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Evaluation of the therapeutic effect of Algerian propolis ointment on burn wounds in rabbits

Evaluación del efecto terapéutico de una pomada a base de propóleos argelinos sobre heridas por quemaduras en conejos

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ABSTRACT

This study evaluates the therapeutic efficacy of Algerian propolis in the treatment of superficial second–degree burns, combining both *in vitro* antibacterial assays and *in vivo* wound healing experiments. The *in vitro* tests revealed that while silver sulfadiazine showed superior antibacterial activity against *Staphylococcus aureus*, the propolis sample P2 exhibited a significant inhibitory effect (19.35 ± 2.29 mm). This variability in antimicrobial action among propolis samples may be attributed to differences in chemical composition, reflecting the botanical diversity of their origin. In the *in vivo* model, topical application of propolis demonstrated markedly better healing outcomes compared to both silver sulfadiazine and the untreated control. All groups started with identical burn severity on day (d) 1 (healing score = 5). From d 20 onward, the propolis group showed significantly faster tissue regeneration, with a complete wound closure (score = 0) achieved by d 25. In contrast, the silver sulfadiazine group reached only 84.5% contraction by d 33, and the control group showed incomplete healing (up to 88.3%). Mean cumulative healing scores further supported the superior performance of propolis (2.79 ± 1.44), compared to silver sulfadiazine (3.70 ± 1.16) and the control (3.74 ± 0.68). Additionally, early hair regrowth was observed in the propolis–treated animals, suggesting enhanced skin regeneration. Importantly, no disruption in body temperature regulation was observed in any of the groups, indicating the safety of propolis use. In conclusion, Algerian propolis exhibits both moderate antibacterial activity and excellent wound healing properties, promoting rapid and complete skin regeneration. Its natural origin, ease of application, and regenerative capacity make it a promising alternative for the management of superficial burns. Further studies are recommended to investigate the mechanisms involved and to optimize its formulation for clinical use.

Key words: Algerian propolis; burn; wound healing; silver sulfadiazine; skin regeneration; *in vivo* model

RESUMEN

Este estudio evalúa la eficacia terapéutica del propóleo argelino en el tratamiento de quemaduras superficiales de segundo grado, combinando ensayos antibacterianos *in vitro* y experimentos de cicatrización *in vivo*. Las pruebas *in vitro* revelaron que, aunque la sulfadiazina de plata mostró una actividad antibacteriana superior contra *Staphylococcus aureus*, la muestra de propóleos P2 presentó un efecto inhibidor significativo (19,35 ± 2,29 mm). Esta variabilidad en la acción antimicrobiana entre las muestras de propóleos podría atribuirse a diferencias en la composición química, reflejo de la diversidad botánica de su origen. En el modelo *in vivo*, la aplicación tópica de propóleos demostró resultados de cicatrización notablemente mejores en comparación con la sulfadiazina de plata y el grupo control no tratado. Todos los grupos comenzaron con una severidad de quemadura idéntica el día (d) 1 (puntuación de cicatrización = 5). A partir del d 20, el grupo tratado con propóleos mostró una regeneración tisular significativamente más rápida, con cierre completo de la herida (puntuación = 0) logrado al d 25. En cambio, el grupo tratado con sulfadiazina alcanzó solo un 84,5% de contracción al d 33, y el grupo control mostró una cicatrización incompleta (hasta un 88,3%). Las puntuaciones medias acumuladas de cicatrización respaldaron aún más el mejor desempeño del propóleos (2,79 ± 1,44), en comparación con la sulfadiazina (3,70 ± 1,16) y el control (3,74 ± 0,68). Además, se observó un crecimiento precoz del pelo en los animales tratados con propóleos, lo que sugiere una mejor regeneración cutánea. Es importante destacar que no se observó alteración de la regulación de la temperatura corporal en ninguno de los grupos, lo que indica la seguridad del uso del propóleos. En conclusión, el propóleos argelino muestra tanto una actividad antibacteriana moderada como excelentes propiedades cicatrizantes, favoreciendo una regeneración cutánea rápida y completa. Su origen natural, facilidad de aplicación y capacidad regenerativa lo posicionan como una alternativa prometedora para el tratamiento de quemaduras superficiales. Se recomiendan estudios adicionales para investigar los mecanismos implicados y optimizar su formulación para uso clínico.

