

# The bacteriology and antimicrobial susceptibility of infected and non-infected dog bite wounds : fifty cases

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With 2 tables and 1 figure

## Abstract

Dog bite wounds are a common reason for dogs requiring veterinary care, but there is surprisingly little data on the bacteriology of bite wounds. A prospective study was performed on dogs with various grades of bite wound to identify the bacteria present in these wounds. Swabs were collected from all wounds for bacterial culture and cytology. All swabs were cultured aerobically and anaerobically and all aerobic cultures were evaluated for antibiotic susceptibility using the Kirby Bauer disk diffusion test. Fifty dogs with 104 bite wounds, inflicted within the previous 72 h, were included. The victims were predominately intact male small breed dogs. Of the 104 wounds, 21 were judged by cytology to be infected and 83 non-infected.

Infected wounds were significantly more likely to culture positive ( $p = 0.02$ ). Sixteen percent of wounds showed no growth. Sixteen percent grew aerobes, 1% anaerobes and 67% a mixture of aerobes and anaerobes. *Pasteurella canis* and pyogenic streptococci were common in infected wounds, whereas *Bacillus spp.*, *Actinomyces spp.* and the oral streptococci were usually found in contaminated wounds. Three anaerobic genera were cultured, namely, *Prevotella*, *Clostridium* and *Peptostreptococcus*.

One case represented the first isolation of *Capnocytophaga canimorsus* in an infected dog bite wound. Although no single antibiotic therapy was considered to be effective against all the bacteria, amoxicillin plus clavulanic acid, 1st and 3rd generation cephalosporins ampicillin or amoxicillin and potentiated sulphonamides gave the best in vitro sensitivity results.

**Keywords:** Bite wounds; Bacteriology; Canine; Dog; Antimicrobial susceptibility

## 1. Introduction

Dog bite victims can account for a significant part of the caseload seen in small animal veterinary practice and human emergency facilities (Callaham, 1980). Based on the available veterinary literature, the bacteriology of dog bite wounds (DBW) inflicted by other dogs is equivocal, with the majority of reports having focused on management alone. In contrast, the complex polymicrobial environment of DBW in humans has been well documented, with the majority of reports having investigated infected wounds. In a clinical setting it has been shown that although 80% of DBW inflicted on people culture positive for bacteria, only 3–20% will become infected (Underman, 1987; Goldstein, 1992). In a review of 10 human bite wound studies, it appeared that only a few organisms accounted for those wounds which became infected, despite the broad diversity of bacteria isolated (Marcy, 1982). These infected wounds had less species diversity with greater bacterial numbers when compared with non-infected wounds (Underman, 1987; Talan et al., 1999). The majority of wounds cultured in humans contained a mixture of aerobes and anaerobes, which are thought to reflect the diverse oral flora of the biting animal and to a lesser extent that of the victim's skin (Goldstein et al., 1978; Talan et al., 1996). Both *Pasteurella spp.* and *Staphylococcus spp.* have been recognised as being potentially important pathogens. Data from a study by Talan et al. (1999) support *Pasteurella's* reputation for pathogenicity and its association with a more rapid onset of clinical signs.

Due to the paucity of animal studies, much of the data in the veterinary textbooks is cited from human studies. This human data contrasts to two separate veterinary studies in which

*Staphylococcus intermedius* was the most common isolate, followed by *Streptococcus* spp. and the coliforms (Kelly et al., 1992; Griffin and Holt, 2001). Unexpectedly, only a few *Pasteurella* species were cultured. *Clostridium* spp. were the only obligate anaerobes isolated in a published study of bite wounds in dogs thus far (Griffin and Holt, 2001). This study aimed to document the complex microbiological population, and antimicrobial susceptibilities as found in non-infected and infected DBW in which specific criteria were used in order to define infection.

## 2. Materials and methods

### 2.1. Specimen sampling

Forty-seven dogs admitted to the Outpatients Clinic of the Onderstepoort Veterinary Academic Hospital and three dogs presented to the Society for the Prevention of Cruelty to Animals (SPCA) between August 2005 and May 2006 for the treatment of DBW were prospectively included in the study. Dogs were included in the study providing the injuries sustained were within 72 h of admission and there was no prior history of having received corticosteroids or antimicrobial treatment. Each dog was evaluated clinically with special attention being paid to its rectal temperature, pulse and respiratory rates and its capillary refill time. All wounds were then individually assessed and accorded an infection status and wound grade. "Infected" wounds were considered to have met two of three criteria: (1) patient had to be pyrexial (rectal temperature of more than 39.7 °C); (2) cytological indicators of wound infection had to be present; (3) wounds had to have a purulent discharge.

