A THESIS FOR THE DEGREE OF MASTER

# Application of cold atmospheric microwave plasma as an adjunct therapy for wound healing in dogs and cats

개와 고양이에서
창상 치유를 위한 보조요법으로서
저온 대기 마이크로파 플라즈마의 적용

2023년 8월

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수의학과 임상수의학(피부과학)

# 개와 고양이에서 창상 치유를 위한 보조요법으로서 저온 대기 마이크로파 플라즈마의 적용

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# Application of cold atmospheric microwave plasma as an adjunct therapy for wound healing in dogs and cats

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# Abstract

Wounds with a wide variety of etiologies are frequently encountered in small animal veterinary practice. Cold atmospheric plasma(CAP) is a novel innovative approach for wound care but it is currently underrepresented in veterinary medicine. The purpose of this study was to investigate the efficacy and safety of using cold atmospheric microwave plasma (CAMP) as an adjunct therapy for wound healing in dogs and cats. Wound healing outcomes were retrospectively analyzed using clinical records of client-owned dogs and cats who were first managed through standard wound care alone (pre-CAMP period) and subsequently via CAMP therapy (CAMP period). The degree of wound healing was estimated based on wound size and a modified wound scoring system. Of the 27 acute and chronic wounds included in the analysis, 81.48% showed complete healing after the administration of CAMP as an adjunct therapy to standard care. Most wounds achieved complete healing in <5 weeks. Compared with the pre-CAMP period, the rate of wound healing significantly increased every week in the CAMP period in terms of in wound size (first week, $p < 0.001$; second week, p = 0.012; third week, $p < 0.001$) and wound score (first week, $p < 0.001$; second week, $p < 0.001$; third week, $p = 0.001$). No adverse events were noted except for mild discomfort and transient erythema. In conclusion, CAMP is a well-tolerated therapeutic option with immense potential to support the treatment of wounds of diverse etiology in small animal practice. Further research is warranted to establish specific criteria for CAMP treatment according to wound characteristics.

**Key words:** cold atmospheric microwave plasma, wound healing, small animal clinical practice

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# List of Figures and Tables

# Contents

# 1. Introduction

Numerous wounds of varied etiology are frequently encountered in small animal veterinary practice. Although several treatment modalities exist depending on primary diseases, clinicians occasionally experience considerable clinical challenges when managing wounds over prolonged periods [1]. Moreover, practitioners should consider the risk of adverse events associated with the use of certain therapeutic agents, such as antimicrobial resistance, contact dermatitis, and adverse drug reactions [2, 3, 4]. Effective wound care, along with advanced therapeutic options, are necessary to ensure that the healing process is successful with minimal risk of undesired reactions or toxicity. Recent studies have reported that cold atmospheric plasma (CAP) has numerous biological effects, including suppression of inflammation, promotion of cell proliferation, and enhancement of angiogenesis and reactive oxygen species production [5, 6, 7]. Owing to these qualities, CAP has been used in the development of an innovative approach to administer wound care and applied in diverse medical specialties, including dermatology, dentistry, neurology, and oncology [8].

Plasma consists of plenty of active components, including charged particles, electric current, UV radiation, and reactive gas species, which can act in synergy with each other [9, 10]. Plasma can occur naturally or be generated artificially from feed gas by adding energy in the forms of electricity, microwave radiation, and heat [11]. Artificial plasma is maintained at atmospheric pressure and near ambient temperature, owing to which it is known as CAP or non-thermal plasma; thus, this form of plasma can have biological applications without causing thermal damage [8]. Especially, cold atmospheric microwave plasma (CAMP) device used in this study was driven by continuous microwaves, eliciting biological responses more effectively even at low temperature when compared to conventional CAP methods using other energy sources [12, 13, 14].

Although the clinical usefulness of plasma in human medicine is well established, its application in veterinary medicine remains under-acknowledged. This is predominantly attributable to the absence of data recorded in clinical settings. To compensate for this, the purpose of this study was to assess the efficacy and safety of CAMP as an adjunct therapy for wound healing in dogs and cats by analyzing real-world cases in veterinary medicine.

# 2. Materials and Methods

## *2.1. Data collection*

A retrospective chart review was performed of client-owned dogs and cats referred to the Veterinary Medical Teaching Hospital at Seoul National University Hospital in Seoul, Korea. The medical records from April 2020 to December 2022 were reviewed to identify all patients who underwent CAMP therapy for wounds of any etiology. All owners were informed of the procedure of CAMP treatment and provided consent prior to the therapy.

Healing outcomes of wounds were analyzed using data of patients first managed by standard wound care alone and subsequently with CAMP therapy. In this study, the term “standard wound care” encompasses a range of treatments commonly employed by individual veterinarians, such as wound disinfection, dressing, bandaging and antibiotic use [15]. Detailed information including age, breed, sex, comorbidities, concomitant medication, and follow-up was collected from the clinical records. The inclusion criterion for the present study was as follows: patients who received treatment for $\geq$1 week using standard wound care alone in our clinic followed by additional CAMP therapies. Cases of patients who were not available for $\geq$2 weekly CAMP therapies were excluded from the analysis.

## *2.2. Plasma device and configuration*

The CAMP-generating device (Bio Stimulation Microwave Plasma version 1.0.;

IonMedical Incorporation, Republic of Korea), accredited for veterinary use in Korea, was used in this study. The CAMP settings utilized for therapy were based on manufacturer's recommendations: microwave frequency, 2.45 GHz; voltage, 3.5 kV; power, 30W; and argon gas flow rate, 15 L/min. Taking the abovementioned settings into consideration, the effluent had a visible length of approximately 10 mm and the temperature at the tip of the plasma jet was maintained at <40°C [14].

## *2.3. Treatment procedure*

CAMP therapy was administered without sedation or analgesia to patients in a conscious state. Each patient was placed in a stable position and manually restrained by assistants. Prior to CAMP application, the wound bed was cleaned with physiological saline to remove devitalized tissue and contaminants. In case of facial wounds, the patients wore protective goggles to protect the eyes from exposure to the plasma effluent. The probe was positioned perpendicular to the wound surface at a distance of approximately 5 mm from the end of the jet orifice. The plasma jet was placed in contact with the lesion surface and moved constantly over the entire wound. Application times were 2–5 min depending on wound size and severity.

CAMP therapies were administered in addition to the conventional standard wound care as considered appropriate on a case-by-case basis, including regular dressing changes, debridement of devitalized tissue, appropriate infection control, and if required, etiology-specific care, such as glycemic control in patients with diabetes. The exact details of the standard wound care were left to the discretion of the treating clinicians as per their routine practice. Data on all concomitant interventions were recorded during the entire treatment period.

