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# Effects of silver sulfadiazine on wound healing in a diabetic rat model: A combined macroscopic and infrared thermographic assessment

## Efectos de la sulfadiazina de plata en la cicatrización de heridas en un modelo de rata diabética: una evaluación combinada macroscópica y termográfica por infrarrojos

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### ABSTRACT

Infrared thermography (IRT) provides a non-invasive method for monitoring wound healing through local temperature changes. This study investigated the potential of IRT for non-invasive monitoring of wound healing in a diabetic rat model, using silver sulfadiazine (SSD)–treated and control wounds as comparative groups. Sixteen male Wistar albino rats were randomly allocated into two groups: a control (CNT) group and an SSD-treated group (n = 8). Experimental diabetes was induced by intraperitoneal administration of streptozotocin (65 mg·kg$^{-1}$). After 1.5×1.5 cm full-thickness excisional wounds on the dorsal surface, topical normal saline was administered to the CNT group, whereas the SSD group received topical silver sulfadiazine treatment. Wound area and thermographic measurements (intra-wound, wound-edge, and normal skin temperatures) were assessed on days 0, 3, 7, and 14, and thermographic images were analyzed using Trotec IC-IR Report software. At days 7 and 14, intra-wound and wound-edge temperatures were lower in the SSD group than in the CNT group, whereas normal skin temperature was higher in the SSD group on day 14. However, the overall group × time interactions were not statistically significant. Wound area decreased significantly over time ($P$<0.001), with numerically smaller wound areas in the SSD group at days 7 and 14; however, the group × time interaction was not statistically significant ($P$=0.105). In conclusion, IRT provided a useful, non-invasive approach for monitoring wound healing through local temperature changes in a diabetic wound model, while SSD was associated with numerically smaller wound areas and lower local temperatures during later healing.

**Key words:** Infrared thermography; wound healing; diabetic; silver sulfadiazine; rat

### RESUMEN

La termografía infrarroja (IRT) ofrece un método no invasivo para monitorizar la cicatrización de las heridas a través de los cambios de temperatura locales. Este estudio investigó el potencial de la IRT para la monitorización no invasiva de la cicatrización de heridas en un modelo de rata diabética, utilizando como grupos comparativos heridas tratadas con sulfadiazina de plata (SSD) y heridas de control. Se distribuyeron aleatoriamente dieciséis ratas Wistar albinas macho en dos grupos: un grupo de control (CNT) y un grupo tratado con SSD (n = 8). Se indujo la diabetes experimental mediante la administración intraperitoneal de estreptozotocina (65 mg·kg$^{-1}$). Tras crear heridas por escisión de espesor total de 1,5×1,5 cm en la superficie dorsal, se administró solución salina normal por vía tópica al grupo CNT, mientras que el grupo SSD recibió tratamiento tópico con sulfadiazina de plata. Se evaluaron el área de la herida y las mediciones termográficas (temperaturas intraherida, en los bordes de la herida y de la piel sana) los días 0, 3, 7 y 14, y las imágenes termográficas se analizaron con el software Trotec IC-IR Report. En los días 7 y 14, las temperaturas intra-herida y en los bordes de la herida fueron más bajas en el grupo SSD que en el grupo CNT, mientras que la temperatura de la piel sana fue más alta en el grupo SSD el día 14. Sin embargo, las interacciones generales entre grupo y tiempo no fueron estadísticamente significativas. El área de la herida disminuyó significativamente con el tiempo ($P$<0,001), con áreas de herida numéricamente menores en el grupo SSD en los días 7 y 14; sin embargo, la interacción grupo × tiempo no fue estadísticamente significativa ($P$ = 0,105). En conclusión, la IRT proporcionó un método útil y no invasivo para monitorizar la cicatrización de las heridas a través de los cambios de temperatura local en un modelo de herida diabética, mientras que la SSD se asoció con áreas de herida numéricamente más pequeñas y temperaturas locales más bajas durante las fases posteriores de la cicatrización.

**Palabras clave:** Termografía infrarroja; cicatrización de heridas; diabético; sulfadiazina argéntica; rata

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## INTRODUCTION

Wound healing represents a multifactorial biological process through inflammatory, proliferative, and remodeling phases [1]. During this process, numerous mechanisms including cellular proliferation, angiogenesis, collagen synthesis, and tissue reorganization occur simultaneously [2].

