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REVIEW

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Primary closure and prophylactic antibiotics for treatment of traumatic wounds caused by mammals, a systematic review and meta-analysis

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Abstract

Purpose To compare primary closure (PC) with delayed/no closure (DC/NC), and compare prophylactic use of antibiotics (PUA) with no use of antibiotics (NUA) in the treatment of traumatic wounds caused by mammals by a systematic review and meta-analysis.

Methods PubMed and Embase databases were searched for eligible randomized clinical trials (RCTs) and observational studies. Qualities of RCTs were assessed according to Cochrane risk of bias tool, qualities of observational studies were assessed according to Newcastle–Ottawa Scale. Primary outcomes included the incidence of wound infection or poor wound healing and the rate of wound cosmesis satisfaction. The relative risks (RRs) of RCTs, odds ratios (ORs) of observational studies and their 95% confidence interval (CI) were extracted directly from included studies or calculated according to the 2 × 2 table obtained by the incidence. The sensitivity analysis, meta-regression and subgroup analysis were performed to identify clinical factors that caused the heterogeneity between studies.

Results Of 26 included studies, 17 studies (8 RCTs and 9 observational studies, 8091 patients) compared PC with DC/NC and 14 studies (7 RCTs and 7 observational studies, 2508 patients) compared PUA with NUA. The pooled OR of all studies (PC versus DC/NC) for wound infection or poor wound healing was 0.79 (95%CI: 0.54, 1.17), the pooled RR of RCTs for wound infection was 0.73 (0.51, 1.06). The pooled OR for cosmesis satisfaction was 3.68 (1.27, 10.68) of 2 studies (PC versus DC) that did not use the negative pressure sealing drainage technique. Subgroup analysis demonstrated that the pooled OR was significant under specific clinical conditions: (1) comparison of PC and DC

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(pooled OR: 0.49 [0.27, 0.90]), (2) prophylactic use of antibiotics (0.56 [0.33, 0.94]), (3) no use of antibiotics (0.63 [0.41, 0.98]), (4) wounds located in limbs/trunk (0.41 [0.23, 0.73]), (5) time to the first medical presentation (TTP) ≤ 10 h (0.59 [0.39, 0.89]). While the pooled OR (PC versus NC) was not significant (0.84 [0.51, 1.37]). The pooled OR of all studies for wound infection (PUA versus NUA) was 0.73 (95%CI: 0.46, 1.17), the pooled RR of RCTs for wound infection was 0.81 (0.46, 1.44). No included studies (PUA versus NUA) reported the outcome of wound cosmesis. Subgroup analysis demonstrated that the pooled OR was significant under specific clinical conditions: (1) injury caused by other type of mammals other than dog (pooled OR: 0.24 [0.06–0.98]), (2) wounds located in face/head (0.13 [0.03, 0.52]).

Conclusions Regardless of whether prophylactic antibiotics are used or not, compared to delayed closure, primary closure should be given priority in treating traumatic wounds caused by mammals which can decrease the incidence of wound infection or poor wound healing and obtain the better wound cosmesis, but it does not show the superiority compared to no closure, unless under some specific clinical conditions. Prophylactic use of antibiotics may not benefit in prevention of wound infection unless under specific clinical conditions, such as wounds caused by mammals other than dogs or wounds located in face/head.

Keywords Injury caused by mammals, Wound closure, Prophylactic antibiotics, Wound infection, Wound cosmesis

Introduction

Traumatic injury caused by mammals is a common and significant public health issue around the world, especially injury caused by stray/domestic dogs and cats account for approximately 95% of this kind of injury. Nearly 100 million people worldwide are bitten by dogs every year [1]. In China, there are 40 million cases of traumatic injury caused by mammals per year, among which more than 10 million cases present to hospitals to receive postexposure prophylaxis (PEP) and treatment [2]. It is estimated that 4.5–4.7 million mammalian bites occur annually in USA, accounting for 2% of all visits to emergency room (ER), furthermore 20% of these cases need PEP and treatment [3, 4]. The standardized PEP and treatment include surgical management of wounds, and prophylaxis method of rabies/tetanus [5]. The surgical management of wounds is a vital part of the whole process of PEP and treatment, which includes wounds irrigation, disinfection, anesthesia (if necessary), debridement, tissue repair (if necessary), wounds closure, drainage and prophylactic use of antibiotics [6–9]. Most cases of traumatic injury caused by mammals can be treated at outpatient, some severe cases require admission in hospital, such as injury of important tissues (vessels, nerve, bone and tendon, etc.), severe tissue defect or infection [10, 11]. Sometimes wounds may need to be performed plastic surgery to achieve better cosmesis effect [12, 13].

The wound healing is a complex process and associated with many factors. One of the most important factors is the presence of infection which can lead to the poor wound healing. Factors associated with wound infection and poor wound healing include type of mammals, time to first medical presentation, characteristics of wounds (location, length and depth) and surgical management, etc. [14, 15]. Traumatic wounds caused by mammals have a high risk of infection. So, some previous studies preferred to leave wounds open all the time or perform delayed suture of wounds after the infection risk eliminated [16, 17]. While more and more studies indicated that the primary closure of wounds caused by mammals may not increase the risk of infection and can give the better cosmetic results [18–20]. Furthermore, plastic surgery and negative pressure drainage techniques, such as local flaps, skin grafting and vacuum sealing drainage (VSD), make the primary closure and better cosmesis outcome for severe cases of injury possible [20–23]. Until now, the choice of primary closure and delayed/no closure is still controversial in managing traumatic wounds caused by mammals. Another controversial problem is the necessity of prophylactic antibiotics. Some studies deemed routine antibiotic therapy as unnecessary if radical wound cleansing and debridement are completed, while others reported the use of broad-spectrum antibiotics in all cases [18, 24, 25]. Although many reviews discussed the management of traumatic injury caused by mammals, the systematic review and meta-analysis of primary closure and prophylactic antibiotics is lacking, especially the choice of treatment regimen cannot reach a consensus in previous reviews [26–28].

In this study, we conducted a systematic review and meta-analysis to mainly compare primary closure (PC) with delayed/no closure (DC/NC) in treatment of traumatic wounds caused by mammals. A secondary comparison between prophylactic use of antibiotics (PUA) and no use of antibiotics (NUA) was also performed. The assessment values of clinical outcomes were the incidence of wound infection or poor wound healing and the rate of wound cosmesis satisfaction. Other factors that can influence the clinical outcomes were explored to identify the appropriate choice of treatment regimen (PC or DC/NC, PUA or NUA) under different clinical conditions.

Methods

Search strategy

This study was preformed according to the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) criteria (supplementary material 1). It was registered on PROSPERO with registration number of CRD42025640800. Eligible studies between January 1980 and December 2024 were searched on PubMed and Embase by using key words as follows: "mammal"; and "bite" or "scratch"; and "wound closure techniques" or "suture" or "closure" or "debridement" or "therapeutic irrigation"; and "wound infection" or "wound healing". The detailed search strategy was in supplementary material 2.

Studies selection

This systematic review included not only randomized controlled trials (RCTs) but also observational studies (including cohort studies and case–control studies). The inclusion criteria were as follows: English language, control studies that compared PC with DC/NC or compared PUA with NUA in the treatment of traumatic wounds caused by mammals, more than 20 patients, patients received standardized surgical treatment (irrigation, radical debridement) before the choice of whether performing wounds closure and prophylactic antibiotics use, and odds ratio (OR) or relative risk (RR) and their 95% Confidence Interval (CI) can be extracted directly or calculated. If OR/RR and 95% CI were not reported directly in studies, the 2× 2 table of which outcome event (wound infection, poor wound healing or wound cosmesis satisfaction) occurrence or not between groups was extracted and used to calculate OR/RR [29, 30].

The exclusion criteria were as follows: inclusion of patients who had diabetes and immunodeficiency, inclusion of injury caused by non-mammalian species, inclusion of wounds not require suturing, inclusion patients with severe injury (bone fracture, major vessel or nerve injuries, and infectious arthritis/osteomyelitis, etc.), detailed treatment regimen (wound closure or prophylactic use of antibiotics) not reported, the target clinical outcomes not reported.

Data extraction and quality assessment

Firstly, eligible studies were screened based on titles and abstracts after duplicate studies were eliminated. Then studies were screened by two board-certified surgeons of emergency (M.C., Y.J.) independently based on the full text. The final inclusion of studies was decided by their consensus. Qualities of RCTs were assessed independently according to Cochrane risk of bias (ROB) tool [31], qualities of observational studies were assessed independently according to Newcastle–Ottawa Scale (NOS) [32]. To extract data, the full texts of final included studies were reviewed in detail, including abstracts, methods, results, figures, and tables. Extracted data included RR (95% CI) of RCTs and OR (95% CI) of observational studies. If the raw data of OR/RR (95% CI) was not reported in a study, it was calculated from the 2× 2 table which generated from incidence of outcome event between experimental and control groups. The comparison of experimental group and control group included PC versus DC/NC, as well as PUA versus NUA. The general characteristics extracted from each included study were study design, nation, number of patients and wounds, mean or median age, sex, type of mammals, department of consultation, time from injury event to first presentation (TTP), characteristics of wounds, method of surgical management, type and period of antibiotics, preventive treatment of rabies/tetanus. The primary outcomes extracted from studies included RR/OR (95% CI) or incidence of wound infection or poor wound healing, RR/OR (95% CI) or rate of wound cosmesis satisfaction. The secondary outcomes included average time of wound healing, incidence of hypertrophic scarring, proportion of inpatient treatment, average length of hospital stay and economic cost. Disagreements were reassessed by the two authors together to reach a consensus.