The complete procedure described above was implemented ≥2 times a week depending on owners' availability and/or compliance. Therapy discontinuation was determined according to the wound healing state, and an additional follow-up examination was performed for more than 2 weeks to assess for recurrence.

## *2.4. Assessment of therapeutic efficacy*

The study was categorized into two main periods: a pre-CAMP period (from "T0" to "T1") followed by a CAMP period (from "T1" to the termination day of CAMP therapy) (Fig. 1). "T1" was the first day of CAMP therapy, and "T0" was set as the time point 1 week (7 days ± 2 days) prior to "T1." The CAMP period started from "T1", and then in sequence, such as "T2", "T3", and "T4", by 1 week (7 days ± 2 days) interval. In the pre-CAMP period, the degree of wound healing was assessed according to optimized standard wound care alone before CAMP treatment. During the CAMP period, patients received CAMP therapies ≥2 times a week in addition to ongoing standard wound care.

The wound area was calculated by multiplying the length and width measured with a ruler. A more comprehensive evaluation of the degree of wound healing was performed by estimating the macroscopic aspect of the lesions according to the scoring system adapted from the Bates-Jensen Wound Assessment Tool [16] and the wound bed scoring for chronic wounds [17] (Table 1). Each parameter was assigned a score of 0–3; therefore, the total score of 0 and 21 indicated that the wound was in the best and worst possible condition, respectively. In the present study, complete healing or closure was defined as 100% epithelialization. The wound healing rate was calculated using the percentage change in wound area or score as follows: [(initial wound area (or score) − final wound area (or score)) / (initial wound area (or score))] × 100. Wound assessment was carried out by the same veterinarian in all cases.

## *2.5. Assessment of therapeutic safety*

Pain response and occurrence of adverse skin reactions including erythema, edema, exudation, and bleeding were monitored during each treatment to determine the tolerability. The degree of pain was assessed based on behavior including vocalization, aggression, attention to wounds, as well as abnormal activity and posture [18]. In addition, owners were asked to report any discomfort and skin changes observed after therapy.

## *2.6. Statistical analysis*

Statistical analysis was performed using the Statistical Analysis System (version 9.4; SAS Institute, USA). Normality of data distribution was assessed using the Shapiro-Wilk and the Kolmogorov-Smirnov tests. The Mann-Whitney U test was used to detect significant differences between the mean wound age of chronic and acute wounds. Differences in wound size and wound score at each time point were assessed by the Friedman's test. To evaluate the statistical differences in wound healing rate between the pre-CAMP period and each week of the CAMP period, the paired sample t-test or the Wilcoxon signed rank test was used for repeated measurements. Data are expressed as a mean ± SD; $p < 0.05$ indicated statistical significance.

# 3. Results

## *3.1. Patient and wound characteristics*

A total of 27 patients with various etiologies were treated for ≥ 1 week using standard wound care alone followed by CAMP therapy. Most patients were dogs (n = 23, 85.19%) including 13 different purebred and one mixed breed; the remaining 4/27 (14.81%) patients were domestic short-hair cats. Further details related to the demographic information for each animal are listed in Table 2 and Table 3.

The wound characteristics at baseline (T0) are displayed in Table 4. Diagnosis of the different types of wounds was established according to clinical signs, laboratory results, further clinical investigations, and, in some cases, additional punch biopsies. The main etiologies were compatible with trauma (n = 9, 33.33%), pedal furunculosis (n = 4, 14.81%), and surgical incision (n = 4, 14.81%). Wounds were predominantly located on the paws (n = 10, 37.04%) and joints (n = 4, 14.81%), and were 0.35–110 $cm^2$ in size, and the size of most lesions (n = 22, 81.48%) was <10 $cm^2$.

In present study, the term "wound age" was defined as the duration during which wounds did not show improvement despite receiving standard wound care. The mean wound age as reported by the owners were 12.48 ± 21.65 weeks (median, 5 weeks; range, 0–96 weeks). The wounds were categorized into two types, acute and chronic, based on the wound duration of four weeks according to previously reported criteria [19]. Of all wounds evaluated, 14/27 (51.85%) wounds were chronic, and 13/27 (48.15%) wounds were acute. The mean wound age of chronic wounds was significantly higher than that of acute wounds ($p < 0.001$). Cytological evidence of bacterial infection was observed in 15/27 (55.56%) wounds at baseline, and 5/27 (18.52%) patients were administered additional oral antibiotics.

## *3.2. Therapeutic efficacy*

As shown in Table 5 and Fig. 2, 22/27 (81.48%) wounds, including 11 acute wounds and 11 chronic wounds, healed completely within 2.55 ± 1.37 weeks of CAMP therapy, with an average of 2.50 ± 0.74 applications per week. In the case of acute wounds, the mean number of plasma applications until closure was 5.27 ± 2.15 times in 2.00 ± 1.00 weeks. Chronic wounds completely healed after 6.64 ± 3.35 plasma application over a mean period of 3.09 ± 1.51 weeks. Except for two cases with chronic wounds, treatment completion was achieved in most cases at <5 weeks. These two cases resulted from trauma and burn injury and required 5 and 6 weeks of CAMP therapy, respectively. After complete wound healing, all but one did not show symptoms in the previous non-healing area within the additional follow-up period of at least 2 weeks. The case of recurred wound, caused by a foreign body reaction, required surgical excision although temporary recovery was observed in terms of wound size, exudate and edema after CAMP therapies.

In 5/27 (18.52%) patients, with 2 acute wounds and 3 chronic wounds, CAMP therapy was discontinued as significant improvement over time was not observed. Two cases presented with acute wounds, which were caused by trauma and injection site panniculitis; the remaining 3 cases of chronic wounds were caused by trauma, dermatophytosis, and pancreatic panniculitis, respectively. Of those, 2 patients with traumatic wounds were lost to follow-up and 2 patients with panniculitis died due to deterioration of health owing to their primary diseases. The patient with dermatophytosis achieved complete wound healing after 3 months as the primary fungal infection resolved with long-term use of antifungal agents.

Overall, mean wound size and mean wound score demonstrated a tendency to decrease over the treatment period (Fig. 3). The treatment period was significantly effective in decreasing wound size and score ($p < 0.001$). The clinical efficacy of CAMP therapy, when added as an adjunct therapy, was assessed by comparing the wound healing rate achieved with CAMP application plus standard care with that achieved via standard care alone. Therefore, the wound healing rate of the pre-CAMP period was compared with that of the first, second, and third week of the CAMP period, respectively. As all but two wounds had completed healing within four weeks, the rest weeks of the CAMP treatment were excluded from the statistical analysis. As shown in Fig. 4, administration of CAMP therapy resulted in a significant increase in the wound healing rate at each week, as indicated in terms of in wound size (first week, $p < 0.001$; second week, $p = 0.012$; third week, $p < 0.001$) and wound score (first week, $p < 0.001$; second week, $p < 0.001$; third week, $p = 0.001$). Fig. 5–7 show images of 3 representative cases at the start and end of CAMP therapy.