However, systemic diseases such as diabetes, as well as factors like increased oxidative stress and prolonged inflammation, significantly delay wound healing [1, 2]. Diabetic wounds are among the most challenging conditions in wound management because healing is often delayed and the risk of infection is considerably increased [3]. Therefore, infection control and maintenance of an appropriate wound-healing environment are important for proper tissue repair [3, 4]. Silver sulfadiazine has long been used as a topical cream because of its broad-spectrum activity against many types of bacteria [3, 4].

Because of this effect on the wound site, it helps create an environment conducive to healing and is therefore frequently used in wound care [3, 4, 5]. Apart from its antimicrobial effects, previous studies have suggested that SSD may influence processes involved in tissue repair [6, 7].

Most studies consider macroscopic parameters at the final stage of the process, such as wound size, contraction of wound edges, and overall appearance of the tissue [8, 9, 10]. However, these may not truly represent the physiological activity taking place within the tissue, particularly during the earlier stages of repair.

This has led to increasing interest in non-invasive methods that provide more objective assessments. Infrared thermography (IRT) is a non–contact technique that detects infrared radiation emitted by the skin and converts it into temperature measurements [11]. It provides functional information by detecting slight surface temperature variations that may be related to changes in blood flow and local tissue activity [11, 12].

Thermography may help in the early evaluation of wound healing and response to treatment because changes in skin surface temperature may precede visible clinical signs [12, 13, 14].

Given its ability to detect local temperature changes, IRT has been proposed as a non-invasive method for assessing wound-related changes [11, 12]. The development of portable, high-resolution devices has facilitated the use of IRT in experimental models and clinical practice [12]. Infrared thermography has been increasingly used as a non-invasive and quantitative method for wound assessment and monitoring, and its application has been reported in different types of wounds, including diabetic foot ulcers [12, 13].

Previous studies have mainly examined local temperature changes in relation to wound status, tissue perfusion, and healing progression [12, 13, 14, 15]. However, the use of IRT for longitudinal monitoring of temperature changes during diabetic wound healing has received less attention, particularly when thermographic findings are evaluated alongside conventional macroscopic measurements of wound closure [12, 15].

Moreover, changes in temperature distribution within the wound, at the wound edge, and in the surrounding normal skin throughout the healing process have not been sufficiently characterized in diabetic wound models [15].

Therefore, this study aimed to investigate the potential of infrared thermography as a non-invasive method for monitoring wound healing in a diabetic wound model, using SSD-treated and control wounds as comparison groups.

## MATERIALS AND METHODS

### Experimental animals and design

In the study, 16 male Wistar albino rats (*Rattus norvegicus*) were divided into two groups, with 8 rats in each group. All experimental procedures were approved by the Local Animal Experimentation Ethics Committee of Hatay Mustafa Kemal University (Approval No. 2026/05–07). During the study, the animals were housed individually under standardized laboratory conditions (22–24°C, 50–60% relative humidity, and a 12 h light/dark cycle) with unrestricted access to food and water.

Streptozotocin (STZ) was used to induce experimental diabetes. Before diabetes induction, the rats were fasted for 12 h. Freshly prepared STZ solution (Focus Biomolecules, Cat. No. 10–2127, PA, USA) was dissolved in citrate buffer (0.1 M, pH 4.5; CAS No. 6132–04–3, ISOLAB Laborgeräte GmbH, Eschau, Germany) and administered intraperitoneally at a dose of 65 $mg \cdot kg^{-1}$ body weight. To prevent hypoglycemic deaths, 5% dextrose solution was added to the drinking water for 48 h. Blood glucose concentrations were assessed on day 3 following STZ administration using tail-vein blood samples and a glucometer (Accu-Chek, Germany). Rats showing glucose values higher than 300 $mg \cdot dL^{-1}$ (16.7 $mmol \cdot L^{-1}$) were considered diabetic.

### Surgical procedure

All surgical procedures during the experimental protocols were performed under appropriate anesthesia. General anesthesia was induced using a combination of Ketamine hydrochloride (Keta-control Doğa İlaç, Türkiye) (60 $mg \cdot kg^{-1}$, i.p.) and Xylazine hydrochloride (Sanalazin, Santavet, Türkiye) (10 $mg \cdot kg^{-1}$, i.p.). The dorsal scapular region was shaved and disinfected with povidone-iodine (Batticon, Adeka, Türkiye). A 1.5×1.5 cm full-thickness excisional wound was then created.