Data synthesis and statistical analysis

The STATA16.0 was used for the synthesis of RRs/ORs with 95% CI. Because ORs can be obtained from retrospective observational studies, RRs can be obtained from RCTs or prospective observational studies, we synthesized RRs and ORs among all studies in meta-analysis and regarded it as the pooled OR finally. The Q test and the inconsistency index (I^2) were used to evaluate the extent of heterogeneity between studies. Heterogeneity was considered to be significant if P of Q test < 0.1 or $I^2 >$ 50% [33]. In this case, the OR was pooled using a random-effects model. Otherwise, a fixed-effects model was used. Publication bias was assessed by using the funnel plot and Egger's test. A symmetric funnel shape and P $>$ 0.05 of Egger's test indicated the absence of publication bias [34]. The sensitivity analysis and meta-regression were used to assess the source of heterogeneity preliminarily. After any one study was omitted, if the pooled result was consistent with the original pooled result, thus it was stable in sensitivity analysis. If the P of meta-regression > 0.05, the clinical factor may not the source of heterogeneity between studies. Otherwise, the factor should be taken into subgroup analysis further. Because many other clinical factors can influence the clinical outcomes other than wounds closure and use of antibiotics, such as the location of wounds, TTP, etc. Subgroup analysis was performed by including different clinical factors that may influence the pooled OR, and finally the source of heterogeneity between studies can be found and different pooled ORs can be identified under different clinical conditions, so that the appropriate choice of treatment regimen (PC or DC/NC, PUA or NUA) can be made under different clinical conditions according to results of subgroup analysis [35, 36].

Results

Characteristics of included studies

A flow diagram showing the process of study screening was provided in Fig. 1. Results of quality assessment of included RCTs and observational studies were presented in Fig. 2 and Table 1 respectively. In general, the quality of included studies was satisfactory.

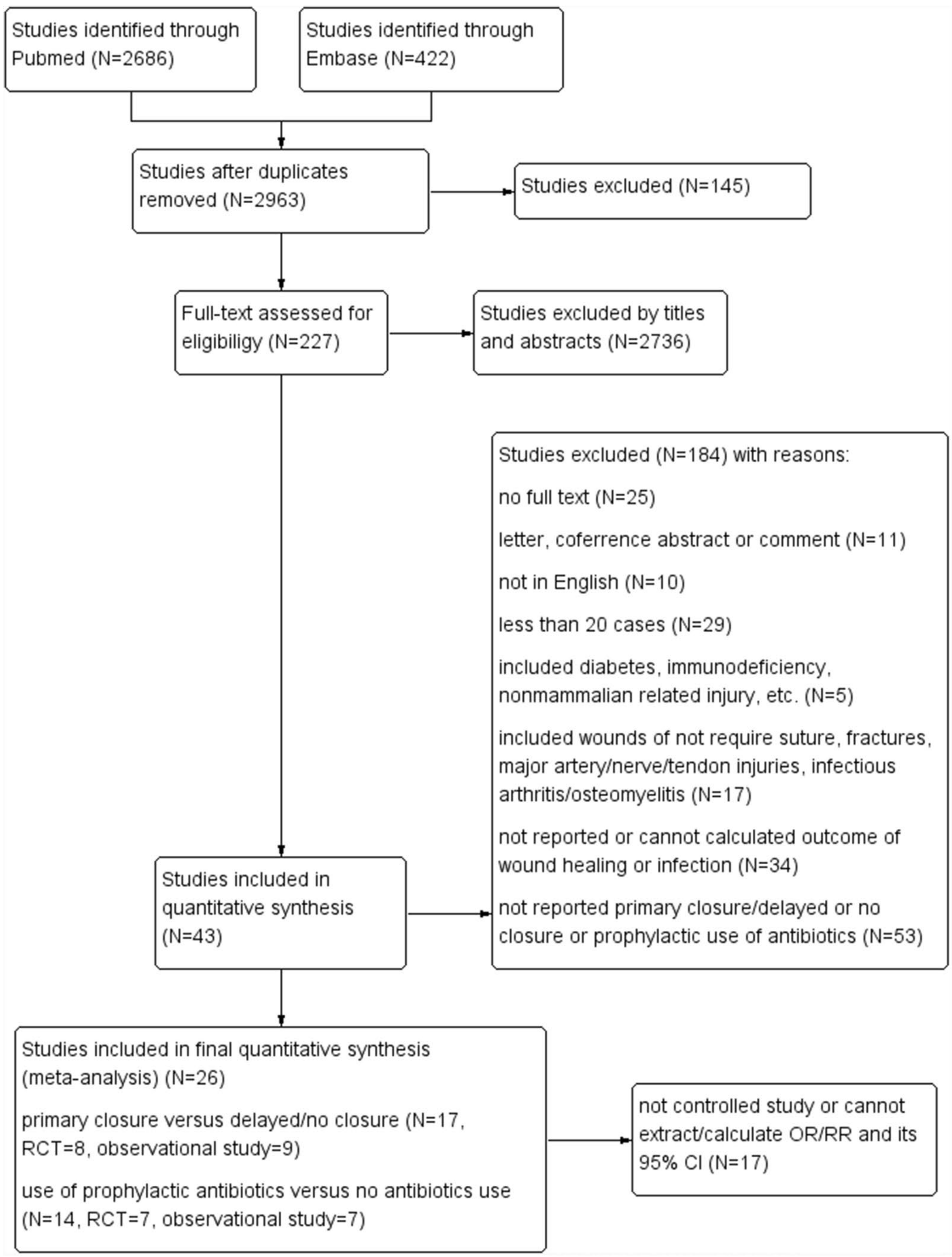

Fig. 1 Flow diagram of study-screening process

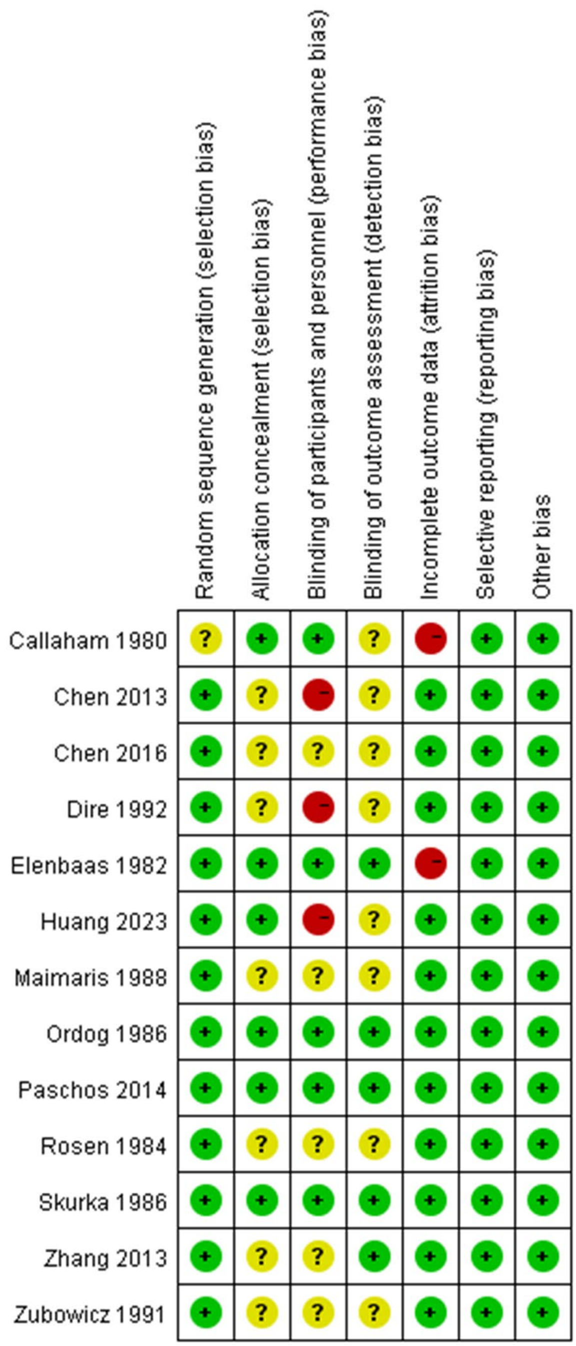

Fig. 2 Quality assessment summary of included RCTs by Cochrane risk of bias tool

In total, 26 studies were finally included [37–62]. The detailed characteristics of studies were presented in supplementary material 3. Seventeen studies (8 RCTs and 9 observational studies, 8091 patients) compared PC with DC/NC [37–53], fourteen studies (7 RCTs and 7 observational studies, 2508 patients) compared PUA with NUA [43, 48, 51–62] (Tables 2 and 3).

Among studies, the mean age ranged from 6 to 47 years, the ratio of male ranged from 30.8 to 92.5%. Eighteen studies only included patients of injury caused by dogs [37, 39, 41, 43–46, 50–54, 56–58, 60–62], five studies also included patients of injury caused by mammals other than dogs [38, 40, 42, 47, 55], three studies only included patients of injury caused by human [48, 49, 59]. Most studies used patients as the unit of analysis, only six studies reported numbers of wounds and also used wounds as the unit to analyze outcomes [50–53, 58, 62]. Eighteen studies reported the mean TTP or the range of TTP, most of which were less than 24 h, while only two studies included patients of TTP more than 24 h [39, 49]. Six studies only included patients with wounds of face or head [37, 39, 46–48, 55], five studies only included patients with wounds of limbs and trunk [38, 41, 45, 49, 59], others included patients with wounds of all parts of body. Only four studies reported the mean length of wounds which ranged from 2.12 to 9.3 cm [41, 43–45], other two studies only reported the range of length [46, 50]. Ten studies reported the depth of wounds in different forms: three studies used Lackmann's classification to define depth of wounds [43, 55, 56, 63]; Zhang reported mean depth of 1.75 cm [45]; Other six studies used the proportion of full-thickness injury to describe the depth of wounds in cohorts [37, 44, 51–53, 58]. All studies completed standardized wound irrigation and radical debridement, wound drainage was reported in six studies, furthermore, Huang and Chen used VSD for wound drainage [37, 41]. The most commonly used antibiotics was amoxicillin/clavulanate and 12 studies reported the mean period of antibiotics which ranged from 2 to 9.4 days. Thirteen studies reported their preventive treatment of tetanus or rabies.