### *3.3. Therapeutic safety*

Although 5/27 (18.52%) dogs displayed mild discomfort, as indicated by vocalization and mobility, excessive restraint or sedation was not necessary during any treatments. Transient erythema was observed in 7/27 (25.93%) patients; however. This complication typically resolved spontaneously within 1 hour. No adverse effects were reported by the owners.

# 4. Discussion

CAP therapy is an innovative approach in the biomedical field and it has remarkable merits including tissue regeneration, cell proliferation, and antiseptic effects [5, 7, 11, 20]. In addition to its non-invasive and practical nature, CAP has made important advances as a versatile tool in human medicine. In particular, several in vitro and clinical studies have demonstrated that CAP reduces the bacterial contamination in wounds and accelerates healing in cases of chronic ulcers [21, 22, 23]. In veterinary medicine, however, plasma therapy has not been sufficiently valued despite the numerous risk factors that hinder wound healing in animals, including infection, metabolic diseases, malnutrition, and wound anatomic location [24, 25]. The present study aimed to assess the efficacy and safety of CAMP, thus confirming the clinical aptitude of plasma application as an adjunctive therapy for wound healing veterinary animal practice.

The outcomes of the present study demonstrated that 81.48% of all acute and chronic wounds showed complete healing through the administration of CAMP therapy as an adjunct therapy in addition to standard care. Although complete healing was achieved in most wounds at <5 weeks, 5 and 6 weeks of CAMP therapy was required in two chronic cases, respectively. The healing effect of CAMP therapy was positive, considering that chronic wounds in this study had persisted between 5–96 weeks before treatment.

Furthermore, in the present study, wounds that were successfully treated demonstrated certain risk factors associated with wound healing. They were commonly located on paws and joints, which are susceptible to infection, dehiscence, and insufficient healing owing to exposure to external forces and motion [25]. In addition, some patients presented with concomitant disorders, including metabolic and endocrine diseases, such as diabetes mellitus, hyperadrenocorticism, and hypothyroidism, common impediments to healing [25]. Despite the abovementioned impediments, a significantly remarkable wound reduction was observed in terms of wound size and score following the administration of CAMP as an adjunct therapy in addition to conventional standard care.

In humans, CAP has been applied to different conditions, including the treatment of pyoderma gangrenosum, chronic eczema, and diabetic foot as well as wounds resulting from laser treatment [21, 22, 26]. Similarly, in this study, wounds of diverse etiologies, including trauma, surgical incision, diabetic ulcer, pressure ulcer and burn injury, were treated. In addition, erosive and ulcerative lesions from various dermatologic disorders involving infectious and inflammatory diseases were treated. In patients with pedal furunculosis as presented in this study, for example, ulcerative skin lesions with fistula may develop in severe conditions. In such cases, prolonged anti-inflammatory and additional antimicrobial therapies are common therapeutic regimens. Lifelong management may be occasionally required, and this increases the likelihood of the occurrence of significant adverse effects. In this regard, CAMP therapy can alleviate the need and burden of medication by ensuring the efficient management of secondary lesions as demonstrated in the patients in the present study.

Cytological evidence revealed that nearly half of the wounds at baseline presented with a bacterial infection. Owing to the administration of concomitant antimicrobial therapies, including topical and systemic agents, evaluation of the antimicrobial efficacy of CAMP was challenging. A previous report demonstrated that the most common bacterium detected in wounds of dogs and cats were *Pseudomonas* spp. and *Staphylococcus* spp. with various antimicrobial resistance [27]. They form biofilms on the surface of wounds, thereby impeding epithelialization and granulation tissue formation, and consequently reducing antibiotic susceptibilities and host defense [28]. In recent in vitro studies, CAMP showed antibacterial efficacy against *Staphylococcus pseudintermedius* and *Pseudomonas aeruginosa* regardless of antibiotic resistance [29]. In addition, CAMP was effective against both planktonic bacteria and biofilm formation of *Pseudomonas aeruginosa* [30]. Given the increasing importance of antibiotic resistance, CAMP application can be considered a promising treatment strategy to achieve infection control and prevention in wounds.

A recent study has proven that CAMP could be a safe therapeutic option by demonstrating the results that it does not significantly change biophysical parameters in dogs [14]. In the present study, CAMP treatment without using any analgesic drug was well-tolerated except for mild discomfort and transient erythema in some patients. There were no adverse events that resulted in the premature discontinuation of CAMP therapy. However, considering that wounds were evaluated only based on macroscopic properties, a more precise assessment including histological analysis is warranted to exclude long-term side effects.

The current study has certain limitations primarily associated with its retrospective and clinical nature. Assessing the effectiveness of CAMP therapy in controlled environments was challenging due to the diverse wound characteristics, comorbidities, and concurrent treatment approaches. Consequently, our objective was to explore whether combining CAMP therapy with standard wound care could result in a notable enhancement in wound healing rates. However, it is crucial to recognize that the study's failure to consider the distinct stages of healing for each wound represents an unavoidable limitation.

Another limitation is the absence of standardized protocols and device settings for CAMP. In this study, the same CAMP settings were applied to every wound in all animals included. Different settings for CAMP parameters such as wavelength, power, and energy density were required depending on the species owing to differences in skin components and wound healing physiology [24, 31]. Therefore, standard application protocols, along with thorough monitoring, are needed most appropriate to the different wound characteristics as a plasma overdose could suppress wound healing due to excessive necrosis or apoptosis [32]. Future studies using a larger study population, including an analysis of the interaction between factors such as patient characteristics, wound features, and CAMP regimens help establish specific criteria for CAMP therapy.

In conclusion, together with previous findings regarding in vitro efficacy and in vivo safety, the current study demonstrated that CAMP is a well-tolerated therapeutic option with great potential to support the treatment of the etiologically different wounds encountered in small animal practice. While further comprehensive and standardized studies are necessary to validate and broaden our findings, the CAMP approach demonstrates promise as an efficient and practical method for wound care in veterinary medicine.