For the purposes of this study, the cytological indicators of wound infection included lesions composed of more than 85% neutrophils, many of which may be degenerate, or neutrophils with phagocytosed bacteria, often in addition to extracellular bacteria (Tyler et al., 1999). Since contaminated wounds may also yield bacterial growth, positive culture alone was not considered to be a criterion for infection in this study. Wounds were classified according to grade of severity. Grade 1 and 2 wounds comprised full skin thickness lacerations and puncture wounds, respectively. Grade 3 wounds were those with lacerations and the presence of dead space and Grade 4 wounds were puncture wounds with a dead space. Lacerations were defined as irregular edged wounds in which the length was greater than 10 mm. Puncture wounds were wounds less than 10 mm in length. This wound classification system is an adaptation of that used by Griffin and Holt (2001). The only difference being that in this study the partial thickness laceration of the skin was omitted.

Culture specimens were collected within 1 h of presentation. The area around each wound was clipped using a no. 40 clipper blade (Oster™) and carefully cleansed using 70% ethanol swabs.

Although it is acknowledged that 70% ethanol is not sporicidal, it does have a wide bacteriocidal and fungicidal activity and has the advantage that it is highly volatile with no residual effect, allowing sampling to be done without the concern that the disinfectant would contaminate the sample. Small sterile cotton-tipped swabs (LabChem, South Africa) were used for sampling deep within puncture wounds and from deep pockets within lacerations. In order to prevent contamination from the wound edges, swabs were taken from between the open jaws of a sterile curved mosquito forceps. They were then placed into 10 ml glass sample bottles containing a deep column of brain heart infusion broth (Difco Laboratories, USA) supplemented with 0.2% cysteine and 1% bacteriological grade agar (anaerobic transport medium). The specimens were directly submitted to the Veterinary Tropical Diseases Bacteriology Laboratory of the Faculty of Veterinary Science, University of Pretoria. For the purposes of this study aerobes and facultative anaerobes were grouped together as aerobes. Only obligate anaerobes were considered to be true anaerobes.

Specimens for cytological evaluation were then taken from the same wounds using sterile cottontipped ear buds and then gently rolled onto glass slides. Once air-dried, each slide was secured between two layers of cardboard and submitted to the Clinical Pathology Laboratory of the Faculty of Veterinary Science, University of Pretoria.

### 2.2. Statistical analysis

Results are depicted as proportions, median and range. Two by two tables were constructed. The Fisher's exact test was used to compare proportions between the following dichotomous

outcome variables: “infected” and “non-infected”; wound age “more than 24 h” and “24 h or less”; “culture positive” and “culture negative” as well as “more severe” (grades 3 and 4) and “less severe” wound grade (grades 1 and 2). Statistical analysis was performed using commercial software.<sup>1</sup> A *p* value of <0.05 was considered statistically significant.

### 2.3. Bacterial isolation and identification

A maximum of 3 swabs were taken from the bite wounds of 50 dogs, resulting in 104 separate samples. The bacteriology was done according to the standard operating procedures of the laboratory. On receipt each swab was streaked out in the anaerobic glove compartment onto plates containing pre-reduced Columbia agar (Oxoid Products, UK) containing 7% citrated horse blood (CBA), non-reduced CBA and MacConkey agar (MAC) (Oxoid Products, UK). The swabs were then reinserted in the transport medium. All plates and the specimens in transport medium were incubated at 37 °C for up to 96 h with the pre-reduced CBA plates being incubated under anaerobic conditions, the unreduced CBA in 5% CO<sub>2</sub> in air, and the MAC plates and specimens incubated in air. The specimens were considered to be culture negative if there was no growth in the anaerobic transport medium as well as on all the other inoculated plates after 96 h of incubation. In the case of growth, a representative of each different colony type was sub-cultured to purify it and then identified using phenotypic identification methods. These methods included in-house prepared tests for the Gram-positive bacteria and the Pasteurellaceae (Quinn et al., 1994) and for the other bacteria commercial test kits, namely: “Streptex streptococcal grouping” (Oxoid Products, UK), API20S, API20NE and API20A (API Systems, BioMérieux sa, France).