Primary closure versus delayed/no closure

Primary outcomes and quantitative synthesis

Most included studies reported the incidence of wound infection and we calculated the RRs/ORs according to the 2× 2 table obtained by the incidence. But two retrospective cohort studies (Seegmueller2020 and Chadaev1996) reported the incidence of poor wound healing (ORs were calculated according to it) instead of incidence of wound infection [38, 49] (Table 2). We also pooled these two ORs with RRs/ORs of other studies to generate the synthesized OR.

The pooled RR of RCTs for wound infection was 0.73 (95% CI: 0.51, 1.06), the pooled OR of observational studies was 0.74 (0.41, 1.34). The pooled OR of all studies was 0.79 (0.54, 1.17) (Fig. 3A, B). Only 3 studies reported the rate of wound cosmesis satisfaction [37, 45, 47], the pooled OR was 1.46 (0.21, 10.26). Two studies did not use the negative pressure sealing drainage technique before

Table 1 Quality assessment of observational cohort study by Newcastle–Ottawa Scale

Study	Selection (score = 4)				Comparability (score = 2)	Outcome (score = 3)			Total score
	Representativeness of the Exposed Cohort	Selection of the non-exposed cohort	Ascertainment of Exposure	Demonstration that outcome of interest was not present at start of study	Comparability of cohorts on the basis of the design or analysis controlled for confounders	Assessment of outcome	Was follow-up long enough for outcomes to occur	Adequacy of follow-up of cohorts	
Coyle2024 [54]	1	1	1	0	2	1	1	1	8
Maurer2023 [55]	0	1	1	0	0	1	1	1	5
Seegmueller2020 [38]	1	1	1	0	1	1	1	1	7
Piccart2019 [39]	1	1	1	0	0	1	1	1	6
McGuire2018 [56]	1	1	1	0	0	1	1	1	6
Sezgin2016 [40]	1	1	0	0	0	1	1	1	5
Jaindl2016 [42]	1	1	1	0	0	1	1	1	6
Tabaka2015 [43]	1	1	1	1	1	1	1	1	8
Kale2011 [47]	1	1	1	0	2	1	1	0	7
Lang2005 [57]	1	1	1	0	0	1	1	0	5
Stierman2003 [48]	1	1	1	0	0	1	1	1	6
Chadaev1996 [49]	1	1	1	0	2	1	1	1	8
Thomas1987 [51]	1	1	1	0	0	1	1	0	5

Total score, 1–3: low quality, 4–6: medium quality, 7–9: high quality

delayed closure was performed, their pooled OR for cosmesis satisfaction was 3.68 (1.27, 10.68) (Fig. 3C). The sensitivity analysis demonstrated the stability of pooled results in case of any one study was omitted (Supplementary Fig. 1 A, C).

Six factors were taken into the meta-regression analysis to identify their influence on pooled OR for wound infection or poor wound healing, including study design (RCTs and observational studies), type of mammals (dog, dog/other mammals, human), different comparison of type of wound closure (PC versus DC, PC versus DC&NC and PC versus NC), proportion of antibiotics use, proportion of head or facial injuries, TTP (> 10 h and ≤ 10 h). All P values were greater than 0.05 (Table 4), which indicated these factors may not influence the result of pooled OR. The bubble plots that explored the continuous variables (proportion of antibiotics use, proportion of head or facial injuries) presented a non-linear pattern, which also indicated no influence of these two factors on the pooled OR (Fig. 4A, B).

Subgroup analysis demonstrated that the pooled OR was significant under some specific clinical conditions: (1) comparison of PC and DC (pooled OR: 0.49 [0.27, 0.90]), (2) prophylactic use of antibiotics (pooled OR: 0.56 [0.33, 0.94]), (3) no use of antibiotics (pooled OR: 0.63 [0.41, 0.98]), (4) wounds located in limbs/trunk (pooled OR: 0.41 [0.23, 0.73]), (5) TTP ≤ 10 h (pooled OR: 0.59 [0.39, 0.89]) (Fig. 5A). But the pooled OR was not significant when PC was compared to NC (pooled OR: 0.84 [0.51, 1.37]).

Publication bias did not exist in studies which compared wound infection or poor wound healing between PC and DC/NC (P = 0.182). Publication bias also did not exist in studies which compared wound cosmesis satisfaction (P = 0.857) (Fig. 6A, B).

Secondary outcomes

Only two studies (Chen2013 and Chen2016) reported average time of wound healing, which demonstrated 10.4 days for limbs and extremities by PC and 15.9 days by NC, 13.8 days for face by PC and 10.4 days by NC [41, 46]. One study (Kale2011) reported the incidence of hypertrophic scarring (7.7% by PC and 38.7% by DC) [47], and one study (Maimaris1988) reported the mean length of hypertrophic scar (1.9 mm by PC and 3 mm by NC) [50]. Three studies (Huang2023, Piccart2019 and

Table 2 Summary of studies of comparison between wounds primary closure and delayed/no closure

Study	Nation	Study design	N (patients)	N (wounds)	Department of consultation	Type of mammal	OR (95% CI) of wound infection or poor wound healing	OR (95% CI) of wound cosmesis satisfaction
Huang2023 [37]	China	RCT	68 34 (PC) 34 (DC)	NR	Emergency	Dog	0.561 (0.123, 2.562)	0.169 (0.049, 0.586)
Seegmueller2020 [38]	Germany	Retro cohort	69 29 (PC) 22 (DC)	NR	Emergency	Dog = 35, cat = 34	0.392 (0.083, 1.86)*	NR
Piccart2019 [39]	Belgium	Retro cohort	223 162 (PC) 36 (DC/NC)	NR	Oral and Maxillofacial Surgery	Dog	0.32 (0.052, 1.99)	NR
Sezgin2016 [40]	Turkey	Retro cohort	205 137 (PC) 68 (DC)	NR	Emergency and Plastic surgery	Dog = 142, cat = 7, horse/cattle = 45, others = 11	0.226 (0.065, 0.778)	NR
Chen2016 [41]	China	RCT	580 251 (PC) 329 (NC)	NR	Emergency	Dog	0.414 (0.198, 0.863)	NR
Jaindl2016 [42]	Austria	Retro cohort	5248 500 (PC) 4748 (NC)	5270	Trauma surgery	Dog = 2530, cat = 930, others = 357, human = 426, self-bites = 1005	0.991 (0.655, 1.501)	NR
Tabaka2015 [43]	USA	Pros multicenter cohort	342 128 (PC) 214 (NC)	NR	Emergency	Dog	3.1 (1.03, 9)#	NR
Paschos2014 [44]	Greece	RCT	82 (PC) 86 (NC)	NR	Trauma and Orthopaedic Surgery	Dog	1.441 (0.478, 4.351)	NR
Zhang2013 [45]	China	RCT	60 (PC) 60 (DC)	NR	Emergency	Dog	1.357 (0.29, 6.341)	2.444 (1.167, 5.121)
Chen2013 [46]	China	RCT	300(PC) 300 (NC)	NR	Emergency	Dog	0.744 (0.4, 1.382)	NR
Kale2011 [47]	India	Retro cohort	54 (PC) 37 (DC)	80 (PC) 59 (DC)	Plastic surgery	Bear = 35, dog = 34, monkey = 11, others = 10	0.825 (0.191, 3.554)	7.579 (1.903, 30.181)
Stierman2003 [48]	USA	Retro cohort	15 (PC) 25 (DC/NC)	42	Otolaryngology, Plastic Surgery, or Oral and Maxillofacial	human	1.667 (1.103, 2.519)	NR
Chadaev1996 [49]	Russia	Retro cohort	79 (PC) 33 (NC)	NR	General surgery	Human	0.105 (0.02, 0.536)*	NR
Maimaris1988 [50]	UK	RCT	96	169 92 (PC) 77 (NC)	Emergency	Dog	0.975 (0.313, 3.032)	NR
Thomas1987 [51]	Australia	Retro cohort	11 (PC) 51 (NC)	62	Emergency	Dog	0.75 (0.081, 6.941)	NR
Elenbaas1982 [52]	USA	RCT	10 (PC) 36 (NC)	11 (PC) 104 (NC)	Emergency	Dog	10.3 (0.598, 177.498)	NR
Callaham1980 [53]	USA	RCT	64	116 34 (PC) 82 (NC)	Emergency	Dog	0.403 (0.084, 1.926)	NR

PC primary closure, *DC* delayed closure, *NC* no closure, *NR* not reported

*OR was calculated by the proportion of poor wound healing, because these studies did not report the infection rate of wounds

OR was provided by the paper, other ORs were calculated by the data in studies

Table 3 Summary of studies of comparison between use of prophylactic antibiotics and no antibiotics use