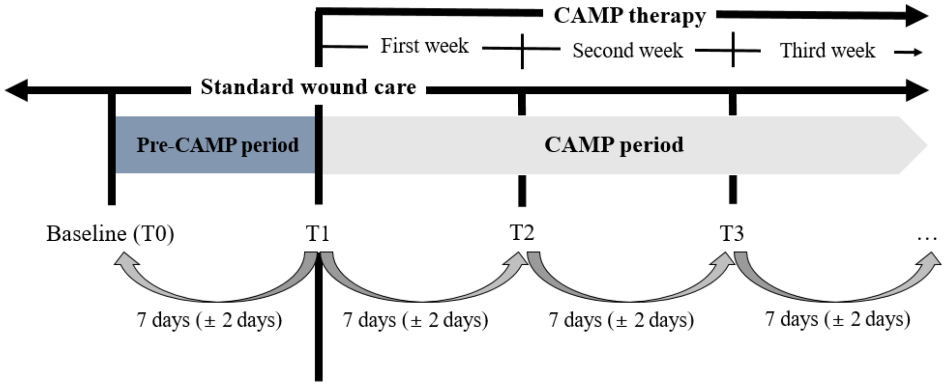



**Figure 1. Schematic representation of two main periods in this study: a pre-CAMP period and a CAMP period**

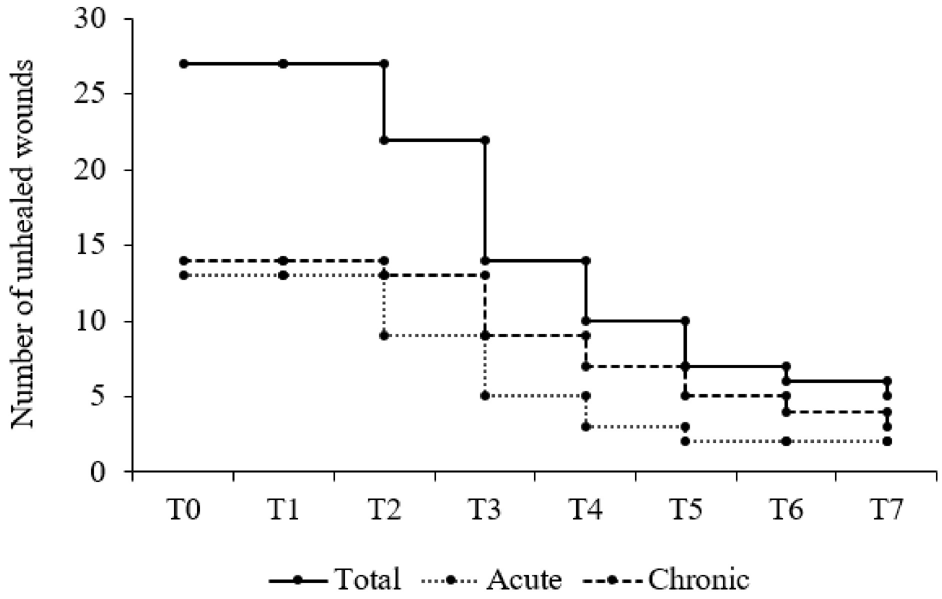



**Figure 2. Number of unhealed wounds over treatment time**

22/27 (81.48%) wounds, including 11 acute wounds and 11 chronic wounds, healed completely via CAMP therapy in addition to standard care. Except for two cases with chronic wounds, treatment completion was achieved in most cases at <5 weeks. These two cases required 5 and 6 weeks of CAMP therapy, respectively. In 5/27 (18.52%) patients, with 2 acute wounds and 3 chronic wounds, CAMP therapy was discontinued as significant improvement over time was not observed.

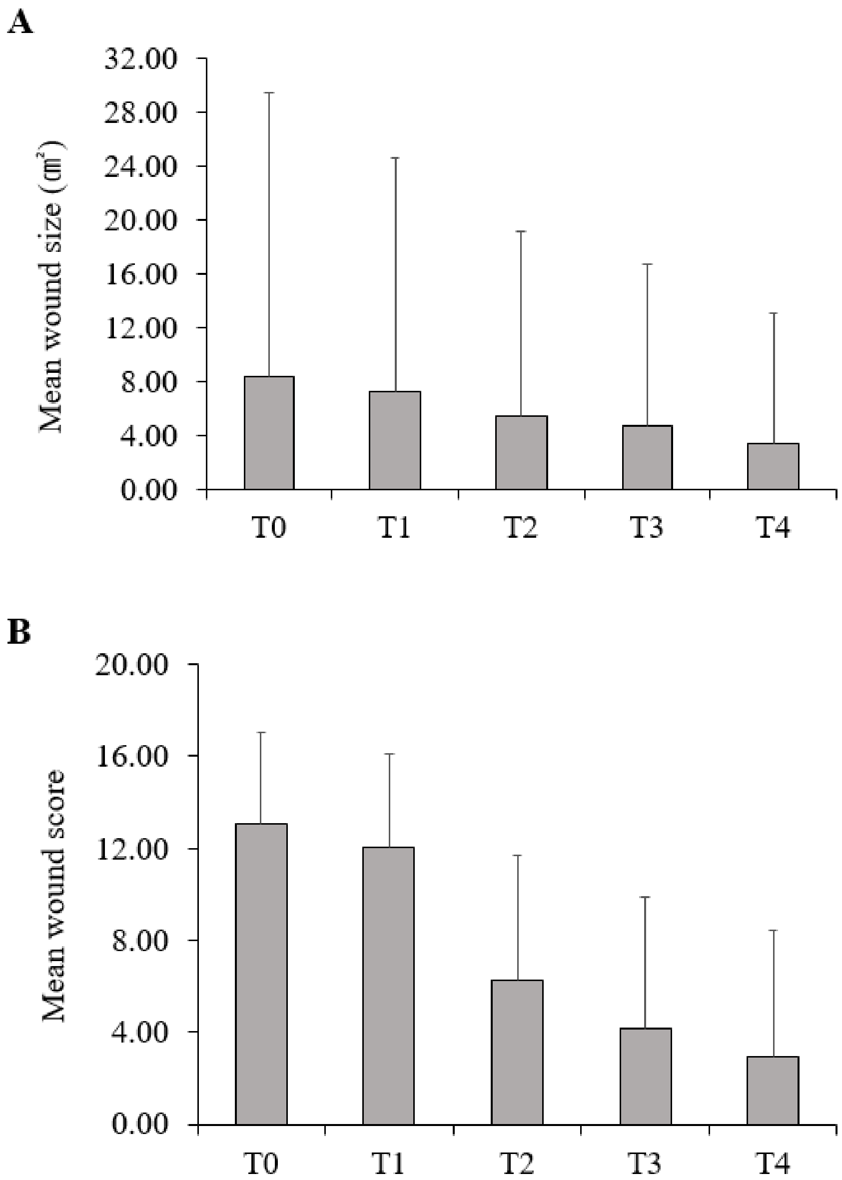
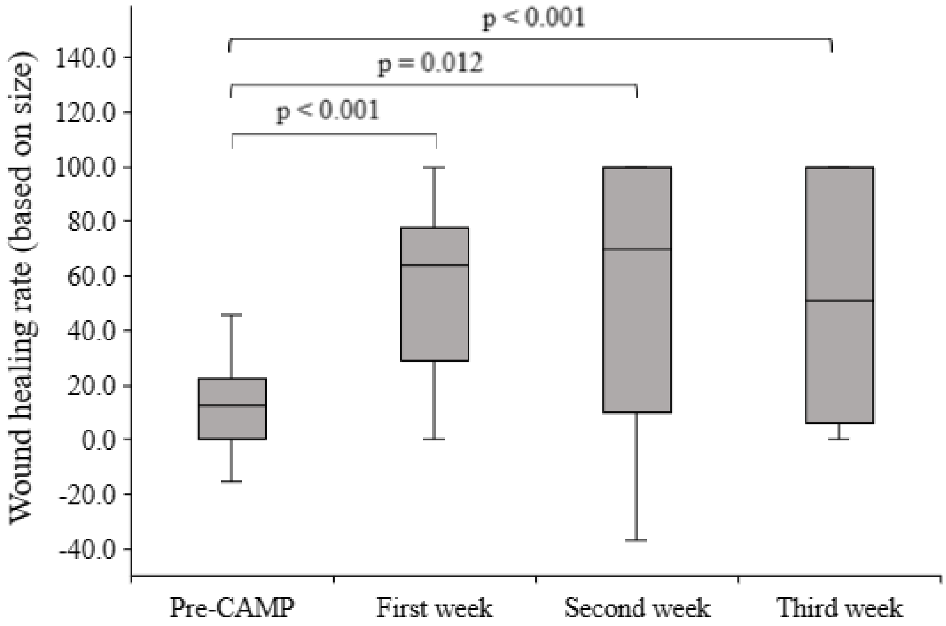