The sixteen rats were randomly allocated into two experimental groups, with eight animals assigned to the control group (CNT) and eight to the silver sulfadiazine-treated group (SSD). In the CNT group, normal saline was applied topically twice daily after the wound was made. The SSD group received topical silver sulfadiazine (Silverdin 1%, Deva, Türkiye) twice daily following wound creation. At each application, a thin and uniform layer of the cream was applied to completely cover the wound surface.

For the purpose of macroscopic evaluation, photographs of the wound sites of all animals were taken on day (d) 0, 3, 7, and 14 following wound creation, and the wound areas were calculated using the ImageJx2 software. Thermographic assessments were

performed on days 0, 3, 7, and 14 using an IRT device (Trotec EC 060 V, Heinsberg, Germany), a non-invasive method.

All thermographic recordings were obtained from a distance of 0.5 m at a perpendicular angle under stable room conditions and at the same time of day throughout the study. The emissivity was set to 0.95, in accordance with previously reported infrared thermography protocols in rats [16].

All measurements were performed in the same room in which the animals were maintained, without transferring them to another environment, thereby minimizing potential temperature changes associated with transportation or environmental transitions. Macroscopic wound measurements and thermographic assessments were performed by a veterinarian specializing in veterinary surgery who was blinded to treatment allocation.

For thermographic evaluation, minimum and maximum temperature values were determined using Trotec IC-IR Report software in three separate regions: the intra-wound, wound-edge, and normal skin. This method was applied similarly to the present study [9]. Representative thermographic images are shown in FIGS. 1 and 2.

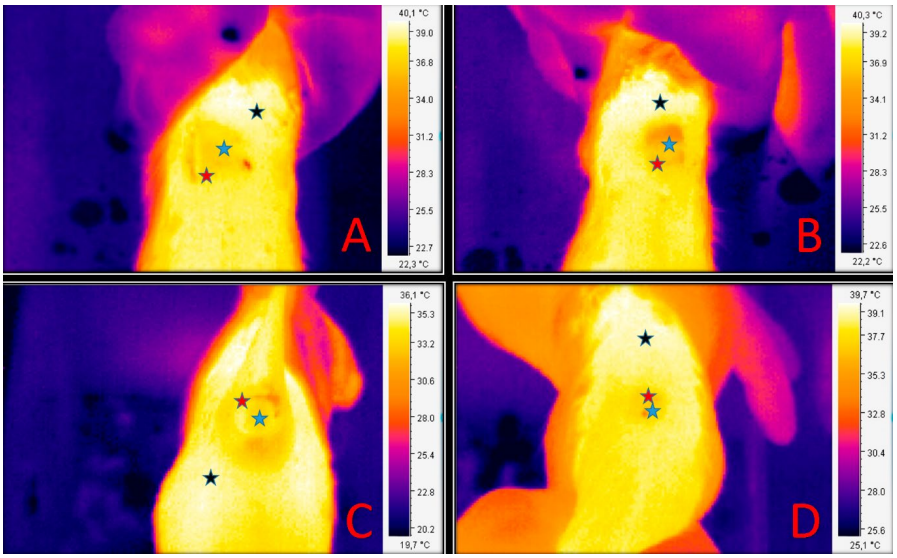



**FIGURE 1. Thermographic measurements of Group CNT at different study days. (A) Representative thermogram obtained on Day 0, (B) day 3, (C) day 7 and (D) day 14 showing infrared thermography (IRT) local temperature measurements from the intra-wound area (blue star), wound-edge (red star), and normal skin region (black star)**