Study	Nation	Study design	N (patients)	N (wounds)	Department of consultation	Type of mammal	RR/OR (95%CI) of wound infection
Coyle2024 [54]	USA	Retro cohort	672 539 (PA) 133 (NA)	NR	Emergency or urgent care center	Dog	1.968 (0.682, 5.675)
Maurer2023 [55]	Germany	Retro cohort	111 102 (PA) 9 (NA)	NR	Oral and Maxillofacial Surgery	Dog = 105, horse = 5, fox = 1	0.258 (0.045, 1.482)
McGuire2018 [56]	Canada	Retro cohort	158 87 (PA) 70 (NA)	191	Emergency	Dog	1.042 (0.226, 4.814)
Tabaka2015 [43]	USA	Pros multicenter cohort	345 143 (PA) 201 (NA)	NR	Emergency	Dog	2.31 (0.873, 6.111)
Lang2005 [57]	Canada	Retro cohort	287 213 (PA) 74 (NA)	NR	Emergency and Plastic surgery	Dog	0.322 (0.116, 0.891)
Stierman2003 [48]	USA	Retro cohort	40 30 (PA) 10 (NA)	42	Otolaryngology, Plastic Surgery, or Oral and Maxillofacial	Human	0.034 (0.003, 0.361)
Dire1992 [58]	USA	RCT	89 (PA) 96 (NA)	95 (PA) 99 (NA)	Emergency	Dog	0.207 (0.024, 1.806)
Zubowicz1991 [59]	USA	RCT	33 (PA) 15 (NA)	NR	Emergency	Human	0.533 (0.332, 0.856)
Thomas1987 [51]	Australia	Retro cohort	35 (PA) 27 (NA)	62	Emergency	Dog	0.267 (0.047, 1.499)
Skurka1986 [60]	USA	RCT	19 (PA) 20 (NA)	NR	Emergency	Dog	2.235 (0.186, 26.908)
Ordog1986 [61]	USA	RCT	179 (PA) 241 (NA)	559	Emergency	Dog	4.145 (0.827, 20.78)
Rosen1984 [62]	USA	RCT	15 (PA) 18 (NA)	35 (PA) 31 (NA)	Emergency	Dog	0.769 (0.111, 5.338)
Elenbaas1982 [52]	USA	RCT	46 22 (PA) 24 (NA)	115 59 (PA) 56 (NA)	Emergency	Dog	1.1 (0.964, 1.255)
Callaham1980 [53]	USA	RCT	64 30 (PA) 32 (NA)	116 54 (PA) 53 (NA)	Emergency	Dog	0.333 (0.079, 1.402)

PA prophylactic antibiotics, *NA* no antibiotics

Chen2016) reported the proportion of inpatient treatment which were 100% (both by PC and DC), 35.4% (detailed incidence by PC or DC/NC not reported) and 94.3% (100% by PC and 90% by NC), respectively [37, 39, 41]. Only Seegmueller 2020 reported the average length of hospital stay (3.3 days by PC and 5.8 days by NC) [38]. No included studies reported the outcome of economic cost. Due to the limited number of studies reporting secondary outcomes, these results were not performed quantitative synthesis.

Prophylactic use of antibiotics versus no use of antibiotics

Primary outcomes and quantitative synthesis

All included studies reported the incidence of wound infection as primary outcome. The pooled RR of RCTs for wound infection was 0.81 (95% CI: 0.46, 1.44), the pooled OR of observational studies was 0.56 (0.22, 1.46). The pooled OR of all studies was 0.73 (0.46, 1.17) (Fig. 3D). No studies reported the rate of wound cosmesis satisfaction. The sensitivity analysis demonstrated the stability of pooled results in case of any one study was omitted (Supplementary Fig. 1B).

Five factors were taken into the meta-regression analysis to identify their influence on pooled OR for wound infection, including study design (RCTs and observational studies), type of mammals (dog, dog/other mammals, human), proportion of primary closure, proportion of head or facial injuries, TTP (> 10 h and ≤ 10 h). All P values were greater than 0.05 (Table 5), which indicated these factors may not influence the result of pooled OR.

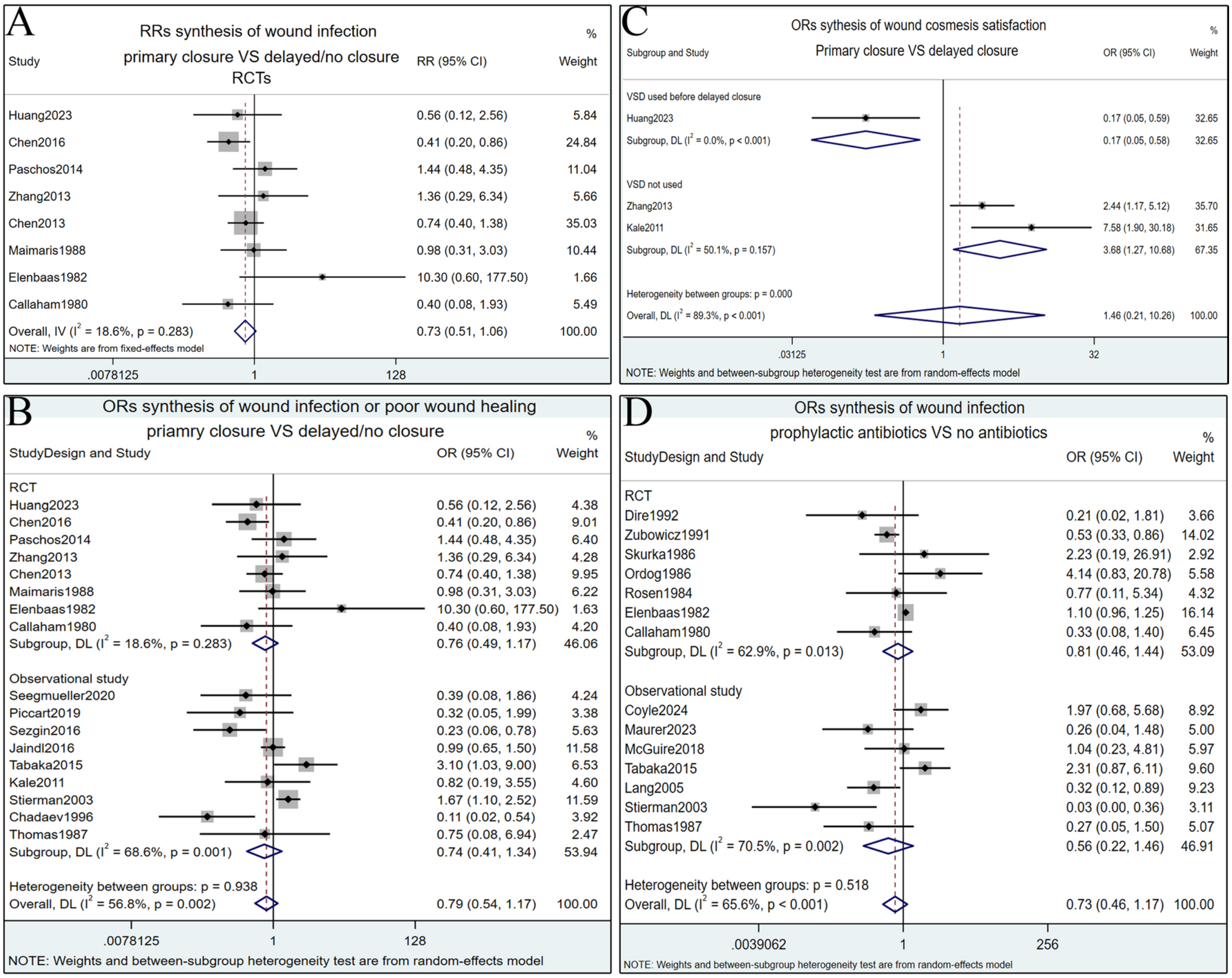

Fig. 3 Summary of forest plots. **A** pooled RR for wound infection (PC versus DC/NC), **B** pooled OR for wound infection or poor wound healing (PC versus DC/NC), **C** pooled OR for wound cosmesis satisfaction (PC versus DC), **D** pooled OR for wound infection (PUA versus NUA)

Table 4 Summary of Meta-regression analysis (primary closure VS delayed/no closure)

Variable	N (study)	Coefficient	P
Study design	RCT = 8 Observational study = 9	0.087	0.845
Type of mammals	Dog = 11 Dog and other mammals = 4 Human = 2	– − 0.443 − 0.21	– 0.417* 0.754*
Different comparison of type of wound closure	PC VS DC = 5 PC VS DC&NC = 2 PC VS NC = 10	– 0.759 0.447	– 0.303 0.405
Proportion of antibiotics use	17	− 0.292	0.607
Proportion of head and facial injuries	16 NR = 1 (omitted)	0.469 –	0.349 –
TTP	> 10 h = 6 ≤ 10 h = 6 NR = 5 (omitted)	− 0.04 –	0.95 –

DC delayed closure, *NC* no closure, *NR* not reported, *PC* primary closure, *TTP* time to presentation