**Figure 3. (A) mean wound size, and (B) mean wound score over the treatment period**

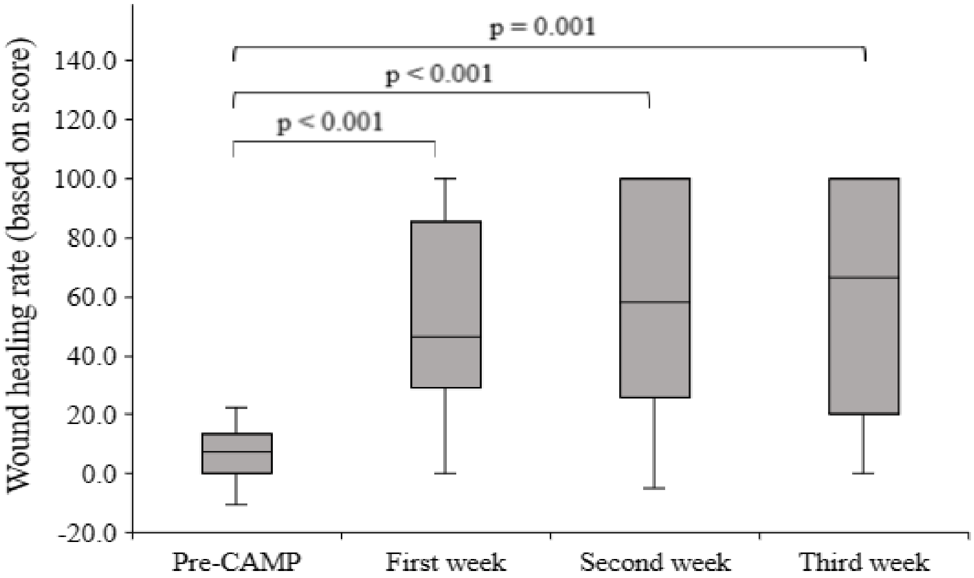
The treatment period was significantly effective in decreasing both wound size and score.

A



p < 0.001
p = 0.012
p < 0.001
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
-20.0
-40.0
Wound healing rate (based on size)
Pre-CAMP
First week
Second week
Third week


B



p = 0.001
p < 0.001
p < 0.001
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
-20.0
Wound healing rate (based on score)
Pre-CAMP
First week
Second week
Third week

**Figure 4. Box plot of wound healing rate based on (A) wound size, and (B) wound score**

Graphic summarize the difference of wound healing rate, compared between the pre-CAMP period and each week of the CAMP period. The wound healing rate during the pre-CAMP period acted as control variables. Administration of CAMP therapy resulted in a significant increase in the wound healing rate at each week in terms of in wound size (first week, $p < 0.001$; second week, $p = 0.012$; third week, $p < 0.001$) and wound score (first week, $p < 0.001$; second week, $p < 0.001$; third week, $p = 0.001$).