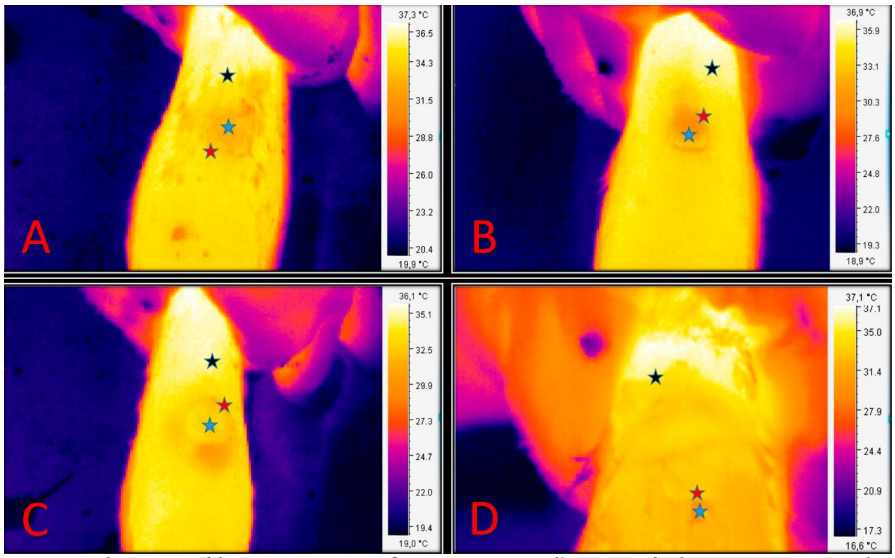



**FIGURE 2. Thermographic measurements of Group SSD according to study days. (A) Representative thermogram obtained on Day 0, (B) day 3, (C) day 7 and (D) day 14 showing infrared thermography (IRT) local temperature measurements from the intra-wound area (blue star), wound-edge (red star), and normal skin region (black star)**

### Statistical analysis

G* Power test software version 3.1.9.4 (Heinrich Heine University Düsseldorf, Germany) was used for the sample size calculation. Based on an effect size of 0.32, an alpha level of 0.05, and a statistical power of 0.80. All data were expressed as mean ± SEM. Normality was assessed using the Shapiro-Wilk test. Data were analyzed to investigate the treatment group, time period, and group x time interaction effects on all outcomes using a two-way repeated measures ANOVA.

In addition, one-way ANOVA was used to compare the groups at each individual time point. Statistical significance was set at $P<0.05$. All statistical analyses were conducted using SPSS version 26 (IBM Corp., Armonk, NY, USA).

## RESULTS AND DISCUSSION

Wound area was measured on d 0, 3, 7, and 14 in the CNT and SSD groups, and the data are presented as mean ± SEM (TABLE I). The repeated-measures ANOVA showed a significant effect of time ($P<0.001$), whereas the main effect of group ($P=0.277$) and the time × group interaction ($P=0.105$) were not significant. Macroscopic images of the wound areas are shown in FIG. 3.

*TABLE I*
**Comparison of wound area between SSD and CNT groups across different time points (mean ± SEM)**

| Parameter | Time | SSD (Mean ± SEM) | CNT (Mean ± SEM) | Time (*P*) | Group (*P*) | Time × Group (*P*) |
|---|---|---|---|---|---|---|
| Wound Area | Day 0 | 2.19 ± 0.06 | 2.15 ± 0.02 | <0.001 | 0.277 | 0.105 |
| | Day 3 | 1.59 ± 0.03 | 1.78 ± 0.12 | | | |
| | Day 7 | 1.06 ± 0.04 | 1.19 ± 0.13 | | | |
| | Day 14 | 0.51 ± 0.04 | 0.63 ± 0.04 | | | |

Note: CNT: control group; SSD: silver sulfadiazine-treated group.

Thermographic measurements of intra-wound, wound-edge, and normal skin temperatures in the SSD and CNT groups are presented in TABLE II.

At baseline (d 0), the groups did not differ significantly with respect to intra-wound, wound-edge, or normal skin temperature ($P>0.05$). Similarly, on d 3, no significant difference was observed between the SSD and CNT groups in any of the measured regions ($P>0.05$).

On d 7, while intra-wound and wound-edge temperatures in the SSD group were significantly lower than those in the CNT group ($P<0.05$), no statistically significant difference was detected in normal skin temperature ($P>0.05$).

On d 14, intra-wound and wound-edge temperatures in the SSD group were significantly lower than those in the CNT group ($P<0.01$). Additionally, a statistically significant difference was observed between the groups in terms of normal skin temperature ($P<0.05$). Across the study period, a significant main effect of time was observed for intra-wound, wound-edge, and normal skin temperatures (all $P<0.001$). However, neither the main effect of group nor the time × group interaction was statistically significant for any thermographic parameter (all $P>0.05$).