### 2.4. Susceptibility of isolates to antibiotics

Antimicrobial susceptibility tests were done on pure, 1-day-old cultures of all the aerobic bacteria (with the exception of *Bacillus* spp.), using the Kirby- Bauer disk diffusion test and Clinical and Laboratory Standards Institute (CLSI) interpretation values (2002). The following antimicrobials were tested: ampicillin, amoxicillin + clavulanic acid, penicillin G, cloxacillin, cephalexin, enrofloxacin, orbifloxacin, doxycycline, a combination of sulphamethoxazole and trimethoprim, gentamicin, amikacin, kanamycin, lincomycin, lincospectin (lincomycin and spectinomycin) and tylosin.

### 2.5. Microscopic assessment (wound cytology)

Smears were stained according to standard operating procedures of the laboratory with a Cam’s quick stain (Kyro-Quick stain, Kyron Laboratories). Each smear was examined under low (10×) and high (50–100×) power magnification for evidence of contamination or infection using the previously described criteria.

The study was approved by the Animal Use and Care Committee and the Research Committee of the University of Pretoria.

## 3. Results

Fifty cases were included in the study. Ages ranged from 6 months to 16 years (median 4 years). Weights ranged from 1 to 50 kg (median 9 kg). Dog breeds found varied from Jack Russell Terriers 16 (32%), Dachshunds 7 (14%), Bull Terriers 3 (6%), crossbreeds 10 (20%) and other varied breeds 14 (28%). Of the 50 dogs, 20 (40%) were intact males, 10 (20%) castrated males, 4 (8%) intact females and 16 (32%) sterilized females. One hundred and four wounds were cultured from 50 patients (median number of wounds per patient, 2). Twelve dogs (24%) had 1 wound, 22 (44%) had 2 wounds and 16 (32%) had 3 or more wounds (range 1–6). Seventy-eight of 104 (75%) of the selected bite wounds cultured were on the cranial half of the body (head; neck; chest and forelimbs) and 26 (25%) were on the caudal half (abdomen; hind limbs and tail). Of the 104 bite wound samples used in this study, 87 (84%) wounds cultured positive, yielding a total of 213 isolates (mean of 2 isolates per bite wound). The median time from being bitten to sampling was 3.5 h (range 40 min to 72 h). Thirty-nine of 50 patients (78%) presented within 24 h after injury and 11 patients presented (22%) between 24 and 72 h after injury. The results of non-infected and infected wounds were considered separately.

### 3.1. Non-infected wounds

Eighty-three wounds were found to be non-infected, of which only 66 cultured positive. The median time between being bitten and sampling was 2 h (range 40 min to 24 h). Thirty-four of 39 patients (87%) presented within 24 h after injury and 2 of 11 patients presented (18%) between 24 and 72 h after injury. Using the wound classification system to gauge severity described above, 13 (16%) wounds were classified as Grade 1, 26 (31%) as Grade 2, 16 (19%) as Grade 3 and 28 (34%) as Grade 4 wounds.

A mixture of aerobes and anaerobes was cultured from 6% (5/83) of the wounds, while aerobes alone were cultured from 72% (60/83) and anaerobes alone from 1% (1/83); while 21% (17/83) of cultures had no growth. The results are presented in Table 1. In order to highlight its importance as a cause of pyogenic infections in dogs, *Staphylococcus intermedius* was considered separately from the coagulase-negative staphylococci. Similarly *Streptococcus canis* and another pyogenic streptococci associated with pyogenic infections were dealt with separately from the other predominantly oral streptococci (Greene and Prescott, 2006). Among the Gram-negative bacteria the Enterobacteriaceae, including *Escherichia coli*, *Klebsiella* species, *Proteus spp.*, *Yersinia enterocolitica* and *Citrobacter spp.* were grouped together. The salt-intolerant members of *Vibrio* species, *Aeromonas spp.* and *Plesiomonas shigelloides*, were included in the Vibrionaceae. *Pasteurella multocida* and *Pasteurella canis* which are common and known causes of wound infection were recorded separately to other members of the Pasteurellaceae.

### 3.2. Infected wounds

Using the criteria for infection in this study, 14 animals (28%) had one or more infected wounds (range 1–3) resulting in a total of 21 (20%) infected wounds. Positive cultures were obtained from all 21 of the wounds that were judged to be infected. Thus compared to non-infected wounds, infected wounds were significantly more likely to culture positive ( $p = 0.021$ ). The median time from being bitten to sampling was 72 h (range 12–72 h). Most infected wounds presented close to the 72 h after having been bitten. Significantly more bites that presented more than 24 h after the event were infected, as compared to those that presented within 24 h or less (9 of 11 versus 5 of 39; Fischer's exact test  $p = 0.004$ ). A comparison was made between the severity of wound grade and the infected status of each wound. Of the 21 infected bite wounds, 16 (76%) were associated with Grade 3 and 4 severities where dead space was present, whilst 5 (24%) were associated with Grade 1 and 2 severities. Despite this higher proportion, more severe bite wounds (Grades 3 and 4) were not statistically more likely than less severe bite wounds (Grades 1 and 2) to be classed as infected ( $p = 0.082$ ).