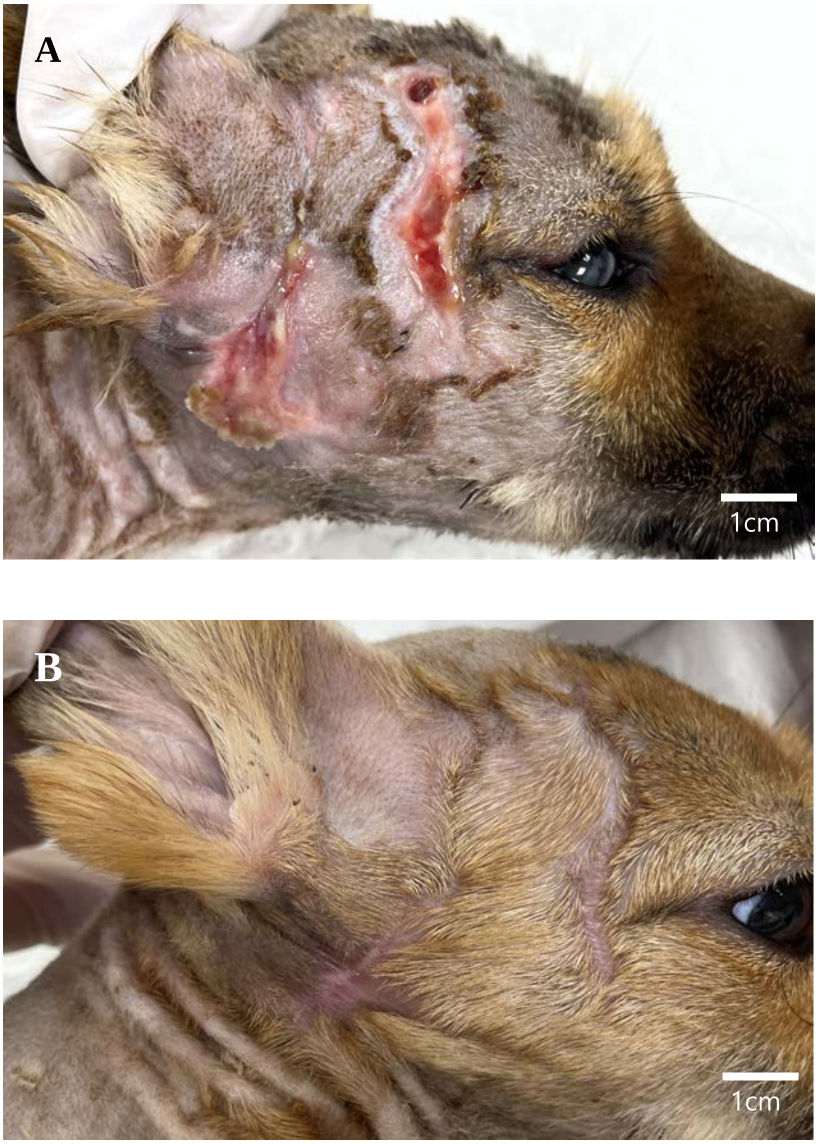



**Figure 5. Traumatic cutaneous myiasis (after larvae removal)**

A 1-year-old, male castrated, mixed dog had had traumatic cutaneous myiasis in the temporal region of the face for approximately 5 weeks. (A) At the beginning of CAMP therapy (T1), the wound was 3.75 $cm^2$; (B) After 2 weeks and four CAMP applications in combination with standard care, the wound was completely healed.

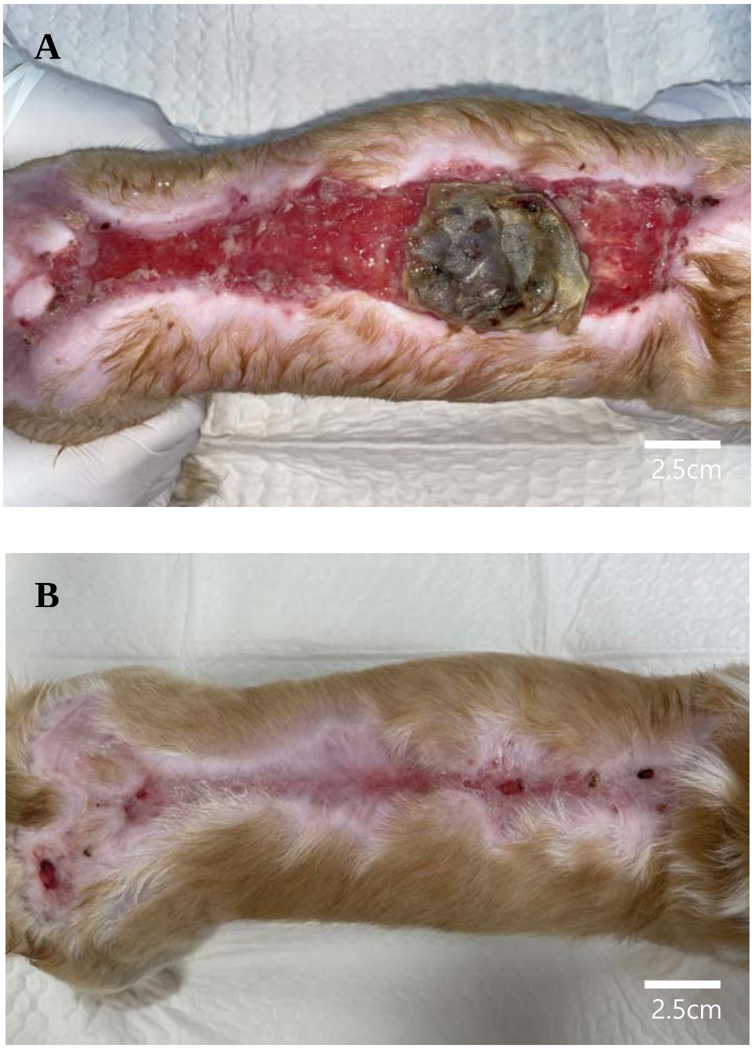



**Figure 6. Large wound from a burn injury**

A 1-year-old, male castrated, dachshund dog with a burn injury covering most of the dorsum area. The wound had existed for 7 weeks in spite of administering the required standard of care. (A) At the beginning of CAMP therapy (T1), the wound was 90 $cm^2$;. (B) After 6 weeks and 12 CAMP applications as an adjunct to standard care, wound healing was achieved.