Infrared thermography is an important assessment tool widely used today due to its non-contact mechanism and the absence of side effects when measuring surface temperature in tissues [12, 15]. It is typically utilized as a thermometer to determine body temperature and to help determine potential local inflammatory changes in peripheral tissues [17]. IRT may also provide information about physiological or pathological tissue changes that are not yet accompanied by overt clinical signs [11].

Fridberg *et al.* (2024) demonstrated the clinical relevance of thermography for wound assessment by identifying areas of inflammation and differentiating pathological conditions, such as infection, from normal healing [14].

*TABLE II*
**Comparison of thermographic measurements between SSD and CNT groups across different time points (mean ± SEM)**

| Parameter | Time | SSD (Mean ± SEM) | CNT (Mean ± SEM) | Day-specific (*P*) | Overall Time (*P*) | Overall Group (*P*) | Overall Time × Group (*P*) |
|---|---|---|---|---|---|---|---|
| Intra-wound | Day 0 | 35.93 ± 0.17 | 36.09 ± 0.16 | 0.18 | <0.001 | 0.138 | 0.114 |
| | Day 3 | 35.60 ± 0.19 | 35.80 ± 0.16 | 0.09 | | | |
| | Day 7 | 35.13 ± 0.19 | 35.40 ± 0.16 | 0.04* | | | |
| | Day 14 | 34.10 ± 0.27 | 34.93 ± 0.26 | 0.002** | | | |
| Wound-edge | Day 0 | 36.43 ± 0.18 | 36.57 ± 0.20 | 0.30 | <0.001 | 0.185 | 0.154 |
| | Day 3 | 36.04 ± 0.17 | 36.18 ± 0.14 | 0.94 | | | |
| | Day 7 | 35.56 ± 0.18 | 35.95 ± 0.20 | 0.03* | | | |
| | Day 14 | 34.25 ± 0.28 | 35.21 ± 0.26 | 0.001** | | | |
| Normal skin | Day 0 | 38.46 ± 0.03 | 38.50 ± 0.11 | 0.65 | <0.001 | 0.586 | 0.086 |
| | Day 3 | 37.65 ± 0.16 | 37.61 ± 0.13 | 0.78 | | | |
| | Day 7 | 36.88 ± 0.13 | 37.05 ± 0.14 | 0.07 | | | |
| | Day 14 | 36.74 ± 0.16 | 36.04 ± 0.36 | 0.04* | | | |

Note: Statistical significance was accepted at *$P<0.05$ and **$P<0.01$. CNT: control group; SSD: silver sulfadiazine-treated group.

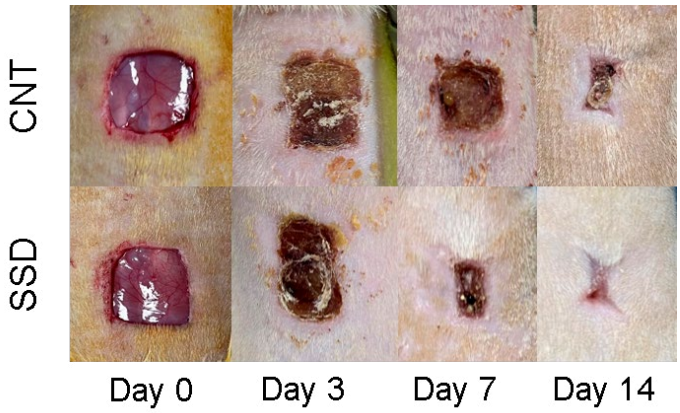



**FIGURE 3. Representative macroscopic images of wound healing in the CNT and SSD groups on days 0, 3, 7, and 14. Wound areas were numerically smaller in the SSD group at later time points. CNT: control group silver, SSD: sulfadiazine-treated group**

It has been stated that since the IRT device measures thermal energy, it is not affected by environmental factors such as daylight, weather conditions, and humidity [17, 18]. However, a recent study indicates that ambient temperature can influence thermography in measurements conducted in enclosed environments [14]. Another study reported that for thermography to yield accurate results, there should be no foreign objects or thick layers of fur on the tissue surface [19].

In the present study, environmental conditions were standardized with an ambient temperature of 22–24°C and humidity of 50–60%. Additionally, all rats were shaved in the wound areas and surrounding regions prior to the procedure, and measurements were taken. These procedures were consistent with those described in previous studies [15, 20].

