophylaxis
Selection of antimicrobial agent(s)
Cutoff time for primary closure

later stage 5. Follow-up visits for wound review should take place at 24–48 h. Attention to patient counseling, dressings, ointment, cleaning, and scar revision assure an optimal outcome.

Antibiotic Prophylaxis

Due to the wide range of potential pathogens and frequent co-infection by several bacteria with differing antimicrobial sensitivities, treatment of bite wounds is challenging [113]. Antibiotic administrations for bite wounds can be either prophylactic or therapeutic. There are certain situations when antibiotic prophylaxis is needed (Table 6).

Goldstein et al. [116] suggest that prophylactic antibiotics reduce the rate of infection. Because the indications for antibiotics do not correlate well with the severity of injury, *prophylaxis is generally recommended for all bites penetrating the skin.*

Traditional approaches involve selective coverage for the most likely pathogens. According to current recommendations [45, 69, 72] amoxicillin/clavulanate is the antimicrobial agent of choice for prophylaxis of bite wounds as it remains active against most animal and human bite-wound isolates. In the series of Kesting et al. [69] none of the patients who received amoxicillin/clavulanate developed infection. In case of allergy to penicillin, available alternatives include cefuroxime axetil for patients with mild allergy, whereas those with a history of a severe reaction can receive doxycycline [117] or a combination of clindamycin with either a fluoroquinolone or trimethoprim-sulfamethoxazole (for children). Azithromycin is probably the most appropriate choice for penicillin-allergic pregnant women. Each of these antimicrobial agents are considered empirical treatments until definite pathogens are identified through accurate culturing and appropriate antimicrobials are established by in vitro susceptibility testing [44, 118] (Tables 7, 8).

Table 6 Indications for prophylactic antibiotics [45, 69, 114, 115]

Cat, pig, wild carnivore, and monkey bites
Presentation more than 8 h after bite
Bites involving hands and feet, face and genitalia
Moderate or severe wounds, deep puncture wounds that may have penetrated joint spaces, bones or tendons, suspected fractures
Primarily closed wounds/wounds requiring surgical repair
Diabetes mellitus
Asplenic patient
Immunocompromised (disease or drugs)
Elderly
Prosthetic heart valve

- First-generation cephalosporins are not as effective as the amoxicillin and clavulanic acid combination because of resistance of some anaerobic bacteria and *E. corrodens.*
- Clindamycin and the penicillinase-resistant penicillins should not be administered without penicillin because of their poorer activity against *P. multocida*.
- Azithromycin is generally more active than clarithromycin against all *Pasteurella* species.
- The newer quinolones (moxifloxacin and gatifloxacin) also possess good activity against all major bite wound pathogens, including anaerobic bacteria [119]; however, their use in pediatric cases is restricted.
- Intravenous antibiotic coverage with ticarcillin clavulanate and hospitalization are indicated for immunodeficient patients, badly infected wounds, or deep injuries with exposed cartilage [115].

Table 7 Summary of empiric antibiotic treatment for facial bite wounds—prophylactic regimens [3, 45]

	Dog	Cat	Human
Pathogenic flora	*Pasteurella* spp., *S. aureus*, anaerobes, *Capnocytophaga*	*Pasteurella multocida* (>50 %), *S. aureus*, anaerobes	Streptococci, *S. aureus*, *E. corrodens*, anaerobes
Primary	Amoxicillin-clavulanate	Amoxicillin-clavulanate	Amoxicillin-clavulanate
Alternative/ allergy	Clindamycin plus either ciprofloxacin or TMP-SMX, azithromycin	Cefuroxime axetil, Clindamycin plus either ciprofloxacin or TMP-SMX, azithromycin	Azithromycin, moxifloxacin

Duration of therapy: 3–5 days; 10–14 days for bone involvement [69, 86, 113]

Table 8 Summary of empiric antibiotic treatment for facial bite wounds—therapeutic regimen [3, 45]

	Dog	Cat	Human
Onset of symptoms	12–48 h post injury	7–18 h post injury	12–36 h post injury
Oral therapy:			
Amoxicillin-clavulanate. For penicillin allergy, clindamycin plus either ciprofloxacin or TMP-SMX			
Intra-venous therapy			
Ampicillin-sulbactam, or ticarcillin-clavulanate, or cefoxitin. Any of this plus amino glycoside for bite wounds heavily contaminated with soil or inflicted by hospitalized patients. For penicillin allergy, clindamycin plus either ciprofloxacin or TMP-SMX			
Duration of therapy: 7–14 days for soft tissue infection; 3 weeks or more for bone involvement			

TMP/SMX trimethoprim-sulphamethoxazole

- Fluoroquinolones are not routinely recommended for children younger than 18 years of age because of concerns about damage to developing cartilage.

Tetanus Prophylaxis

All bite wounds are considered tetanus-prone injuries thus the tetanus immunization status of the animal bite patient must be established [72, 98, 113] (Table 9).

Rabies Prophylaxis

Rabies threatens millions of people in developing countries. Thousands of victims die each year, despite it being a vaccine-preventable disease [121]. In India, about 15 million people are bitten by animals, mostly dogs, every year and need rabies post exposure prophylaxis (RPEP). Almost 50,000 people die each year from the disease, with India carrying the greatest burden of more than 20,000 deaths annually [93].