Of the 17 samples which cultured positive for anaerobes, 12 (71%) were from infected bite wounds of Grade 3 or 4 severities, while 5 (29%) were from grade 1 and 2 severities. The more severe grades of wound (3 and 4) were thus more likely to be infected by anaerobes than wounds of Grades 1 and 2 ( $p = 0.018$ ).

A mixture of aerobes and anaerobes was cultured from 57% (12/21) of the infected wounds, while aerobes alone were cultured from 43% (9/21). The aerobic bacteria isolated from wounds are listed in Table 1. The most common Gram-positive bacteria were the pyogenic streptococci, *Streptococcus canis* and *Staphylococcus intermedius*. Surprisingly *Staphylococcus aureus* was not cultured. The most common Gram-negative bacteria were *Pasteurella canis*, *Pasteurella multocida* followed by the Enterobacteriaceae and the non-glucose fermenters. In this study the Gram-negative, non-glucose fermenters consisted mainly of oral microflora such as *Acinetobacter spp.*, *Moraxella spp.*, *Burkholderia spp.*, *Flavobacterium spp.* and *Pseudomonas spp.* and were thus grouped together. Included in this group was a single isolate of *Capnocytophaga carnimorsus*. Anaerobic isolates included *Prevotella melaninogenica* (59%) and *Clostridium spp.* (18%) (Table 2). The fact that the ubiquitous spore-forming *Bacillus spp.* were not isolated from infected wounds is indicative of the care taken in sampling to avoid sample contamination.

Considering the antimicrobial susceptibility of all the bacteria isolated from infected wounds, the most effective antimicrobials in vitro were potentiated sulphonamides (89% susceptibility), amoxicillin plus clavulanic acid (85.4%) and cephalexin/cephalothin (83%), the least effective were lincomycin (3.6%), gentamicin (43.6%) and kanamycin (49%). However this pattern

changed slightly when only the common pathogens were taken into consideration. In this case potentiated sulphonamides, cephalixin and ceftiofur followed by amoxicillin and clavulanic acid and amoxicillin are the most effective in vitro as shown in Fig. 1.

#### 4. Discussion

The results of this study showed that the most common dogs requiring veterinary attention for bite wounds were juvenile, small breed, pure bred intact males. The findings of a previous study (Griffin and Holt, 2001) are similar in respect to age and sex, with the exception that large, cross-bred dogs were more prevalent in that study.

The veterinary literature provides no clear guidelines to determine whether wounds are infected or not and tends to rely heavily on work done in humans.

In this study two of the three criteria used to determine infection, namely pyrexia and purulence have been used in a previous human study (Talan et al., 1999) which included additional criteria such as erythema, swelling, tenderness, lymphangitis and leukocytosis. However, many of these criteria are difficult to apply directly in a DBW study. Erythema and swelling are subjective parameters, particularly with respect to the presence of skin pigment and the presence of a thick hair coat. Tenderness is based on subjective pain scoring which may be difficult to interpret in animals with severe wounds or in more stoic animals and lymphadenitis may be more useful in people in which the majority of DBW occur to the distal extremities with accessible lymph nodes. Leukocytosis however, may be a useful tool to consider using in future studies.

For these reasons, it was decided to include wound cytology which is able to determine the presence of phagocytosed bacteria within neutrophils and whether purulence was present, even if it was not observed clinically. The latter is considered to be a strong indicator of an acute bacterial infection (Tyler et al., 1999). The combination of pyrexia, purulence and cytology was unique to our study.

The high percentage (84%) of positive cultures in this current study equates with human bite wound studies (Goldstein et al., 1978, 1980). It does, however, exceed the results of similar canine investigations, which evidenced 68% in a study that cultured aerobes alone and 67% in a second study which excluded clinically infected wounds at presentation (Kelly et al., 1992; Griffin and Holt, 2001). If non-infected wounds are examined, our findings differ from the other recorded veterinary bacteriology studies, in that more members of the Pasteurellaceae and proportionally less enteric bacteria and *Pseudomonas* species were isolated. In a retrospective study performed by Kelly et al. (1992) on 87 untreated dog bite victims, wounds were cultured for aerobic growth and antimicrobial susceptibility. The most common pathogens isolated from wounds were *Staphylococcus intermedius* (23%), *E. coli* (18%), non-lactose fermenting coliforms (14%) and *Pseudomonas* spp. (14%). Anaerobic cultures, however, were not performed and the wounds of 66% of the dogs were older than 3 days. In a more recent investigation, Griffin and Holt (2001) documented bite wounds in 37 dogs in which aerobic and anaerobic cultures were determined for each sample. The most common aerobic isolates were *Staphylococcus intermedius* (20%), *Enterococcus* spp. (15%), coagulase-negative staphylococci (13%) and *E. coli* (13%).