Since wound healing reflects the balance between wound closure, inflammation, tissue regeneration, and remodeling processes, it is one of the most important parameters used to assess the course of healing [20, 21, 22, 23].

Wound area decreased significantly over time in both groups (time effect, $P<0.001$). Although the SSD group showed numerically smaller wound areas at days 7 and 14, the overall group effect ($P = 0.277$) and group × time interaction ($P = 0.105$) were not statistically significant.

The numerical differences in wound area between the groups became more apparent at later time points; however, these differences should be interpreted cautiously because the overall group × time interaction was not statistically significant. Similar results have been reported in previous studies, indicating that topical antimicrobial agents accelerate wound contraction, particularly during the proliferative phase [4, 20, 24, 25, 26].

Previous studies on SSD have suggested that its antimicrobial activity may help limit prolonged inflammation and create a favorable environment for wound healing by reducing bacterial burden [4, 7]. Furthermore, these studies have suggested that SSD may support fibroblast activity, collagen deposition, and re-epithelialization during the healing process [5, 6]. In this study, the SSD-treated wounds were smaller and showed lower intra-wound and wound-edge temperatures at the later time points.

These findings may be related to the effects previously reported for SSD, although the underlying mechanisms were not directly examined in this study. Thermography can detect local temperature changes during wound healing without direct contact with the tissue [11, 12]. Changes in local temperature may reflect differences in tissue perfusion and physiological activity within the wound [12]. Local temperature changes during wound healing may provide indirect information about changes in tissue perfusion and the local healing environment [15].

In a previous study investigating wound inflammation using thermographic measurements, changes in thermographic temperature were associated with the progression of wound inflammation [27]. The SSD group was associated with lower local temperatures at both the intra-wound and wound-edge regions on days 7 and 14, which may be associated with the later stages of wound healing.

Similar studies have also shown that healing models are associated with lower local temperatures at the later stages of healing, when an effective therapeutic intervention has been administered [13, 27].

The temperature differences between the intra-wound and wound-edge regions and the surrounding normal skin may reflect spatial differences in the local physiological processes occurring during wound healing. This finding is consistent with previous observations of temperature variation across different regions of healing wounds [15].

On d 14, normal skin temperature also differed significantly between the SSD and CNT groups ($P<0.05$). This finding suggests that the thermographic differences associated with SSD treatment may extend beyond the wound region into the surrounding skin. However, thermographic changes should be interpreted as indirect indicators of local physiological changes rather than as direct evidence of specific biological mechanisms.

Therefore, the observed improvement in wound closure and the accompanying thermographic changes may be particularly relevant in diabetic wound models, where delayed healing and impaired microcirculation are commonly reported.

This study has some limitations. First, biochemical inflammation markers and oxidative stress parameters were not evaluated. Consequently, the molecular mechanisms underlying the thermographic findings could not be fully elucidated. Additionally, the absence of histopathological evaluation limits a detailed analysis of the healing process at the tissue level. In future studies, the combined evaluation of thermography with histological and biochemical analyses will provide more comprehensive results.

## CONCLUSIONS

This study suggests that SSD treatment was associated with numerically smaller wound areas and lower local temperatures at later stages of healing in a diabetic rat wound model. Infrared

thermography may provide a useful, non-invasive approach for monitoring local temperature changes during wound healing

**Author's contributions**

OK and CTI designed the study. OK and CTI conducted the experimental study and OK performed the thermographic recordings. Both authors revised and approved the final version of manuscript.

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**Conflict of interests**

The authors declare that they have no conflict of interest.

## BIBLIOGRAPHIC REFERENCES

[1] Han G, Ceilley R. Chronic wound healing: a review of current management and treatments. Adv. Ther. [Internet]. 2017; 34(3):599–610. doi: https://doi.org/f92rm8

[2] Brem H, Tomic-Canic M. Cellular and molecular basis of wound healing in diabetes. J. Clin. Invest. [Internet]. 2007; 117(5):1219–1222. doi: https://doi.org/d963xh

[3] Tarameshloo M, Norouzian M, Zarein-Dolab S, Dadpay M, Gazor R. A comparative study of the effects of topical application of *Aloe vera*, thyroid hormone and silver sulfadiazine on skin wounds in Wistar rats. Lab. Anim. Res. [Internet]. 2012; 28(1):17–21. doi: https://doi.org/rtf5