*Compared to other two groups

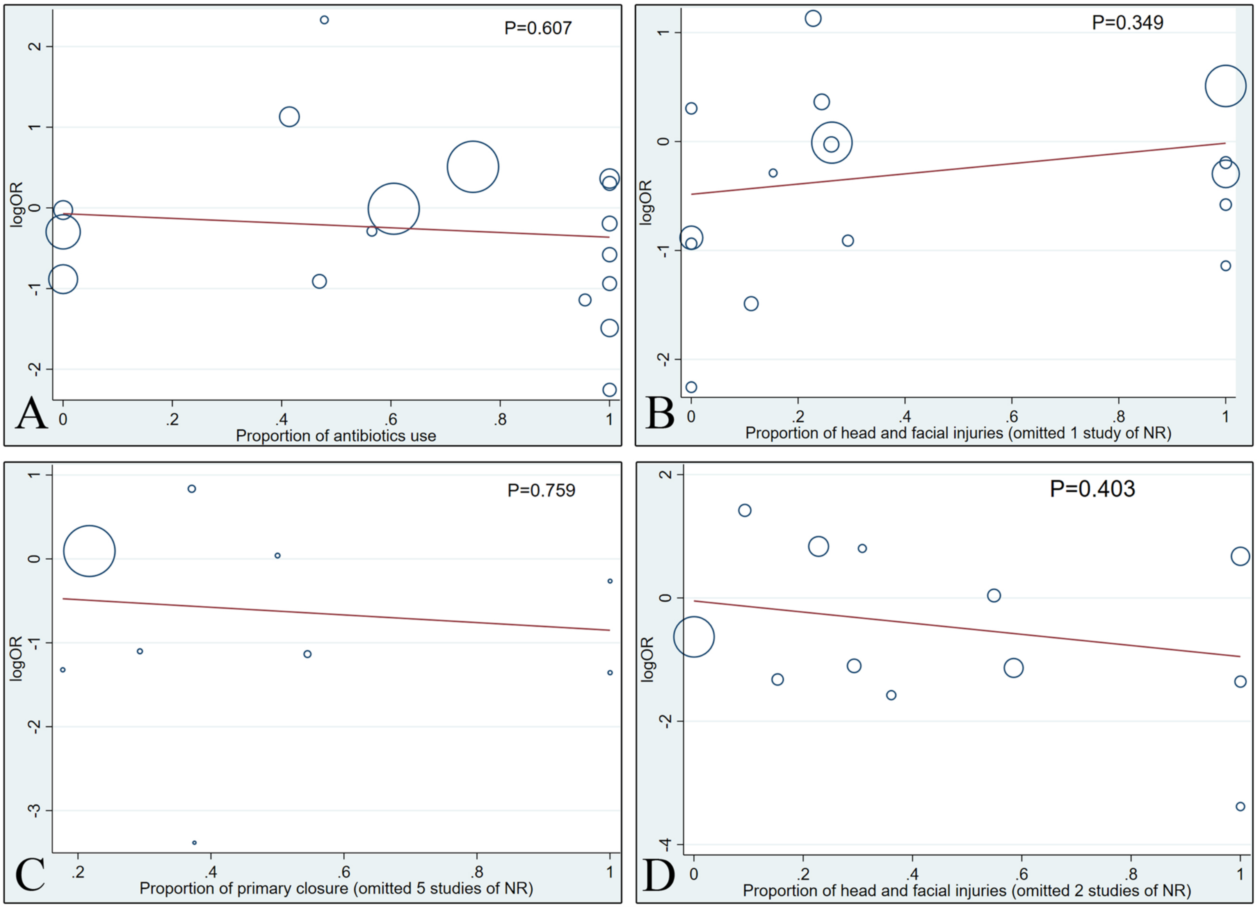

Fig. 4 Bubble plots that explored the influence of continuous variables on pooled OR. **A** proportion of antibiotics use (PC versus DC/NC), **B** proportion of head or facial injuries (PC versus DC/NC), **C** proportion of primary closure (PUA versus NUA), **D** proportion of head or facial injuries (PUA versus NUA)

The bubble plots that explored the continuous variables (proportion of primary closure, proportion of head or facial injuries) presented a non-linear pattern, which also indicated no influence of these two factors on the pooled OR (Fig. 4C, D).

Subgroup analysis demonstrated that the pooled OR was significant under some specific clinical conditions: (1) injury caused by other type of mammals other than dog (pooled OR: 0.24 [0.06–0.98]), (2) wounds located in face/head (pooled OR: 0.13 [0.03, 0.52]) (Fig. 5B).

Publication bias did not exist in studies which compared wound infection between prophylactic use of antibiotics and no use of antibiotics (P = 0.149) (Fig. 6C).

Secondary outcomes

No studies reported the average time of wound healing. One study (Maurer 2023) reported the incidence of hypertrophic scarring (7.2%), but it did not compare PUA with NUA [55]. No studies compared the proportion of inpatient treatment between PUA and NUA. Only Maurer 2023 [55] reported the average length of hospital stay of 2 ± 1 days, but it did not compare PUA with NUA as well. No included studies reported the outcome of economic cost. Due to the limited number of studies reporting secondary outcomes, these results were not performed quantitative synthesis.

Discussion

The surgical treatment of traumatic wounds caused by mammals is a standard procedure comprising of wound irrigation, disinfection, anesthesia, debridement, tissue repair, wound closure, drainage and prophylactic use of antibiotics at present. Although other surgical procedures certainly benefit wounds healing and prognosis of patients in previous published studies and guidelines, primary closure and prophylactic use of antibiotics are still controversial till now [64–66]. Because of limited RCTs, there were limited systematic reviews and meta-analysis that discussed these questions, and a certain conclusion cannot be addressed [26–28, 67]. In this meta-analysis,

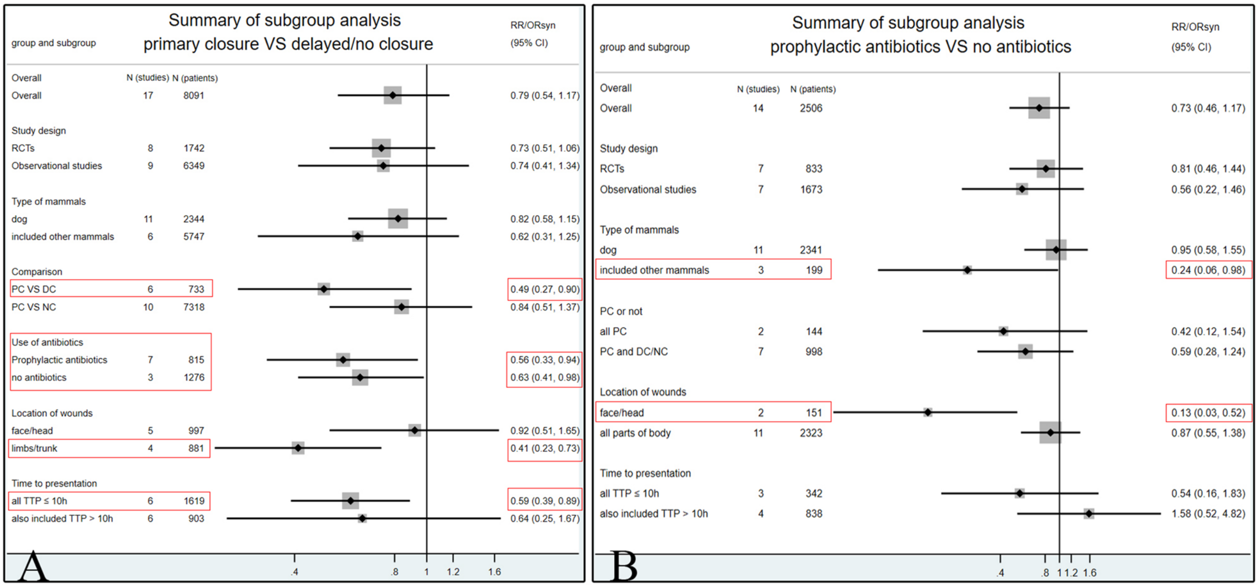

Fig. 5 Summary of forest plots by subgroup analysis. **A** PC compared with DC/NC, **B** PUA compared with NUA. The red box marked clinical factors which caused the pooled OR to be significant in subgroup analysis

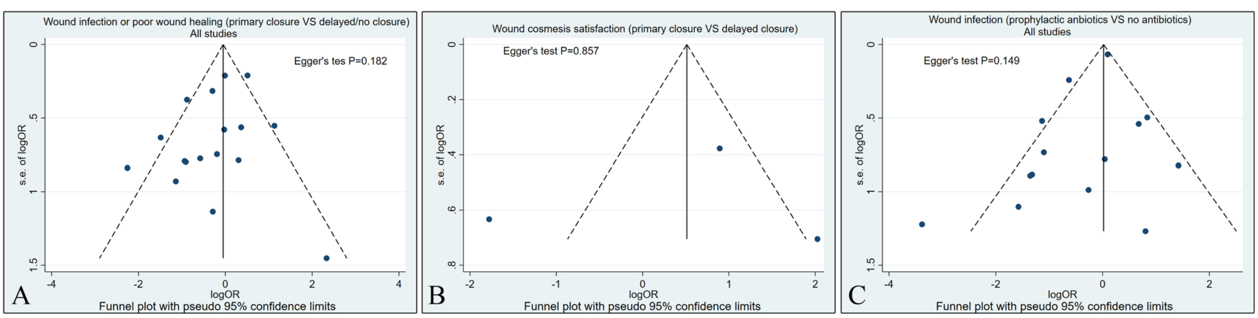

Fig. 6 Funnel plots of publication bias. **A** For wound infection or pool wound healing (PC versus DC/NC), **B** for wound cosmesis satisfaction (PC versus DC), **C** for wound infection (PUA versus NUA)

Table 5 Summary of meta-regression analysis (prophylactic antibiotics vs no antibiotics)

Variable	N (study)	Coefficient	P
Study design	RCT = 7 Observational study = 7	0.308	0.625
Type of mammals	Dog = 11 Dog and other mammals = 1 Human = 2	– − 1.273 − 1.182	– 0.324* 0.154*
Proportion of primary closure	9 NR = 5 (omitted)	− 0.456	0.759
Proportion of head and facial injuries	12 NR = 2 (omitted)	− 0.902	0.403
TTP	> 10 h = 4 ≤ 10 h = 3 NR = 7 (omitted)	− 1.066 –	0.263 –

NR not reported, *TTP* time to presentation

*Compared to other two groups

we also included prospective and retrospective observational studies other than RCTs to expand sample sizes, which may increase the credibility of synthesized ORs.

Primary closure versus delayed/no closure

Although the pooled OR (0.79, 95%CI: [0.54, 1.17]) of all studies and pooled RR (0.73, 95%CI: [0.51, 1.06]) of RCTs were not significant statistically, they may present the reduction trend of incidence of wound infection or poor wound healing if the primary closure was performed. In the meta-regression analysis and subgroup analysis, compared to delayed closure, primary closure was significantly associated with the lower odds of wound infection or poor wound healing (pooled OR: 0.49 [0.27, 0.90]). While primary closure was not different with no closure in the odds of wound infection (pooled OR: 0.84 [0.51, 1.37]). Thus, primary closure had the superiority in avoiding wound infection or poor wound healing compared to delayed closure, but not compared to no closure. It was also demonstrated that primary closure was associated with the lower odds of wound infection or poor wound healing regardless of whether antibiotics being used (pooled OR: 0.56 [0.33, 0.94]) or not (pooled OR: 0.63 [0.41, 0.98]). Furthermore, if the time from injury to medical presentation was less than 10 h or wounds were located in limbs or trunk, primary closure can benefit in the wound healing significantly. Thus, these results indicated that primary closure should be the first choice in the surgical treatment of traumatic wounds caused by mammals under these conditions.