Palabras clave: Propóleos argelinos; quemadura; cicatrización de heridas; sulfadiazina de plata; regeneración cutánea; modelo *in vivo*

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INTRODUCTION

As the body's largest organ, the skin plays a crucial role in shielding internal structures from environmental insults. Its constant exposure to external conditions makes it highly vulnerable to diverse forms of injury, especially thermal burns [1]. Burns represents a major global public health concern, significantly affecting not only the physiological functions of patients but also their long–term psychological well–being [2].

The regeneration of skin following burn injuries is a complex biological process involving multiple cell populations and molecular signaling pathways regulated by cytokines and growth factors [3].

Burn wound healing typically progresses through three successive phases: an early immune response stage, a tissue regeneration phase, and a maturation phase that leads to scar development [4].

A thorough understanding of the mechanisms regulating these stages could facilitate the development of innovative, more effective, and less invasive treatments that may limit burn progression within the first few hours post–injury [5].

Given the limitations of conventional therapies—such as cost, accessibility, side effects, and microbial resistance—natural remedies are attracting increasing scientific attention. Among these, "bee glue" is a substance produced by *Apis mellifera* from various plant sources. Used since antiquity for its medicinal properties, propolis is widely employed in traditional and alternative medicine for treating skin disorders [6, 7].

The color, odor, and the chemical profile of propolis are influenced by local flora, climate, and geographic location [7, 8]. Pharmacologically, propolis possesses various beneficial properties, with particular interest in its cutaneous wound–healing potential [9]. It contributes to tissue repair by modulating fibronectin expression and promoting collagen formation in burn wounds [10]. Moreover, it stimulates the synthesis of glycosaminoglycans, essential for granulation tissue formation, cellular regeneration, and wound closure [11].

In this context, the investigation of Algerian propolis—derived from a rich and diverse local flora—becomes particularly relevant. Despite its traditional uses, its pharmacological potential in wound healing remains underexplored.

This study seeks to investigate, through both *in vitro* and *in vivo* approaches, the healing efficacy of Algerian propolis on skin burn lesions.

MATERIALS AND METHODS

In vitro study

Quantification of the polyphenolic fraction (polyphenols and flavonoids) in three collected samples

The analysis of the active compounds in the collected samples was performed at the specialized laboratory CARI ASBL, based in Belgium, renowned for its expertise in the analysis of bee products. Three Algerian propolis samples were analyzed. The first sample (P1), collected from the Laghouat region (El Kheneg), showed a total polyphenol concentration of 7.30 mg GAE·g^{-1} and a flavonoid content of 2.00 mg QE·g^{-1}. The second sample (P2), from the Tipaza region, exhibited higher levels, with 35.25 mg GAE·g^{-1} for polyphenols and 15.95 mg QE·g^{-1} for flavonoids. Finally, the third sample (P3), collected in the Souk Ahras region (Bir Bouhouche), showed intermediate values: 19.00 mg GAE·g^{-1} and 6.50 mg QE·g^{-1}, respectively [12].

Extraction procedure for Algerian propolis samples

Propolis extraction was performed at the Biochemistry Laboratory within the Faculty of Sciences of Tiaret. To begin with, the raw samples (P1, P2, and P3) were finely chopped and subjected to maceration. Precisely 15 g of each sample were measured using a high–precision Kern balance (max 120 mg, Germany) and immersed in 150 mL of 70% ethanol. After maceration, the solutions were passed through Whatman No. 1 filter paper to eliminate residues. The clear extracts were then transferred to Petri dishes, and ethanol was gently removed using a drying oven (Heraeus, Germany) set at 45°C. Once dried, the purified propolis was carefully collected and preserved in dark conditions at 4°C (Condor, Algeria) for further use [12, 13, 14].