[4] Kumandaş A, Karslı B, Kürüm A, Çınar M, Elma E. Comparison of the effects of zinc-silver cream and *Nigella sativa* oil on wound healing and oxidative stress in the wound model in rats. Ank. Univ. Vet. Fak. Derg. [Internet]. 2020; 67(1):33–40. doi: https://doi.org/rtf4

[5] Atiyeh BS, Costagliola M, Hayek SN, Dibo SA. Effect of silver on burn wound infection control and healing: review of the literature. Burns [Internet]. 2007; 33(2):139–148. doi: https://doi.org/drgsx4

[6] Rigo C, Ferroni L, Tocco I, Roman M, Munivrana I, Gardin C, Cairns WRL, Vindigni V, Azzena B, Barbante C, Zavan B. Active silver nanoparticles for wound healing. Int. J. Mol. Sci. [Internet]. 2013; 14(3):4817–4840. doi: https://doi.org/f4nw8t

[7] Pekşen M, Kurt A, Soylu S, Tuzcu M, Bostancı M, Mollaoğlu M, Akabay U, Şen M. Comparison of the healing effects of silver sulfadiazine cream 1% and the essential oil of *Hypericum perforatum* on scald burn wound in a rat model. Basic Clin. Sci. [Internet]. 2014; 3(1):1–8. doi: https://doi.org/rtf3

[8] Assar DH, Elhabashi N, Mokhbatly AA, Ragab AE, Elbialy ZI, Rizk SA, Albalawi AE, Althobaiti NA, Al Jaouni S, Atiba A. Wound healing potential of licorice extract in rat model: antioxidants, histopathological, immunohistochemical and gene expression evidences. Biomed. Pharmacother. [Internet]. 2021; 143:112151. doi: https://doi.org/gtqhdn

[9] Chinko BC, Precious-Abraham AD. Wound healing activity of hydromethanolic *Dioscorea bulbifera* extract on male Wistar rat excision wound models. Pharmacol. Res. Mod. Chin. Med. [Internet]. 2024; 11:100425. doi: https://doi.org/rtf2

[10] Andjić M, Draginić N, Kočović A, Jeremić J, Vučićević K, Jeremić N, Krstonošić VS, Božin B, Kladar VD, Čapo I, Andrijević L, Pecarski D, Bolevich SB, Jakovljevic VL, Bradić J. Immortelle essential oil-based ointment improves wound healing in a diabetic rat model. Biomed. Pharmacother. [Internet]. 2022; 150:112941. doi: https://doi.org/rtfz

[11] Turner TA. Diagnostic thermography. Vet. Clin. North Am. Equine Pract. [Internet]. 2001; 17(1):95–111. doi: https://doi.org/rtfx

[12] Rahman S, Ogilvie T, Okonski D, Ramsay K, Geng R, Tesarek J, Swoboda L, Fraser RD. A comprehensive scoping review on the use of point-of-care infrared thermography devices for assessing various wound types. Int. Wound J. [Internet]. 2025; 22(8):e70741. doi: https://doi.org/rtfw

[13] Ramirez-GarciaLuna JL, Bartlett R, Arriaga-Caballero JE, Fraser RD, Saiko G. Infrared thermography in wound care, surgery, and sports medicine: a review. Front. Physiol. [Internet]. 2022; 13:838528. doi: https://doi.org/gtv2wg

[14] Fridberg M, Bafor A, Iobst CA, Laugesen B, Jepsen JF, Rahbek O, Kold S. The role of thermography in assessment of wounds: a scoping review. Injury [Internet]. 2024; 55(11):111833. doi: https://doi.org/rtfv

[15] Deveci MZY, İşler CT, Kırgız Ö. Investigation of wound healing by infrared thermography in a full-thickness skin wound model in rats. J. Appl. Biol. Sci. [Internet]. 2022; 16(3):493–502. doi: https://doi.org/rtft

[16] Domínguez-Oliva A, Hernández–Ávalos I, Olmos-Hernández A, Villegas-Juache J, Verduzco-Mendoza A, Mota-Rojas D. Thermal response of laboratory rats (*Rattus norvegicus*) during the application of six methods of euthanasia assessed by infrared thermography. Animals [Internet]. 2023; 13(18):2820. doi: https://doi.org/rtfs