Despite widespread vaccination programs of domestic animals, rabies remains a worldwide threat; as it is nearly always fatal, RPEP should be considered for all unprovoked animal bite victims. Biting animals with unknown or unclear immunization status that are available for quarantine, should be observed for 10 days, during which prophylaxis should begin at the first clinical sign of the disease. Because of local variations in animal vectors and endemics, consultation with a state or local health department is prudent before a decision is made to initiate RPEP. Details for the administration of RPEP with human rabies immune globulin (RIG) and vaccine can be found in the current recommendations of the Advisory Committee on Immunization Practices (ACIP) [122, 123].

Previously, ACIP recommended a 5-dose rabies vaccination regimen with human diploid cell vaccine (HDCV) or purified chick embryo cell vaccine (PCECV). But the new recommendations (2010) reduce the number of vaccine doses to four [124]. The studies indicated that 4 vaccine doses in combination with RIG elicited adequate immune responses and that a fifth dose of vaccine did not contribute to more favorable outcomes.

- For persons previously unvaccinated with rabies vaccine, the reduced regimen of 4 doses of HDCV or PCECV should be administered intramuscularly (in the deltoid area in adults, or into the lateral thigh in young children). The first dose of the 4-dose course should be administered as soon as possible after exposure (day 0). Additional doses then should be administered on days 3, 7 and 14 after the first vaccination.
- ACIP recommendations for the use of RIG remain unchanged. For persons who previously received a complete vaccination series (pre- or post exposure prophylaxis) with a cell-culture vaccine or who previously had a documented adequate rabies virus-neutralizing antibody titer following vaccination with nonce-culture vaccine, the recommendation for a 2-dose PEP vaccination series has not changed.
- Similarly, the number of doses recommended for persons with altered immunocompetence has not changed; for such persons, PEP should continue to comprise a 5-dose vaccination regimen with 1 dose of RIG.
- Recommendations for pre-exposure prophylaxis also remain unchanged, with 3 doses of vaccine administered on days 0, 7, and 21 or 28. Prompt rabies PEP combining wound care, infiltration of RIG into and around the wound, and multiple doses of rabies cell-culture vaccine continue to be highly effective in preventing human rabies.

Table 9 Recommended guidelines for tetanus prophylaxis [120]

History of adsorbed tetanus toxic (doses)	Tetanus-prone wounds	Tetanus-prone wounds	Nontetanus-prone wounds	Nontetanus-prone wounds
	Td[a]	TIG[f]	Td[a]	TIG[b]
Uncertain or <3	Yes	Yes	Yes	No
3 or more[c]	No[e]	No	No[d]	No

Td tetanus & diphtheria toxoids, *TIG* tetanus immune globulin

[a] For children less than 7 years old, diphtheria and tetanus toxoids and acellular pertussis vaccine adsorbed (DTaP) (diphtheria and tetanus toxoids adsorbed [DT], if pertussis vaccine is contraindicated) are preferred to tetanus toxoid alone. For persons 7 years old and older, Td is preferred to tetanus toxoid alone

[b] When TIG and Td are given concurrently, separate syringes and separate sites should be used

[c] If only 3 doses of toxoid have been received, a 4th dose of toxoid, preferably an adsorbed toxoid, should be given

[d] Yes, if more than 10 years since last dose

[e] Yes, if more than 5 years since last dose (more frequent boosters are not needed and can accentuate side effects)

[f] *TIG* human tetanus immune globulin

Complications

The main complications of mammalian bites are tissue damage from the bite itself, infection and psychological distress. Injuries sustained from a bite are dependent on the animal species and dentition, ferocity of attack and the anatomical location of the bite.

Deep infection can result in septic arthritis, osteomyelitis, tenosynovitis and compartment syndrome. Other complications include tetanus, rabies, cat scratch fever, rat bite fever, tularemia, pasteurellosis, leptospirosis, and plague. Rare complications include endocarditis, meningitis, brain abscess, and sepsis with disseminated intravascular coagulation, especially in immunocompromised individuals [40, 72, 115].

Prevention of Animal Bites

Prevention strategies include close supervision of child-dog interactions, public education about responsible dog ownership and dog bite prevention, stronger animal control laws, better resources for enforcement of these laws and better reporting of bites. Anticipatory guidance by pediatric health care providers should attend to dog bite prevention. The need to improve community knowledge of rabies and the availability and affordability of rabies vaccine must be highlighted. Dog bite injury should be routinely coded by the ICD9 (E code 906.0) or the corresponding ICD10 code. Similarly, standardized methods for measuring and reporting dog populations are required.

On the Horizon

Rabies has been considered a nearly uniformly fatal disease if untreated. Report of a 15-year-old girl who survived rabies was published in 2005 [125]. The patient did not receive immune prophylaxis but was treated by induction of coma, intense antiviral therapy, and full critical care level of support. The intervention provided to this patient might lead to greater survival and improved neurologic outcome in the future.

Conclusion

Animal bites are an important health-care problem and a common cause of maxillofacial trauma throughout the world. The injuries sustained from an animal bite are dependent upon the characteristics of the biting animal, the method and ferocity of attack, animal's dentition and the anatomical location of the bite. In addition to physical and psychological trauma, bite wounds commonly become infected. The philosophy regarding management of these injuries has undergone a transformation from that of allowing the wounds to heal by secondary intention to a more aggressive approach that optimizes the esthetic results by primary closure. Failure to adequately irrigate and debride these wounds is undoubtedly the most common mistake made in the management of these wounds.

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