Bacterial sensitivity testing of propolis extracts using the disc diffusion method

Mueller–Hinton agar was first liquefied using a microwave oven (Samsung GE86V, Malaysia), then distributed into Petri dishes and left to solidify at room temperature. The bacterial suspension was prepared by adjusting the optical density to 0.08–0.13 using a spectrophotometer (Hitachi, Japan), corresponding to the 0.5 McFarland turbidity standard. A volume of 1 mL of *Staphylococcus aureus* (ATCC 6528), obtained from the Microbiology Laboratory of the Faculty of Sciences in Tiaret, was used to inoculate the solidified medium. The plates were then left for 15 minutes to allow uniform pre–diffusion [12, 13].

The antimicrobial assay was carried out at the Laboratory of Animal Hygiene and Pathology, affiliated with the same institution. The sensitivity of *S. aureus* to the ethanolic propolis extracts was evaluated by the standard disc diffusion method on Mueller–Hinton agar. Sterile paper discs (6 mm diameter), previously autoclaved, were impregnated with 100 mg·mL^{-1} of each ethanolic extract (EEPA1, EEPA2, and EEPA3). These were aseptically placed on the inoculated agar alongside control discs: one with Trimethoprim–Sulfadiazine as a positive control, and another impregnated with petroleum jelly as a negative control.

After two hours at room temperature to ensure uniform diffusion of the active compounds, the plates were incubated in an incubator (Germany, Memmert) at 37°C for 24 h. Following incubation, inhibition zone diameters were measured in millimeters using a digital caliper, following the procedures described by Boudra *et al.* and Balouri *et al.* [12, 15].

Bacterial classification based on inhibition zone diameter

In accordance with the criteria defined by Couquet *et al.* [16], bacteria were classified based on the diameter of the inhibition

zone: strains were considered “sensitive” when the diameter exceeded 12 mm, “moderately sensitive” when it ranged between 6 and 11 mm, and “resistant” when it was less than 5 mm.

Preparation of propolis–based ointment (Pharmaceutical form)

1. **Preparation of the oily phase:** The oily phase was prepared using 40 g of pure petroleum jelly as an excipient. It was gently heated until completely liquefied to ensure a uniform base.

2. **Dispersion of the active ingredient:** The active compound, ethanolic extract of propolis (EEP2), prepared at 100 $mg \cdot mL^{-1}$, was incorporated into the melted base in an amount of 1 g. The mixture was thoroughly and homogeneously dispersed under light–protected conditions to preserve the stability and therapeutic efficacy of the final product [13].

***In vivo* study**

Experimental design and animal grouping

The study involved twelve (12) healthy New Zealand White rabbits (*Oryctolagus cuniculus*), each weighing around 3 kg (Microlife, France). Subjects were randomly allocated into three groups of four animals. The first group received treatment with the ethanolic propolis extract (EEPA), while the remaining groups were assigned to control and comparison protocols.

- **Group 1 (PG)** received a topical treatment consisting of the previously prepared ointment, applied to a standardized experimental burn (3 cm in diameter).

- **Group 2 (SDG)** underwent the same burn protocol but was treated with silver sulfadiazine.

- **Group 3 (CG)** served as untreated control and received no therapeutic intervention.

Preoperative preparation and anesthetic protocol

The experimental area was carefully shaved and meticulously cleansed with water and soap, followed by a detergent to effectively eliminate both transient and resident skin flora.

Anesthesia was initiated with premedication consisting of a combination of Acepromazine (0.75 $mg \cdot kg^{-1}$, IM) for tranquilization and Xylazine (2.5 $mg \cdot kg^{-1}$, SC) to provide both perioperative and postoperative analgesia. General anesthesia was then induced using Ketamine, administered intramuscularly at a dose of 35 $mg \cdot kg^{-1}$ [13, 14, 17].

Burn induction procedure

The generation of thermal lesions was performed using a metallic device with a diameter of 3.3 cm, preheated for 5 min. The heated instrument (a metallic valve, Germany) was applied with gentle pressure to the shaved skin of the rabbits for a duration of 20 s to produce the desired thermal injury [18] (FIG. 1).