[17] Mota-Rojas D, Ogi A, Villanueva-García D, Hernández–Ávalos I, Casas-Alvarado A, Domínguez-Oliva A, Lendez P, Ghezzi M. Thermal imaging as a method to indirectly assess peripheral vascular integrity and tissue viability in veterinary medicine: animal models and clinical applications. Animals [Internet]. 2023; 14(1):142. doi: https://doi.org/rtfr

[18] Eddy AL, Van Hoogmoed LM, Snyder JR. The role of thermography in the management of equine lameness. Vet. J. [Internet]. 2001; 162(3):172–181. doi: https://doi.org/cv8fgw

[19] Ludwig N, Gargano M, Luzi F, Carenzi C, Verga M. Applicability of infrared thermography as a non invasive measurements of stress in rabbit. World Rabbit Sci. [Internet]. 2007; 15(4):199–206. doi: https://doi.org/ghx5wn

[20] Temel-Soylu TM, Kececiler-Emir C, Rababah T, Ozel C, Yucel S, Basaran-Elalmis Y, Altan D, Kirgiz O, Secinti İE, Kaya U, Altug ME. Green electrospun poly (vinyl alcohol) /gelatin-based nanofibrous membrane by incorporating 45S5 bioglass nanoparticles and urea for wound dressing applications:

characterization and *in vitro* and *in vivo* evaluations. ACS Omega [Internet]. 2024; 9(19):21187–21203. doi: https://doi.org/rtfq

[21] Kırgız Ö, Altuğ ME, Özkan H, Han MC, Akçakavak G, Özarslan AC, Yücel S. 45S5 bioactive glass-ointment positively effects on wound healing in rats by regulating TNFα, IL–10, VEGF, and TGFβ. J. Clin. Lab. Anal. [Internet]. 2024; 38(17–18):e25094. doi: https://doi.org/rtfp

[22] Deveci MZY, Kırgız Ö, Özkan H, İşler CT, Akçakavak FK, Yurtal Z, Yakan A. Wound healing activities of eucalyptol on full thickness excisional skin wound model in rats. Ank. Univ. Vet. Fak. Derg. [Internet]. 2026; 73(1):83–92. doi: https://doi.org/rtfn

[23] Kang X, Guan P, Xiao C, Liu C, Guan Y, Lin Y, Tian Y, Ren K, Huang Y, Fu R, Ning C, Fan L, Tan G, Zhou L. Injectable intrinsic photothermal hydrogel bioadhesive with on-demand removability for wound closure and MRSA-infected wound healing. Adv. Healthc. Mater. [Internet]. 2023; 12(13):e2300067. doi: https://doi.org/rtfm

[24] Serarslan G, Altuğ E, Kontas T, Atik E, Avci G. Caffeic acid phenethyl ester accelerates cutaneous wound healing in a rat model and decreases oxidative stress. Clin. Exp. Dermatol. [Internet]. 2007; 32(6):709–715. doi: https://doi.org/bgdvd4

[25] Całkosiński I, Dobrzyński M, Rosińczuk J, Dudek K, Chrószcz A, Fita K, Dymarek R. The use of infrared thermography as a rapid, quantitative, and noninvasive method for evaluation of inflammation response in different anatomical regions of rats. Biomed. Res. Int. [Internet]. 2015; 2015:972535. doi: https://doi.org/gb58dh

[26] Kırgız Ö, Kırgız FC, Akçakavak G, Alakuş İ, Karataş Ö, Alakuş H, Gökçek İ, Bayraktar HS, Ceylan E, Akçakavak Kazak F. Topical eucalyptol accelerates the healing of MRSA-infected diabetic wounds in rats by regulating TLR4, NF–κB, VEGFA and MMP–9 pathways. Tissue Cell [Internet]. 2026; 102:103602. doi: https://doi.org/rtfk

[27] de Souza PB, de Cerqueira CBS, Costa LMDS, Leite MMP, Marchionni AMT, de Lima Dantas JB, Medrado ARAP. Evaluation of thermal variation of skin wounds in rats subjected to biomodulatory therapies. Thermol. Int. [Internet]. 2024; 34(1):5–14. Available in: https://n9.cl/8t4hlf