In comparing infected wounds from dog bites in dogs and humans, there are some marked similarities as well as significant differences. In the study by Talan et al. (1999) there was a predominance of *Pasteurella canis* and *Staphylococcus aureus*. This is in contrast to our findings, in which *Pasteurella multocida* and *Staphylococcus intermedius*, a canid bacterium related to *Staphylococcus aureus*, were most common, and where *Staphylococcus aureus* was not cultured. However, if *Pasteurella canis* is considered its incidence of 66% (7/13) is comparable. Non-pathogenic genera that are common in the oral cavity and the environment, such as the oral streptococci, and *Bacillus* and *Actinomyces* spp., were common in the contaminated wounds, but were not associated with infected wounds.

In this study a single isolate of *Capnocytophaga canimorsus* was isolated from an infected bite wound involving the head of the victim. Although this bacterium is recorded as a cause of serious infection associated with dog bites in humans, this is the first documented case of *C. canimorsus* in an infected DBW, even though it was isolated together with other organisms. In fact, the only other documented case of an animal infection is that of a dog-inflicted bite wound in a pet rabbit (van Duijkeren et al., 2006). One possible explanation for this apparent low prevalence is the fastidious nature of the organism and its tendency for slow growth. Another reason is that *C. canimorsus* may be overgrown in the presence of a polymicrobial

environment and is therefore not recognised. This bacterium is considered to be a part of the microflora of the oral cavity of dogs (Weber and Hansen, 1991).

Fifty-nine percent (10/17) of all anaerobes cultured were *Prevotella* spp. All of these isolates were from Grade 3 and 4 infected bite wounds of which 50% involved the head. This may be due to the presence of dead space associated with these wounds, an environment which may be more conducive to anaerobic replication. Although low case numbers in this study do not allow for statistical evaluation, it would appear that bite wounds of a severe nature that involve the head are particularly prone to infection with anaerobes, in this case *Prevotella* spp. The most frequently isolated bacteria in recent human studies include *Fusobacterium*, *Bacteroides*, *Peptostreptococcus* and *Prevotella* spp. (particularly *P. melaninogenica* and *P. intermedia*) (Griego et al., 1995; Talan et al., 1996; Merriam et al., 2003). These anaerobes, with the possible exception of *Clostridium* spp., are thought to originate from the oral cavity as the mixed oral flora of dogs has been shown to be rich in populations of *Bacteroides* spp. and the black pigmented anaerobic bacilli (BPABs) consisting of *Porphyromonas* and *Prevotella* spp. (Alexander et al., 1997; Allaker et al., 1997). Since alcohol is not effective at eliminating bacterial spores, it may be argued that contamination from the surrounding skin or environment may have falsely elevated the number of clostridia cultured in this study. However, this would seem unlikely considering that great care was taken to avoid the skin edges. This is supported by the fact that the ubiquitous, spore-forming *Bacillus* species were not cultured from the infected wounds.

The indications for antibiotic prophylaxis in surgical trauma have been well documented where patient, wound and environmental factors contribute towards rational decision making. However, despite their common use, much controversy surrounds the empirical use of antibiotics in bite wounds in animals (Callaham, 1988; Griffin and Holt, 2001; Kelly et al., 1992; Underman, 1987). Whilst some studies have advocated the use of antibiotics for all penetrating bite wound injuries (Greene, 1998) others have suggested prompt intravenous treatment in severely injured or compromised patients in combination with appropriate wound debridement and lavage (Pavletic, 1999).