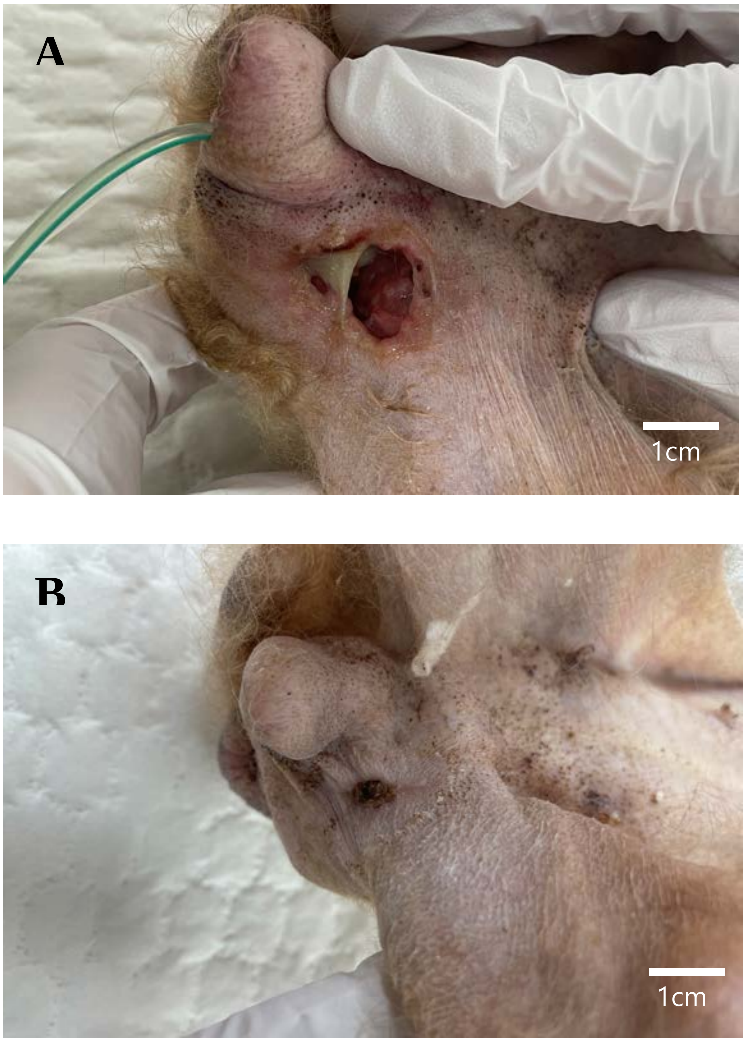



**Figure 7. Deep diabetic ulcer**

A 13-year-old, male castrated, poodle dog with a diabetic ulcer in the groin. Despite the administration of standard care, including insulin treatment, the wound had not been healed. (A) At the beginning of CAMP therapy (T1), the wound was 1.56 $cm^2$; (B) After 2 weeks and four CAMP applications in addition to standard care, the wound was fully closed.

**Table 1. Modified wound scoring system for evaluating the macroscopic aspect of wounds**

| | 0 | 1 | 2 | 3 |
|---|---|---|---|---|
| Healing edges | > 75% | 50 - 75% | 25 – 50% | None |
| Exudate amount | None | Scant | Moderate | Severe |
| Exudate type | None | Bloody | Serous or Serosanguineous | Purulent |
| Edema | None | Mild | Moderate | Severe |
| Pink wound bed (amount of healthy granulation) | > 75% | 50 – 75% | 25 – 50% | None |
| Necrotic tissue type | Non-visible | White or Grey | Yellow slough | Black eschar |
| Greatest wound depth | None (almost even) | Mild | Moderate | Severely depressed or raised when compared to peri-wound skin |

**Table 2. Description of signalment data for 27 patients**

| No. | Species | Breed | Sex | Age (years) | Wound Location | Wound Etiology | Baseline wound size | Healing outcome |
|---|---|---|---|---|---|---|---|---|
| 1 | Ca | LR | MC | 3 | Hock joint | TR | 0.49㎠ | C |
| 2 | Ca | YT | M | 8 | Forepaw | PF | 0.42㎠ | C |
| 3 | Ca | MP | FS | 8 | Axilla | TR | 0.64㎠ | C |
| 4 | Ca | LR | F | 1 | Hindpaw | PU | 1㎠ | C |
| 5 | Ca | GS | M | 4 | Forepaw | TR | 2.6㎠ | I |
| 6 | Ca | PD | MC | 6 | Hip | TR | 18㎠ | C |
| 7 | Ca | WC | FS | 8 | Hock joint | SI | 8.4㎠ | C |
| 8 | Ca | CS | MC | 7 | Flank | PN | 13.75㎠ | C |
| 9 | Ca | BF | M | 4 | Forepaw | VS | 0.42㎠ | I |
| 10 | Ca | WT | MC | 9 | Stifle joint | TR | 1.5㎠ | C |
| 11 | Ca | PD | MC | 5 | Inguina | SI | 0.4㎠ | C |
| 12 | Ca | MT | MC | 3 | Hindpaw | VS | 0.7㎠ | C |
| 13 | Ca | CS | MC | 11 | Forepaw | SI | 0.35㎠ | C |
| 14 | Ca | DH | MC | 1 | Dorsum | BI | 110㎠ | C |
| 15 | Ca | MX | MC | 1 | Face | MY | 4.76㎠ | C |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 16 | Ca | PD | MC | 14 | Inguina | DU | 1.56㎠ | C |
| 17 | Ca | YT | MC | 10 | Hindpaw | TR | 1.3㎠ | I |
| 18 | Ca | ST | MC | 6 | Forepaw | PF | 0.9㎠ | C |
| 19 | Ca | MT | MC | 8 | Flank | PN | 1.5㎠ | C |
| 20 | Ca | LR | MC | 11 | Hock joint | SI | 15㎠ | C |
| 21 | Ca | BF | MC | 2 | Forepaw | PF | 0.8㎠ | C |
| 22 | Ca | ST | MC | 12 | Forepaw | PF | 0.56㎠ | C |
| 23 | Ca | SY | FS | 10 | Face | TR | 4.5㎠ | C |
| 24 | Fe | DSH | MC | 4 | Inguina | TR | 8.05㎠ | C |
| 25 | Fe | DSH | FS | 4 | Thigh | DP | 1.3㎠ | I |
| 26 | Fe | DSH | MC | 4 | Dorsum | NC | 9㎠ | C |
| 27 | Fe | DSH | FS | 10 | Hip | PN | 18㎠ | I |

Abbreviations : Ca=Canine, Fe=Feline, LR=Labrador retriever, YT=Yorkshire terrier, MP=Miniature pinscher, GS=German shepherd, PD=Poodles, WS=Welsh corgis, CS=Cocker spaniel, BF=Bichon frise, WT=White terrier, DH=Dachshund, MT=Maltese, MX=Mixed breed, ST=Shih Tzu, SY=Samoyed, DSH=Domestic short hair cat, TR=Trauma, PF=Pedal furunculosis, PU=Pressure ulcer, SI=Surgical injury, PN=Panniculitis, VS=Vasculitis, BI=Burn injury, MY=Myiasis, DU=Diabetic ulcer, DP=Dermatophytosis, NC=Nocardiosis, C=Completion, I=Incompletion.

**Table 3. Patient characteristics**

| | All wounds (N = 27) | Acute wounds (N = 13) | Chronic wounds (N = 14) |
|---|---|---|---|
| Species, n (%) | | | |
| Dog [a] | 23 (85.19) | 13 (48.15) | 10 (37.04) |
| Cat[b] | 4 (14.81) | 0 (0) | 4 (14.81) |
| Age, years | | | |
| mean ± SD | 6.44 ± 3.66 | 5.92 ± 2.87 | 6.93 ± 4.32 |
| Sex, n (%) | | | |
| Male castrated | 18 (66.67) | 7 (25.93) | 11 (40.74) |
| Female spayed | 5 (18.59) | 2 (7.41) | 3 (11.11) |
| Intact male | 3 (11.11) | 3 (11.11) | 0 (0) |
| Intact female | 1 (3.70) | 1 (3.70) | 0 (0) |