Compared to delayed closure, the primary closure did not obtain a higher rate of wound cosmesis satisfaction (pooled OR: 1.46 [0.21, 10.26]). But the pooled OR was generated from only 3 studies, the heterogeneity was very high between studies [37, 45, 47]. Because Huang 2023 [37] used the VSD in wounds treatment before delayed closure was performed, its result showed that delayed closure had the higher rate of wounds cosmesis satisfaction than primary closure (OR: 0.17 [0.05, 0.59]). But other two studies (Zhang 2013 and Kale 2011) which did not use the negative pressure sealing drainage technique reported opposite result (OR: 3.68 [1.27, 10.68]). Thus, primary closure should be suggested in the department without the negative pressure sealing drainage technique considering the factor of wounds cosmesis satisfaction.

Because secondary outcomes were reported in limited studies, they were not performed meta-analysis. The average time of wound healing by primary closure was shorter than no closure, and the primary closure had lower incidence of hypertrophic scarring and smaller wound scar. Seegmueller 2020 [38] reported that primary closure caused shorter length of hospital stay for patients than no closure. Many outcomes should be considered in traumatic injury caused by mammals. Most previous studies assessed the wound infection as the main outcome, limited studies assessed other clinical outcomes, such as wound cosmesis, average time of wound healing, etc. Only incidence of wound infection and rate of wound cosmesis satisfaction can be performed meta-analysis in this study. So we used these two outcomes as primary outcomes to compare PC with DC/NC.

Based on all results above, no matter prophylactic antibiotics were used or not, compared to delayed closure, primary closure should be given priority in treating traumatic wounds caused by mammals which may decrease the incidence of wound infection or poor wound healing and obtain the better wound cosmesis. But primary closure did not show the superiority compared to no closure, unless under some specific clinical conditions, including wounds located in limbs/trunks and TTP less than 10 h.

Prophylactic use of antibiotics versus no use of antibiotics

The pooled OR (0.73, 95%CI: [0.46, 1.17]) of all studies and pooled RR (0.81, 95%CI: [0.46, 1.44]) of RCTs demonstrated that prophylactic use of antibiotics cannot decrease the odds of wound infection. The meta-regression analysis and subgroup analysis indicated that prophylactic use of antibiotics can decrease the odds of wound infection if wounds were caused by mammals other than dogs (pooled OR: 0.24 [0.06–0.98]) or located in face/head (pooled OR: 0.13 [0.03, 0.52]). Although different mammals carried different bacteria, all the traumatic wounds caused by them had the possibility of wound infection. Because most previous studies only explored injury caused by dogs, the data of injury caused by other mammals was limited. In this meta-analysis, type of mammals was only regarded as a factor that may influence of pooled OR of primary outcomes. Furthermore no previous studies compared wild mammals with domestic mammals in their analysis, so we did not take this factor into subgroup analysis in our study. Clinical factors, especially type of mammals or domestic/wild mammals should be considered comprehensively in studies in future. No included studies compared secondary outcomes between prophylactic use of antibiotics and no use of antibiotics.

Compared to previous meta-analysis

There were four systematic reviews and meta-analysis which compared PC with DC/NC or compared PUA with NUA (Table 6) [26–28, 67]. All of them only included RCTs, so their included studies were limited and their results of meta-analysis were not robust. Our study included more RCTs than previous meta-analysis and also included observational studies so that sample sizes

Table 6 Previous meta-analysis of pooled OR/RR comparing PC with DC/NC and comparing PUA with NUA

Study	Type of included studies	Type of mammals	Number of included studies	Pooled OR/RR for wound infection (PC versus DC/NC) and 95% CI	Pooled OR/RR for wound infection (PUA versus NUA) and 95% CI	Pooled OR/RR for wound cosmesis satisfaction (PC versus DC/NC) and 95%CI	Pooled OR/RR for wound cosmesis (PUA versus NUA) and 95%CI
Bhaumik2019 [27]	Only RCT	Only dogs	4 [44–46, 50]	RR = 1.01 (0.97, 1.05) (PC vs NC) RR = 1.02 (0.93, 1.11) (PC vs DC)	–	**− 1.31 (− 2.03, − 0.59)***	–
Cheng2014 [28]	Only RCT	Only dogs	4 [44–46, 50]	RR = 0.93 (0.60, 1.42) (PC vs DC/NC)	–	–	–
Medeiros2001 [26]	Only RCT	All mammals	8 [52, 58–60, 62]	–	RR = 0.49 (0.15, 1.58) **RR = 0.10 (0.01, 0.86)#** **RR = 0.02 (0.00, 0.33)†**	–	–
Cummings1994 [67]	Only RCT	Only dogs	8 [52, 53, 58, 62, 60]	/	**RR = 0.56 (0.38, 0.82)**	–	–
Our study	RCT and observational study	All mammals	17 (PC vs DC/NC) 14 (PUA vs NUA)	OR = 0.79 (0.54, 1.17) RR = 0.73 (0.51, 1.06)‡ **OR = 0.49 (0.27, 0.90) (PC VS DC)** OR = 0.84 (0.51, 1.37) (PC vs NC)	OR = 0.73 (0.46, 1.17) RR = 0.81 (0.46, 1.44)‡	1.46 (0.21, 10.26) **3.68 (1.27, 10.68)§**	–

Bold face type indicates statistical significance

DC delayed closure, *NC* no closure, *PC* primary closure, *PUA* prophylactic use of antibiotics, *NUA* no use of antibiotics

*Not pooled RR, calculated by the difference of validated cosmetic outcome score (Vancouver Scar Scale)

For hand wounds

† For wounds caused by human

‡ Pooled RR generated from RCTs alone

§ PCversus DC without the negative pressure sealing drainage technique used

were large enough to make a more convincing meta-analysis. The RCTs and observational studies were also performed meta-analysis respectively, so that the heterogeneity between them can also be demonstrated. Two studies reported the pooled RR for wound infection, both of them did not indicate the superiority of primary closure on delayed closure/no closure [27, 28]. Although our study showed that the primary closure was not associated with the lower odds of wound infection (pooled OR: 0.79 [0.54, 1.17]), our subgroup analysis demonstrated that primary closure had significantly lower incidence of wound infection compared to delayed closure. Results of previous studies were different with this result of our study, which proved the superiority and possibility of primary closure in treating with wounds caused by mammals. Two studies reported the pooled RR for wound infection (PUA versus NUA) [26, 67], Medeiros 2001 [26] demonstrated that prophylactic use of antibiotics can benefit hand wounds and wounds caused by human. But Cummings 1994 [67] indicated that prophylactic use of antibiotics can significantly decrease the incidence of wound infection caused by dogs (RR: 0.56 [0.38, 0.82]). These two studies both included 8 RCTs, our study identified 6 same RCTs as them and 1 additional RCT [61], seven observational studies were also included. The pooled OR/RR of our study did not demonstrate a superiority of PUA on the prevention of wounds infection. Medeiros 2001 [26] and Cummings 1994 [67] had different results, especially for wounds caused by different type of mammals. Our result of subgroup analysis was similar with that of Medeiros 2001 [26], which indicated that wounds caused by dogs may not need PUA, but wounds caused by other mammals need PUA. Our result of subgroup analysis indicated that facial/head wounds need PUA to prevention infection, which was different with that of Medeiros 2001 [26]. Only Bhaumik 2019 [27] reported the outcome of wound cosmesis which used the mean difference of Vancouver Scar Scale score (VSS), an objective assessment indicator [68, 69]. Although it showed the superiority of primary closure on wound cosmesis, its result was not robust because of only one study of Paschos 2014 included in analysis. Our meta-analysis only found 3 studies that assessed the rate of wound cosmesis satisfaction, which also showed the superiority of primary closure compared to delayed closure if other advanced techniques (such as VSD) was not used before delayed closure.

In summary, our meta-analysis included more studies and conducted a more comprehensive analysis than previous meta-analysis, which obtained robust results that primary closure had superiority on the prevention of wound infection or poor wound healing and wound cosmesis than delayed closure. Although primary closure did not show the superiority compared to no closure, our study found that it can reveal advantage and be the first choice under two specific clinical conditions. Prophylactic use of antibiotics may not benefit in prevention of wound infection unless under some specific clinical conditions.

Bias, applicability and limitations

Although the sensitivity analysis demonstrated the stability of pooled results, the heterogeneity existed between included studies. This heterogeneity is the main source of bias. The meta-regression and subgroup analysis were performed to identify clinical factors that may cause the heterogeneity between included studies. The results demonstrated that the pooled OR (PC versus DC/NC) became significant under some specific clinical conditions, including PC compared with DC, confirmed prophylactic use or no use of antibiotics, wounds located in limbs/trunk and time to presentation less than 10 h. The pooled OR (PUA versus NUA) was significant under specific clinical conditions, including wounds caused by mammals other than dogs and facial/head wounds. Publication bias did not exist in our study. Other clinical factors, for example, length of wounds, depth of wounds, type of suture material, use of wound drainage, type and period of antibiotics, which can cause the heterogeneity were not taken into meta-regression and subgroup analysis because limited studies (< 2) reported them or they were reported in different forms among included studies. Further studies should control these confounding factors that can cause bias. Another factor that may cause bias was the calculation of outcomes. Although we thought it was more appropriate to use the number of wounds as unit to calculate incidence of wound infection and cosmesis satisfaction, only three included studies did so, and others calculated outcomes based on the number of patients [50, 52, 53]. Because the sample size of these three studies accounted for small proportion of sample size of all studies, it was thought that inclusion of these three studies would not influence results of meta-analysis. In general, the quality of included studies was good enough to get certain evidence in meta-analysis, and the potential bias was controlled to some extent.