In humans, antibiotic therapy for bite wounds is considered therapeutic and not prophylactic (Smith et al., 2000). In order to select an appropriate antibiotic, it is recommended that aerobic and anaerobic cultures be performed on infected wounds as well as antimicrobial susceptibility testing. It is believed that cultures performed on wounds that are not clinically infected are of little value in determining the potential infectious organism or selecting the correct antimicrobial (Douglas, 1975; Goldstein et al., 1978, 1980; Pavletic and Trout, 2006). This may be facilitated by using wound cytology and the stricter definition of what constitutes an infected wound. From the results of this study, recommended empiric antibiotic coverage for infected bite wounds of low severity should include ampicillin, amoxycillin, cephalexin or a potentiated sulphonamide. The widespread antimicrobial susceptibility to potentiated sulphonamides in this study may be as a consequence of their infrequent use in veterinary practice. However, certain characteristics should be taken into account if it is to be considered for more than first line empiric use. Acquired resistance to sulphonamides develops rapidly; they are bacteriostatic; they compete with penicillins for plasma binding sites; and are less effective in PABA-rich (purulent) sites of infection.

For these reasons, sulphonamides are less desirable as first-choice therapy than ampicillin or amoxycillin. For infected wounds of greater severity in which the potential risk to the patient is extreme, empiric coverage with amoxycillin–clavulanate should provide a broad enough spectrum of activity. A second option is the administration of ceftiofur, a third generation cephalosporin. The use of most fluoroquinolones and the aminoglycosides such as gentamicin should be avoided prior to the culture results being available, as they are ineffective against the anaerobic bacteria. Although anaerobic susceptibility was not determined in our study, it has been shown that a third of *Prevotella* spp. are  $\beta$ -lactam producers (Jousmies-Somer et al., 1995). Thus amoxycillin–clavulanate and metronidazole are the antibiotics of choice when dealing with anaerobic infections.

## 5. Conclusions

In support of other bite wound investigations, the results of the present study show that the majority of DBW will culture positive. The most common bacterial populations cultured from infected wounds in the author's study included the pyogenic streptococci, *Streptococcus canis*, *Pasteurella canis*, *Pasteurella multocida* and *Staphylococcus intermedius*.

In addition, our results show that anaerobes are more commonly found in bite wounds than previously thought and that with meticulous sampling, transport and culture techniques their true prevalence may be revealed. The knowledge gained from this study may also allow for further investigation and the differentiation of non-infected from infected bite wounds by the use of cytology and a few clinical parameters. Using the study's model for infection and knowing that a large proportion of wounds were found to be infected after a 24-h period, it may be possible for the veterinarian to rapidly identify those "high-risk wounds" which have the potential to become infected. This may be of particular importance in more severe wounds that have associated dead space and are more likely to yield anaerobic growth. However, even though 20% of the non-infected bite wounds cultured no viable bacteria in this study, it may still be appropriate to consider all bite wounds as contaminated in their management (Neal and Key, 1976; Waldron and Zimmerman-Pope, 2003). This is especially true as grade of severity was not predictive of whether a wound would culture positive or not.

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## References

1. Alexander, C.J., Citron, D.M., Hunt, G.S., Claros, M.C., Talan, D., Goldstein, E.J.C., 1997. Characterization of saccharolytic *Bacteroides* and *Prevotella* isolates from infected dog and cat bite wounds in humans. *J. Clin. Microbiol.* 35, 406–411.
2. Allaker, R.P., Young, K.A., Langlois, T., de Rosayro, R., Hardie, J.M., 1997. Dental plaque flora of the dog with reference to fastidious and anaerobic bacteria associated with bites. *J. Vet. Dent.* 14, 127–130.
3. Callaham, M., 1980. Dog bite wounds. *J. Am. Med. Assoc.* 244, 2327–2328.
4. Callaham, M., 1988. Controversies in antibiotic choices for bite wounds. *Ann. Emerg. Med.* 17, 1321–1330.
5. Clinical and Laboratory Standards Institute, 2002. Performance standards for antimicrobial susceptibility testing, 12th informational supplement. Approved standard M100-S12. National Committee for Clinical Laboratory Standards, Wayne, PA, pp. M31-A2.
6. Douglas, L.G., 1975. Bite wounds. *Am. Fam. Physician* 11, 93.
7. Goldstein, E.J.C., 1992. Bite wounds and infection. *Clin. Infect. Dis.* 14, 633–638.
8. Goldstein, E.J.C., Citron, D.M., Finegold, S.M., 1980. Dog bite wounds and infection: a prospective clinical study. *Ann. Emerg. Med.* 9, 508–512.
9. Goldstein, E.J.C., Citron, D.M., Wiold, B., Blachman, U., Sutter, V.L., Miller, T.A., Finegold, S.M., 1978. Bacteriology of human and animal bite wounds. *J. Clin. Microbiol.* 8, 667–672.
10. Greene, C.E., 1998. *Bacterial Diseases. Infectious Diseases of the Dog and Cat.* W.B. Saunders Company, Philadelphia, pp. 179–343.
11. Greene, C.E., Prescott, J.F., 2006. Streptococcal and other Gram positive bacterial infections. In: Greene, C.E. (Ed.), *Infectious Diseases of the Dog and Cat.* Saunders, Elsevier.
12. Griego, R.D., Rosen, T., Orengo, I.F., Wolf, J.E., 1995. Dog, cat and human bites: a review. *J. Am. Acad. Dermatol.* 33, 1019–1029.
13. Griffin, G.M., Holt, D.E., 2001. Dog-bite wounds: bacteriology and treatment outcome in 37 cases. *J. Am. Anim. Hosp. Assoc.* 37, 453–460.
14. Jousmies-Somer, H.R., Summanen, P.H., Finegold, S.M., 1995. *Bacteroides*, *Porphyromonas*, *Prevotella* *Fusobacterium* and other anaerobic Gram-negative bacteria. In: Murray, P.R., Baron, E.J., Tenover, M.A., Tenover, F.C. (Eds.), *Manual of Clinical Microbiology.* ASM Press, pp. 603–620.
15. Kelly, P.J., Mason, P.R., Els, J., Matthewman, L.A., 1992. Pathogens in dog bite wounds in dogs in Harare, Zimbabwe. *Vet. Record* 131, 464–466.
16. Marcy, S.M., 1982. Infections due to dog and cat bites. *Pediatr. Infect. Dis.* 1, 351–356.