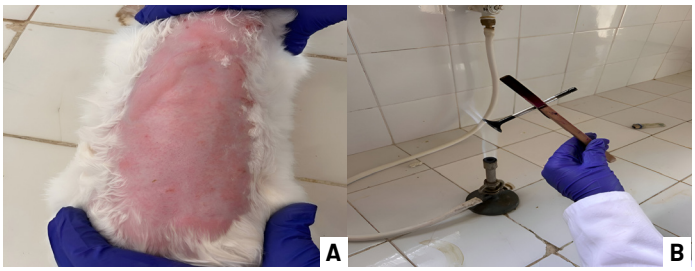

FIGURE 1. A: Preparation of the experimental area by shaving, B: Burn induction

In the first group, a thin film of EEPA–based formulation was gently spread over the burn sites. The second group received a 1% silver sulfadiazine cream applied as a 2 mm–thick layer. No treatment was administered to the control group (CG) (FIG. 2).

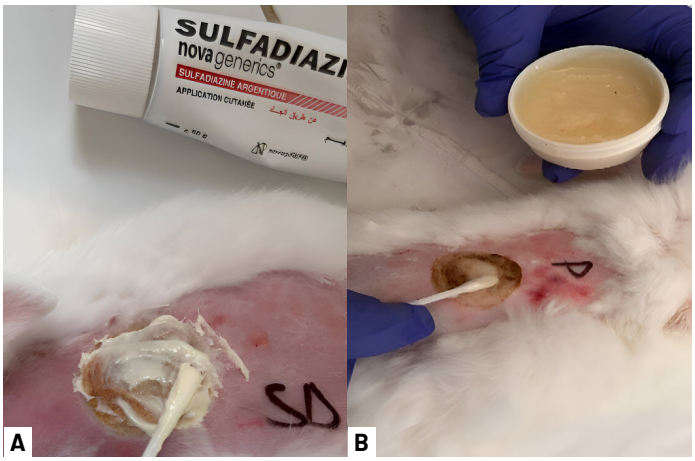

FIGURE 2. Application of specific treatments to the burn areas. A: 1% silver sulfadiazine cream. B: Propolis–based ointment

Clinical monitoring parameters

The burn wounds were protected from any external source of contamination by the application of a dry, sterile dressing, which was changed every 24 h. At each dressing change, a visual inspection of the wound was performed, accompanied by photographic documentation, and continued until complete healing. In parallel, rectal body temperature was measured (Rossmax, China) daily for up to 15 d.

Macroscopic evaluation parameters of burn wounds

The effectiveness of the healing process was assessed daily over a period of 33 d using a customized scoring system that considered the severity of the burn lesions [19]. This system, adapted from Sene *et al.* [18], assigns a score ranging from 0 to 5:

- **Score 0:** Complete healing; tissue repair is fully achieved.

- **Score 1:** Burn wound is nearly healed; minimal residual signs remain.

- ***Score 1.5:** Burn wound is nearly healed, with very small scab remnants or faint signs of incomplete epithelialization.
- **Score 2:** Scab remnants are still visible; burn wound size is reduced (skin reconstruction phase).
- ***Score 2.5:** Scab remnants are visible, burn wound size is reduced, indicating the skin reconstruction phase, with slightly open burn wounds.
- **Score 3:** All necrotic tissue (scabs) is removed; open burn wounds and exudation are present.
- ***Score 3.5:** Open burn wounds are present with moderate exudation; early granulation tissue is visible.
- **Score 4:** Partial removal of necrotic skin; ulceration and exudation remain in the burn wound.
- ***Score 4.5:** Extensive necrotic tissue persists with deeper ulcerations and heavy exudation; early signs of debridement may appear in the burn wound.
- **Score 5:** Necrotic skin fully covers the burn wound; no visible signs of healing initiation.