This meta-analysis included studies from different countries and continents, the sample size was large and the population was very representative. Most included studies only regarded patients injured by dogs as research objects, eight (30.8%) studies included patients injured by all types of mammals. So the results of meta-analysis can apply to different populations caused by mammals.

This meta-analysis had some limitations. (1) Many outcomes should be taken into consideration when choosing the most appropriate treatment method. When dealing with traumatic wounds caused by mammals, wounds infection, healing and cosmesis were certainly the most important primary outcomes. These outcomes were also the most extensively studied in previous studies, while other secondary outcomes were rarely contained, for example, time of wound healing, incidence of hypertrophic scarring, proportion of inpatient treatment, length of hospital stay and economic cost. So these secondary outcomes were not performed meta-analysis due to limited sample sizes. (2) Although the outcome of wound cosmesis can be quantified by VSS, only one study used this more accurate method. Other 3 studies which used rate of wound cosmesis satisfaction were performed meta-analysis in this study, which was a little inaccurate due to its subjectivity of assessment. (3) The factor (domestic versus wild mammals) that can influence the choice of strategy of wounds closure and use of antibiotics was not included in previous studies until now. So we did not perform subgroup analysis to explore this factor in this study and further study exploring this factor was prompted to be meaningful.

Conclusions

Regardless of whether prophylactic antibiotics are used or not, compared to delayed closure, primary closure should be given priority in treating traumatic wounds caused by mammals which can decrease the incidence of wound infection or poor wound healing and obtain the better wound cosmesis, but it does not show the superiority compared to no closure, unless under some specific clinical conditions (patients of limbs/trunk wounds, time to presentation less than 10 h). Prophylactic use of antibiotics may not benefit in prevention of wound infection unless under specific clinical conditions, such as wounds caused by mammals other than dogs or wounds located in face/head. To prove these conclusions, further RCTs of high quality are urgently needed, and should concentrate in controlling clinical confounding factors of baseline more effectively and assessing clinical outcomes comprehensively, especially secondary outcomes, which can guide doctors to choose the most appropriate treatment regimen under different clinical conditions.

Supplementary Information

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Additional file 1.

Additional file 2.

Additional file 3.

Additional file 4.

Author contributions

MC: conceptualization, methodology, software, formal analysis, resources, data curation, writing-original draft, and writing reviewing and editing. YJ: methodology, software, formal analysis, resources, data curation, and writing-reviewing and editing. ZC and JQ: resources, data curation, and writing-reviewing and editing. ZZ, YX and SL: supervision and writing-reviewing and editing. RC and YS: supervision and project administration. All authors contributed to the article and approved the submitted version.

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Availability of data and materials

The original data and materials of this study are included in the article/Supplementary Material, further inquiries can be directed to the corresponding authors.

Declarations

Ethics approval and consent to participate

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Competing interests

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References

1. Jackson AC. Human Rabies: a 2016 update. Curr Infect Dis Rep. 2016;18(11):38. https://doi.org/10.1007/s11908-016-0540-y.
2. Zhou H, Li Y, Chen RF, Tao XY, Yu PC, Cao SC, et al. Technical guideline for human rabies prevention and control (2016). Zhonghua Liu Xing Bing Xue Za Zhi. 2016;37(2):139–63. https://doi.org/10.3760/cma.j.issn.0254-6450.2016.02.001.
3. Essig GF Jr, Sheehan C, Rikhi S, Elmaraghy CA, Christophel JJ. Dog bite injuries to the face: Is there risk with breed ownership? A systematic review with meta-analysis. Int J Pediatr Otorhinolaryngol. 2019;117:182–8. https://doi.org/10.1016/j.ijporl.2018.11.028.
4. Smith PF, Meadowcroft AM, May DB. Treating mammalian bite wounds. J Clin Pharm Ther. 2000;25(2):85–99. https://doi.org/10.1046/j.1365-2710.2000.00274.x.
5. Lewis T, Baack K, Gomez L, Nichols H, Lemmons C, Zeger W. Rabies post-exposure prophylaxis in the emergency department. Am J Emerg Med. 2024;78:202–5. https://doi.org/10.1016/j.ajem.2024.01.027.
6. World Health O. Rabies vaccines: WHO position paper, April 2018—recommendations. Vaccine. 2018;36(37):5500–3. https://doi.org/10.1016/j.vaccine.2018.06.061.
7. Fernandez R, Green HL, Griffiths R, Atkinson RA, Ellwood LJ. Water for wound cleansing. Cochrane Database Syst Rev. 2022;9(9): CD003861. https://doi.org/10.1002/14651858.CD003861.pub4.
8. Aziz H, Rhee P, Pandit V, Tang A, Gries L, Joseph B. The current concepts in management of animal (dog, cat, snake, scorpion) and human bite wounds. J Trauma Acute Care Surg. 2015;78(3):641–8. https://doi.org/10.1097/TA.0000000000000531.
9. Kramer A, Assadian O, Frank M, Bender C, Hinz P, Working Section for Clinical Antiseptic of the German Society for Hospital H. Prevention of post-operative infections after surgical treatment of bite wounds. GMS Krankenhhyg Interdiszip. 2010. https://doi.org/10.3205/dgkh000155.
10. Mankowitz SL. Laceration management. J Emerg Med. 2017;53(3):369–82. https://doi.org/10.1016/j.jemermed.2017.05.026.
11. Wichers IM, Bouma M. NHG "Traumatic wounds and bite wounds" treatment guideline. Ned Tijdschr Geneeskd. 2017;161:D1538.
12. Eppley BL, Schleich AR. Facial dog bite injuries in children: treatment and outcome assessment. J Craniofac Surg. 2013;24(2):384–6. https://doi.org/10.1097/SCS.0b013e31827fee33.
13. Mendoza JM, Chi JJ. Reconstruction of animal bite injuries to the head and neck. Curr Opin Otolaryngol Head Neck Surg. 2019;27(5):407–12. https://doi.org/10.1097/moo.0000000000000564.
14. Philipsen TE, Molderez C, Gys T. Cat and dog bites. What to do? Guidelines for the treatment of cat and dog bites in humans. Acta Chir Belg. 2006;106(6):692–5. https://doi.org/10.1080/00015458.2006.11679983.
15. Griego RD, Rosen T, Orengo IF, Wolf JE. Dog, cat, and human bites: a review. J Am Acad Dermatol. 1995;33(6):1019–29. https://doi.org/10.1016/0190-9622(95)90296-1.
16. Stevens DL, Bisno AL, Chambers HF, Dellinger EP, Goldstein EJ, Gorbach SL, et al. Practice guidelines for the diagnosis and management of skin and soft tissue infections: 2014 update by the Infectious Diseases Society of America. Clin Infect Dis. 2014;59(2):e10-52. https://doi.org/10.1093/cid/ciu444.
17. Fleisher GR. The management of bite wounds. N Engl J Med. 1999;340(2):138–40. https://doi.org/10.1056/NEJM199901143400210.
18. Elizabeth MG. Examining evidence on dog bite injuries and their management in children. Nurs Child Young People. 2017;29(3):35–9. https://doi.org/10.7748/ncyp.2017.e859.
19. Yadav AK, Jaisani MR, Pradhan L, Dongol A, Singh A, Acharya P, et al. Animal inflicted maxillofacial injuries: treatment modalities and our experience. J Maxillofac Oral Surg. 2017;16(3):356–64. https://doi.org/10.1007/s12663-016-0918-2.
20. Chen E, Hornig S, Shepherd SM, Hollander JE. Primary closure of mammalian bites. Acad Emerg Med. 2000;7(2):157–61. https://doi.org/10.1111/j.1553-2712.2000.tb00519.x.
21. Chaudhry MA, Macnamara AF, Clark S. Is the management of dog bite wounds evidence based? A postal survey and review of the literature. Eur J Emerg Med. 2004;11(6):313–7. https://doi.org/10.1097/00063110-200412000-00003.
22. Ochoa B, Eldredge RS, Gilbert M, Padilla B, Notrica DM, Armstrong C, et al. Postoperative wound infection after primary closure in pediatric dog bite injuries. J Surg Res. 2024;303:199–205. https://doi.org/10.1016/j.jss.2024.09.007.
23. Wu PS, Beres A, Tashjian DB, Moriarty KP. Primary repair of facial dog bite injuries in children. Pediatr Emerg Care. 2011;27(9):801–3. https://doi.org/10.1097/PEC.0b013e31822c1112.
24. Kesting MR, Holzle F, Pox C, Thurmuller P, Wolff KD. Animal bite injuries to the head: 132 cases. Br J Oral Maxillofac Surg. 2006;44(3):235–9. https://doi.org/10.1016/j.bjoms.2005.06.015.
25. Wolff KD. Management of animal bite injuries of the face: experience with 94 patients. J Oral Maxillofac Surg. 1998;56(7):838–43. https://doi.org/10.1016/s0278-2391(98)90009-x. (**discussion 43-4**).
26. Medeiros I, Saconato H. Antibiotic prophylaxis for mammalian bites. Cochrane Database Syst Rev. 2001;2: e001738. https://doi.org/10.1002/14651858.CD001738.