17. Merriam, C.V., Fernandez, H.T., Citron, D.M., Tyrrell, K.L., Warren, Y.A., Goldstein, E.J.C., 2003. Bacteriology of human bite wound infections. *Anaerobe* 9, 83–86.
18. Neal, T.M., Key, J.C., 1976. Principles of treatment of dog bite wounds. *J. Am. Anim. Hosp. Assoc.* 12, 657–660.
19. Pavletic, M.M., 1999. *Atlas of Small Animal Reconstructive Surgery*. W.B. Saunders, Philadelphia.
20. Pavletic, M.M., Trout, N.J., 2006. Bullet, bite and burn wounds in dogs and cats. *Vet. Clin. North Am.* 36, 873–893.
21. Quinn, P.J., Carter, M.E., Markey, B., Carter, G.R., 1994. *Clinical Veterinary Microbiology*. Wolfe, London, UK.
22. R Development Core Team, 2005. R: A Language and Environment for Statistical Computing, R Foundation for Statistical Computing, Vienna, Austria. URL <http://www.R-project.org> (ISBN: 3- 900051-07-0).
23. Smith, P.F., Meadowcroft, A.M., May, D.B., 2000. Treating mammalian bite wounds. *J. Clin. Pharm. Ther.* 25, 85–99.
24. Talan, D.A., Citron, D.M., Abrahamian, F.M., Moran, G.J., Goldstein, E.J.C., 1999. Bacteriologic analysis of infected dog and cat bites. *N. Engl. J. Med.* 340, 85–92.
25. Talan, D.A., Moran, G.J., Abrahamian, F., Winer, M.R., Citron, D.M., Goldstein, E.J.C., 1996. The bacteriology of infected cat and dog bite wounds. *Acad. Emerg. Med.* 3, 536.
26. Tyler, R.D., Cowell, R.L., Meinkoth, J.H., 1999. Cutaneous and subcutaneous lesions: masses, cysts, ulcers and fistulous tracts. In: Cowell, R.L., Tyler, R.D., Meinkoth, J.H. (Eds.), *Diagnostic Cytology and Haematology of the Dog and Cat*. Mosby Inc., pp. 23–32.
27. Underman, A.E., 1987. Bite wounds inflicted by dogs and cats. *Vet. Clin. North Am.* 17, 195–207.
28. van Duijkeren, E., van Mourik, C., Broekhuizen, M., Leuven, M., Gaastra, W., Houwers, D., 2006. First documented *Capnocytophaga canimorsus* infection in a species other than humans. *Vet. Microbiol.* 118, 148–150.
29. Waldron, D.R., Zimmerman-Pope, N., 2003. Superficial skin wounds. In: Slatter, D. (Ed.), *Textbook of Small Animal Surgery*. W.B. Saunders Co., Philadelphia, pp. 259–273.
30. Weber, D.J., Hansen, A.R., 1991. Infections resulting from animal bites. *Infect. Dis. Clin. North Am.* 5, 663–680.