*With a slight modification made

Evaluation of burn contraction

According to the protocol established by Wendelken *et al.* [20], burn contraction was assessed by calculating the percentage reduction in wound surface area over time. The initial burn area was determined using a tracing method: the edges of the lesion were outlined on a transparent acetate sheet using a fine–tipped pencil, then transferred onto graph paper to calculate the surface.

The percentage of wound contraction was estimated using the formula described by Subalakshmi *et al.* and Boudra *et al.* [13, 21], with slight modification:

$$\% \text{ Contraction } = \left(\frac{\text{Burn lesion on day 0} - \text{Burn lesion on day "n"}}{\text{Burn lesion on day 0}} \right) \times 100$$

"n" refers to the subsequent evaluation days, ranging from day 1 to d 33.

To enhance measurement accuracy and minimize bias associated with manual tracing, the burn surface area was estimated by subdividing the graph paper squares into halves, thirds, and quarters [20]. The resulting outlines were then digitized and analyzed using AutoCAD 2016 software [13, 21].

In the context of this study, the term "wound," commonly used in standard protocols, was replaced with "burn" to more accurately reflect the nature of the experimentally induced lesions.

Statistical analysis

To assess the influence of temperature on treatment outcomes, mean values and standard deviations were calculated for the three groups (Propolis, Sulfadiazine, and Control). Statistical analysis was performed using IBM SPSS® version 27 through a one–way ANOVA.

RESULTS AND DISCUSSION

In Vitro

Antibacterial efficacy of Algerian propolis extracts against *Staphylococcus* spp

Staphylococcus aureus, a bacterium frequently involved in skin infections and known for its resistance to multiple antibiotics, serves as a relevant model for evaluating the effectiveness of natural antimicrobial agents such as propolis [13]. The results are presented in TABLE I.

The results show variable inhibition zones depending on the ethanolic extracts tested: sample P1 showed an average inhibition zone of 7.39 ± 0.79 mm, P2 reached 19.35 ± 2.29 mm, and P3 measured 8.13 ± 0.69 mm. These findings indicate a low sensitivity of *S. aureus* to samples P1 and P3, while strong antibacterial activity was observed with sample P2.

TABLE I
Inhibition zones of ethanolic extracts of Propolis (EEAP1, EEAP2, EEAP3) and Sulfadiazine against *Staphylococcus aureus*

IZP (Ø mm)			IZS (Ø mm)	IZCG (Ø mm) (Ethanol)	IZPJ (Ø mm)
P1	P2	P3	30.6 ± 0.50	0	0
7.39 ± 0.79	19.35 ± 2.29	8.13 ± 0.69			

IZP: Inhibition Zone of Propolis, IZS: Inhibition Zone of Sulfadiazine, IZCG: Inhibition Zone in the Control Group, IZPJ: Inhibition Zone of Petroleum Jelly

These variations may be stemmed from the variability in the chemical profiles of the extracts, especially regarding their polyphenolic content and other biologically active constituents that contribute to anti–infective effectiveness. These observations are consistent with the findings of Daraghmeh and Imtara [22], who investigated propolis originating from various Palestinian locations and observed inhibition zones of 29.6 ± 0.78 mm and 14 ± 0.45 mm against *S. aureus*. Similarly, Sarkez [23] found that a Libyan ethanolic propolis extract at a concentration of 40 mg/200 µL induced an inhibition zone of 19.73 mm, further confirming the anti–infective capacity of the product from diverse geographical sources.

The antimicrobial activity of propolis is mainly due to its natural active substances, especially plant–based antioxidants known for their effectiveness against *S. aureus* [24]. El–Guendouz *et al.* [25] also demonstrated the potent antibacterial effect of Moroccan propolis against *S. aureus*, with no resistance development observed after repeated exposure. In addition, they reported strong antibiofilm activity, which is particularly relevant in chronic skin infections, where biofilms play a key role in persistence and treatment resistance.

Furthermore, Zhang *et al.* [9] reported that Chinese red propolis extract acts by disrupting bacterial cell walls and membranes, thereby inhibiting bacterial growth. Their metabolomic analysis

revealed significant alterations in bacterial metabolism, suggesting a complex, multi–targeted mechanism of action.