SD = Standard Deviation

a = Bichon frise, Cocker spaniel, Dachshund, German shepherd, Labrador retriever, Miniature pinscher, Maltese, Poodles, Samoyed, Shih Tzu, Welsh corgis, White terrier, Yorkshire terrier, Mixed breed

b = Domestic short hair cat

**Table 4. Baseline wound characteristics**

| | All wounds (N = 27) | Acute wounds (N = 13) | Chronic wounds (N = 14) |
|---|---|---|---|
| Wound age, weeks | | | |
| mean ± SD | 12.48 ± 21.65 | 1.46 ± 1.05 | 22.71 ± 26.49 |
| median (range) | 5.00 (0.00 – 96.00) | 1.00 (0.00 – 4.00) | 8.00 (5.00 – 96.00) |
| Wound location, n (%) | | | |
| Forepaw | 7 (25.93) | 4 (14.81) | 3 (11.1) |
| Hindpaw | 3 (11.11) | 2 (7.41) | 1 (3.70) |
| Hock joint | 3 (11.11) | 2 (7.41) | 1 (3.70) |
| Stifle joint | 1 (3.70) | 1 (3.70) | 0 (0) |
| Thigh | 1 (3.70) | 0 (0) | 1 (3.70) |
| Hip | 2 (7.41) | 1 (3.70) | 1 (3.70) |
| Groin | 3 (11.11) | 1 (3.70) | 2 (7.41) |
| Axilla | 1 (3.70) | 1 (3.70) | 0 (0) |
| Trunk | 4 (14.81) | 1 (3.70) | 3 (11.1) |
| Face | 2 (7.41) | 0 (0) | 2 (7.41) |
| Wound etiologies, n (%) | | | |
| Pedal furunculosis | 4 (14.81) | 1 (3.70) | 3 (11.1) |
| Trauma | 9 (33.33) | 5 (18.52) | 4 (14.81) |
| Surgical incision | 4 (14.81) | 3 (11.1) | 1 (3.70) |
| Pressure ulcer | 1 (3.70) | 1 (3.70) | 0 (0) |
| Vasculitis | 2 (7.41) | 2 (7.41) | 0 (0) |
| Primary infection | 2 (7.41) | 0 (0) | 2[a] (7.41) |
| Panniculitis | 3 (11.11) | 1 (3.70) | 2 (7.41) |

| | | | |
|---|---|---|---|
| Diabetic ulcer | 1 (3.70) | 0 (0) | 1 (3.70) |
| Burn injury | 1 (3.70) | 0 (0) | 1 (3.70) |
| Underlying diseases[b], n (%) | | | |
| Allergic dermatitis | 6 (22.22) | 2 (7.41) | 4 (14.81) |
| Diabetes mellitus | 3 (11.1) | 1 (3.70) | 2 (7.41) |
| Hyperadrenocorticism | 1 (3.70) | 0 (0) | 1 (3.70) |
| Hypothyroidism | 1 (3.70) | 1 (3.70) | 0 (0) |
| Neoplastic diseases | 3 (11.11) | 3[c] (11.1) | 0 (0) |
| Presence of secondary bacterial infection, n (%) | 15 (55.56) | 6 (22.22) | 9 (7.41) |

SD = Standard Deviation

a = Nocardiosis and dermatophytosis, respectively

b = One patient had allergic dermatitis, diabetes mellitus, and hypothyroidism together. Another patient had allergic dermatitis and hyperadrenocorticism together.

c = Unknown origin of adenocarcinoma, history of mast cell tumor and soft tissue sarcoma, respectively.

**Table 5. Treatment outcomes**

| | All wounds (N = 27) | Acute wounds (N = 13) | Chronic wounds (N = 14) |
|---|---|---|---|
| Complete wound closure, n (%) | | | |
| Total | 22 (81.48) | 11 (40.74) | 11 (40.74) |
| Before 5 weeks of the CAMP therapy | 20 (74.07) | 11 (40.74) | 9 (33.33) |
| Duration of CAMP therapy until closure, weeks | | | |
| mean ± SD | 2.55 ± 1.37 | 2.00 ± 1.00 | 3.09 ± 1.51 |
| median (range) | 2.00 (1.00 – 6.00) | 2.00 (1.00 – 4.00) | 3.00 (1.00 – 6.00) |
| Number of CAMP therapy until closure, n | | | |
| mean ± SD | 5.95 ± 2.84 | 5.27 ± 2.15 | 6.64 ± 3.35 |
| median (range) | 6.00 (2.00 – 12.00) | 6.00 (2.00 – 9.00) | 6.00 (3.00 – 12.00) |
| Frequency of CAMP therapy until closure, n per week | | | |
| mean ± SD | 2.50 ± 0.74 | 2.81 ± 0.87 | 2.18 ± 0.40 |
| median (range) | 2.00 (2.00 – 5.00) | 2.00 (2.00 – 5.00) | 2.00 (2.00 – 3.00) |

CAMP = Cold Atmospheric Microwave Plasma, SD = Standard Deviation

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국문초록

# 개와 고양이에서 창상 치유를 위한 보조요법으로서 저온 대기 마이크로파 플라즈마의 적용

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Cold atmospheric microwave plasma (CAMP, 저온 대기 마이크로파 플라즈마)는 창상 치유에 있어 획기적인 치료법이다. 하지만 수의학에서는 효용성에 대해 잘 알려져 있지 않다.

이 논문은 개와 고양이의 창상 치료에서 CAMP를 보조적 요법으로 이용함으로써 그 효과와 안정성에 대하여 조사하는 것을 목적으로 하였

다. 창상 치유 효과는 우선 표준 창상 관리 기법으로 치료 받은 뒤 (pre-CAMP 기간) 그 다음 CAMP로 치료 받은 (CAMP 기간) 반려견과 반려묘의 의료 기록을 이용하여 회고적으로 분석되었다. 창상 치유의 정도는 창상 크기와 창상 점수화 시스템을 기반으로 하여 측정되었다.

급성 또는 만성의 창상을 지닌 반려견과 반려묘 총 27마리 중 81.48%가 표준 치료법에 보조적으로 CAMP를 적용한 이후 완전하게 치유되었으며. 그 중 대부분이 5주 이내로 회복되었다. 'pre-CAMP 기간' 과 비교할 때, 'CAMP 기간' 의 각 주마다 창상 치유 속도는 유의적으로 증가하였다. 경미한 불편감이나 일시적인 발적을 제외한 다른 부작용은 관찰되지 않았다.

결론적으로, CAMP는 소동물 임상에서 마주할 수 있는 다양한 병인의 창상을 치료하는 데 효과적인 치료법이 될 수 있음을 시사한다. 향후 연구를 통하여 각기 다른 창상의 특성에 따라 구체적인 치료 기준의 설립이 필요할 것으로 보인다.

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**주요어**: 저온 대기 마이크로파 플라즈마, 창상 치유, 소동물 임상
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