**Table 1**  
Aerobic bacterial isolates from 50 cases of dog bite wounds ( $n = 213$ )<sup>a</sup>

	Non-infected		Infected		Total isolates (%)
	Isolates	Species	Isolates	Species	
<b>Gram-positive</b>					
Coagulase-negative <i>Staphylococcus</i> spp. <sup>b</sup>	8	2	3	2	11 (5%)
<i>Staphylococcus intermedius</i>	21	1	5	1	26 (12%)
Commensal <i>Streptococcus</i> spp. (mainly oral streptococci)	11	3	2	1	13 (6%)
<i>Streptococcus canis</i>	7	1	8	1	15 (7%)
Pyogenic streptococci (excluding <i>S. canis</i> )	4	4	9	3	13 (6%)
<i>Bacillus</i> spp.	13	3	0	0	13 (6%)
<i>Actinomyces</i> spp.	7	4	0	0	7 (3%)
<i>Corynebacterium</i> spp.	7	4	2	1	9 (4%)
Other Gram-positive bacteria	3	2	2	1	5 (2%)
Total species		24		10	112 (53%)
<b>Gram-negative</b>					
Pasteurellaceae (excluding <i>P. multocida</i> and <i>P. canis</i> )	4	3	1	1	5 (2%)
<i>Pasteurella multocida</i>	26	1	5	1	31 (15%)
<i>Pasteurella canis</i>	4	1	7	1	11 (5%)
Enterobacteriaceae	11	5	4	2	15 (7%)
Vibrionaceae 2 2 2 2 4 (2%)					
Non-glucose fermenters	31	7	4	3	35 (16%)
Total species		19		10	101 (47%)
Total species		43		20	
Total isolates (%)					213 (100%)

<sup>a</sup>Each isolate represents a distinct colony type or bacterial species isolated per wound.

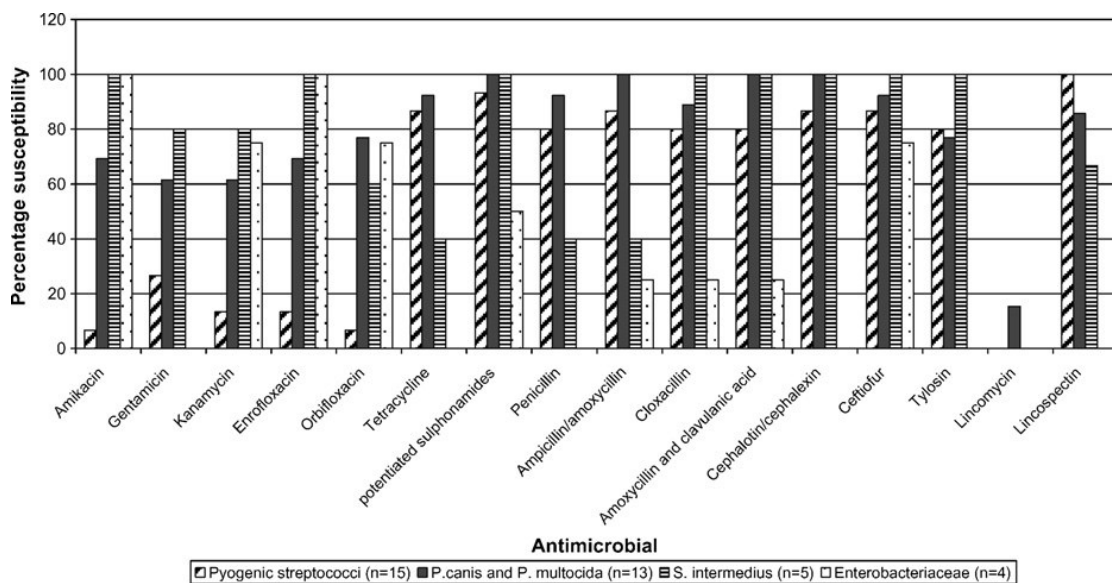


<sup>b</sup>Since there was a large number of species cultured and only known pathogenic bacteria were identified to species level, it was decided to group them in such a way as to highlight the known pathogenic and common bacteria.

**Table 2**

Anaerobic bacteria cultured from 50 cases of dog bite wounds ( $n = 17$ )

	Non-infected wound isolates	Infected wound isolates	Total isolates (%)
<i>Prevotella melaninogenica</i>	0	10	10 (59%)
<i>Clostridium</i> spp. (not <i>C. perfringens</i> )	2	2	4 (24%)
<i>C. perfringens</i>	1	1	2 (12%)
<i>Peptostreptococcus</i> spp.	1	0	1 (6%)
Total	4	13	17 (100%)



**Fig. 1.** Percentage antimicrobial susceptibility of known bacterial pathogens isolated from infected DBW