27. Bhaumik S, Kirubakaran R, Chaudhuri S. Primary closure versus delayed or no closure for traumatic wounds due to mammalian bite. Cochrane Database Syst Rev. 2019;12(12): Cd011822. https://doi.org/10.1002/14651858.CD011822.pub2.
28. Cheng HT, Hsu YC, Wu CI. Does primary closure for dog bite wounds increase the incidence of wound infection? A meta-analysis of randomized controlled trials. J Plast Reconstr Aesthet Surg. 2014;67(10):1448–50. https://doi.org/10.1016/j.bjps.2014.05.051.
29. Andrade C. Understanding relative risk, odds ratio, and related terms: as simple as it can get. J Clin Psychiatry. 2015;76(7):e857–61. https://doi.org/10.4088/JCP.15f10150.
30. Simon SD. Understanding the odds ratio and the relative risk. J Androl. 2001;22(4):533–6.
31. van Tulder M, Furlan A, Bombardier C, Bouter L. Editorial Board of the Cochrane Collaboration Back Review G. Updated method guidelines for systematic reviews in the cochrane collaboration back review group. Spine (Phila Pa 1976). 2003;28(12):1290–9. https://doi.org/10.1097/01.BRS.0000065484.95996.AF.
32. Stang A. Critical evaluation of the Newcastle-Ottawa scale for the assessment of the quality of nonrandomized studies in meta-analyses. Eur J Epidemiol. 2010;25(9):603–5. https://doi.org/10.1007/s10654-010-9491-z.
33. Higgins JP, Thompson SG, Deeks JJ, Altman DG. Measuring inconsistency in meta-analyses. BMJ. 2003;327(7414):557–60. https://doi.org/10.1136/bmj.327.7414.557.
34. Egger M, Davey Smith G, Schneider M, Minder C. Bias in meta-analysis detected by a simple, graphical test. BMJ. 1997;315(7109):629–34. https://doi.org/10.1136/bmj.315.7109.629.
35. Shi XQ, Wang ZZ. Application of Meta-regression and subgroup analyses of heterogeneity disposal in Meta-analysis. Zhonghua Liu Xing Bing Xue Za Zhi. 2008;29(5):497–501.
36. Ioannidis JP. Interpretation of tests of heterogeneity and bias in meta-analysis. J Eval Clin Pract. 2008;14(5):951–7. https://doi.org/10.1111/j.1365-2753.2008.00986.x.
37. Huang L, Wang L, Yang J, Zhang H. Clinical effect analysis of using medical glue versus conventional suturing to treat dog bite in children's maxillofacial region after negative pressure sealing drainage: a randomized trial. Medicine (Baltimore). 2023;102(37): e34837. https://doi.org/10.1097/md.0000000000034837.
38. Seegmueller J, Arsalan-Werner A, Koehler S, Sauerbier M, Mehling I. Cat and dog bite injuries of the hand: early versus late treatment. Arch Orthop Trauma Surg. 2020;140(7):981–5. https://doi.org/10.1007/s00402-020-03443-1.
39. Piccart F, Dormaar JT, Coropciuc R, Schoenaers J, Bila M, Politis C. Dog bite injuries in the head and neck region: a 20-year review. Craniomaxillofac Trauma Reconstr. 2019;12(3):199–204. https://doi.org/10.1055/s-0038-1660441.
40. Sezgin B, Ljohiy M, Akgol Gur ST. Animal-inflicted open wounds in rural Turkey: lessons learned and a proposed treatment algorithm for uncertain scenarios. Int Wound J. 2016;13(6):1282–8. https://doi.org/10.1111/iwj.12493.
41. Chen R, Huang L, Zheng J, Jia Y, Liu Y, Shan Y. Negative pressure wound therapy for serious dog bites of extremities: a prospective randomized trial. Am J Emerg Med. 2016;34(6):1006–10. https://doi.org/10.1016/j.ajem.2016.02.043.
42. Jaindl M, Oberleitner G, Endler G, Thallinger C, Kovar FM. Management of bite wounds in children and adults-an analysis of over 5000 cases at a level I trauma centre. Wien Klin Wochenschr. 2016;128(9–10):367–75. https://doi.org/10.1007/s00508-015-0900-x.
43. Tabaka ME, Quinn JV, Kohn MA, Polevoi SK. Predictors of infection from dog bite wounds: which patients may benefit from prophylactic antibiotics? Emerg Med J. 2015;32(11):860–3. https://doi.org/10.1136/emermed-2014-204378.
44. Paschos NK, Makris EA, Gantsos A, Georgoulis AD. Primary closure versus non-closure of dog bite wounds. A randomised controlled trial. Injury. 2014;45(1):237–40. https://doi.org/10.1016/j.injury.2013.07.010.
45. Xiaowei Z, Wei L, Xiaowei H, Yunbei X, Zhenhua L, Yeqing Y, et al. Comparison of primary and delayed wound closure of dog-bite wounds. Vet Comp Orthop Traumatol. 2013;26(3):204–7. https://doi.org/10.3415/vcot-12-04-0053.
46. Chen R, Huang L, Zheng J, Wang L. Emergency treatment on facial laceration of dog bite wounds with immediate primary closure: a prospective randomized trial study. BMC Emerg Med. 2013;13(Suupl 1):S2. https://doi.org/10.1186/1471-227x-13-s1-s2.
47. Kale SM, Patil SB, Khare N, Jain A. Animal bites-should primary reconstruction be the standard treatment? Eur J Plast Surg. 2011;34(5):367–73. https://doi.org/10.1007/s00238-010-0532-3.
48. Stierman KL, Lloyd KM, De Luca-Pytell DM, Phillips LG, Calhoun KH. Treatment and outcome of human bites in the head and neck. Otolaryngol Head Neck Surg. 2003;128(6):795–801. https://doi.org/10.1016/s0194-59980300254-7.
49. Chadaev AP, Jukhtin VI, Butkevich AT, Emkuzhev VM. Treatment of infected clench-fist human bite wounds in the area of metacarpophalangeal joints. J Hand Surg Am. 1996;21(2):299–303. https://doi.org/10.1016/s0363-5023(96)80125-0.
50. Maimaris C, Quinton DN. Dog-bite lacerations: a controlled trial of primary wound closure. Arch Emerg Med. 1988;5(3):156–61. https://doi.org/10.1136/emj.5.3.156.
51. Thomas PR, Buntine JA. Man's best friend?: a review of the Austin Hospital's experience with dog bites. Med J Aust. 1987;147(11–12):536–40.
52. Elenbaas RM, McNabney WK, Robinson WA. Prophylactic oxacillin in dog bite wounds. Ann Emerg Med. 1982;11(5):248–51. https://doi.org/10.1016/s0196-0644(82)80093-0.
53. Callaham M. Prophylactic antibiotics in common dog bite wounds: a controlled study. Ann Emerg Med. 1980;9(8):410–4. https://doi.org/10.1016/s0196-0644(80)80153-3.
54. Coyle C, Shi J, Leonard JC. Antibiotic prophylaxis in pediatric dog bite injuries: Infection rates and prescribing practices. J Am Coll Emerg Physicians Open. 2024;53: e13210. https://doi.org/10.1002/emp2.13210.
55. Maurer M, Schlipkoter C, Gottsauner M, Waiss W, Meier JK, Fiedler M, et al. Animal bite injuries to the face: a retrospective evaluation of 111 cases. J Clin Med. 2023. https://doi.org/10.3390/jcm12216942.
56. McGuire C, Morzycki A, Simpson A, Williams J, Bezuhly M. Dog bites in children: a descriptive analysis. Plast Surg (Oakv). 2018;26(4):256–62. https://doi.org/10.1177/2292550318767924.
57. Lang ME, Klassen T. Dog bites in Canadian children: a five-year review of severity and emergency department management. CJEM. 2005;7(5):309–14. https://doi.org/10.1017/s1481803500014494.
58. Dire DJ, Hogan DE, Walker JS. Prophylactic oral antibiotics for low-risk dog bite wounds. Pediatr Emerg Care. 1992;8(4):194–9. https://doi.org/10.1097/00006565-199208000-00005.
59. Zubowicz VN, Gravier M. Management of early human bites of the hand: a prospective randomized study. Plast Reconstr Surg. 1991;88(1):111–4. https://doi.org/10.1097/00006534-199107000-00019.
60. Skurka J, Willert C, Yogev R. Wound infection following dog bite despite prophylactic penicillin. Infection. 1986;14(3):134–5. https://doi.org/10.1007/bf01643478.
61. Ordog GJ. Cephradine in the prophylactic treatment of dog bites. Can Fam Physician. 1986;32:743–9.
62. Rosen RA. The use of antibiotics in the initial management of recent dog-bite wounds. Am J Emerg Med. 1985;3(1):19–23. https://doi.org/10.1016/0735-6757(85)90005-1.
63. Lackmann GM, Draf W, Isselstein G, Tollner U. Surgical treatment of facial dog bite injuries in children. J Craniomaxillofac Surg. 1992;20(2):81–6. https://doi.org/10.1016/s1010-5182(05)80472-x.
64. Chen T, Karim M, Grace ZT, Magdich AR, Carniol EC, Benson BE, et al. Surgical management of facial dog bite trauma: A contemporary perspective and review. World J Otorhinolaryngol Head Neck Surg. 2023;9(2):123–30. https://doi.org/10.1002/wjo2.75.
65. Liu S, Liu C, Chen QJ, Zhu ZG, Lyu XJ, Wang CL, et al. Interpretation of the national regulation for the rabies exposure Prophylaxis (2023 edition). Zhonghua Liu Xing Bing Xue Za Zhi. 2023;44(10):1497–506. https://doi.org/10.3760/cma.j.cn112338-20230905-00127.
66. Obrien KL, Nolan T, Rabies SW. The WHO position on rabies immunization - 2018 updates. Vaccine. 2019;37(Suppl 1):A85–7. https://doi.org/10.1016/j.vaccine.2018.10.014.
67. Cummings P. Antibiotics to prevent infection in patients with dog bite wounds: a meta-analysis of randomized trials. Ann Emerg Med. 1994;23(3):535–40. https://doi.org/10.1016/s0196-0644(94)70073-7.
68. Oliveira GV, Chinkes D, Mitchell C, Oliveras G, Hawkins HK, Herndon DN. Objective assessment of burn scar vascularity, erythema, pliability, thickness, and planimetry. Dermatol Surg. 2005;31(1):48–58. https://doi.org/10.1111/j.1524-4725.2005.31004.

69. Hollander JE, Valentine SM, McCuskey CF, Turque T, Singer AJ. Long-term evaluation of cosmetic appearance of repaired lacerations: validation of telephone assessment. The Stony Brook Wound Registry Study Group. Ann Emerg Med. 1998;31(1):92–8.

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