These findings highlight the therapeutic potential of propolis, particularly for treating skin infections commonly associated with *S. aureus*, including resistant strains. Its efficacy lies in its ability to disrupt bacterial structures, inhibit essential metabolic functions, and prevent biofilm formation. Along with its low potential for resistance development, propolis emerges as an effective natural alternative for topical use. The propolis tested in our study shares these therapeutic properties with previously described samples, further supporting its value as a natural antimicrobial agent.

In vivo

Post–Burn body temperature monitoring in Rabbits

The average rectal temperatures recorded over the 15-day period were 38.57 ± 0.37°C for the Propolis group (PG), 38.48 ± 0.19°C for the Silver Sulfadiazine group (SDG), and 38.45 ± 0.22°C for the Control group (CG). There were no statistically significant differences among the groups, indicating that the treatments had no measurable effect on the animals' core body temperature (P=0.036).

Overall, these findings suggest that all rabbits maintained normal and stable core body temperatures throughout the experimental period (Rossmax, China). According to Will [26], the normal rectal temperature in rabbits ranges between 38.5 and 40°C. This reference range aligns with the values presented in TABLE II, where the average body temperatures remained relatively stable across the three experimental groups: 38.57 ± 0.37°C in the Propolis group, 38.48 ± 0.19°C in the SDG, and 38.45 ± 0.22°C in the CG.

The stability of body temperature observed in all groups indicates a consistent physiological response to both the treatments and the thermal injury, suggesting good tolerance to the experimental conditions.

TABLE II
Body temperature (°C) for each group

Body Temperature	PG	SDG	CG
Mean ± SD	38.57 ± 0.37	38.48 ± 0.19	38.45 ± 0.22

PG: PropolisGroup; SDG: Silver Sulfadiazine Group; CG: Control Group

Macroscopic parameters for burn assessment

Contraction rate of the burn area

The results presented in TABLE III show that the group treated with a propolis–based ointment achieved complete healing of an initial burn area of 8.55 cm² within 25 to 26 d. In comparison, burns in the group treated with silver sulfadiazine required approximately 33 d and did not reach full healing, with a contraction rate of 84.5%. As for the control group (CG), no complete retraction of the burn was found after 33 d, despite a contraction rate of 88.30%.

TABLE III
Burn Contraction Rate / Contraction Percentage

	Initial woundsize: 8.55 cm²					
Animals	PG		SDG		CG	
	BCR	CP	BCR	CP	BCR	CP
R1	25 d	100%	33 d	88.30%	33 d	83.50%
R2	25 d	100%	33 d	84.67%	33 d	71.92%
R3	26 d	100%	33 d	84.32%	33 d	85.84%
R4	26 d	100%	33 d	84.67%	33 d	88.30%

PG: Propolis group. SDG: Silver Sulfadiazine group. CG: Control group/ Rabbit (1, 2, 3, 4). BCR: Burn contraction rate. CP: Contraction percentage

The initial burn area, estimated at 8.55 cm², increased during the early stages of lesion development. This expansion, observed from day 1 to d 10 in the propolis group, from d 1 to d 17 in the silver sulfadiazine group, and from d 1 to d 8 in the control group, can be explained by several pathophysiological mechanisms. According to Salibian *et al.* [27], one of the main contributing factors is burn wound conversion. This phenomenon corresponds to the progression of an initially superficial burn to a deeper form, resulting in a visible enlargement of the necrotic area.

In the present study, burns treated with propolis showed faster healing compared to those in the sulfadiazine–treated and untreated groups. The delayed healing observed in the latter may result from slower re–epithelialization and less efficient tissue contraction, two key processes involved in wound closure.

These findings are consistent with several earlier studies highlighting the beneficial effects of propolis in burn treatment. Jastrzębska–Stojko *et al.* [28] reported that a balm combining propolis and honey, applied at concentrations of 1% and 3%, enhanced healing in a dose–dependent manner by stimulating collagen formation, with greater efficacy than silver sulfadiazine. Similarly, Gregory *et al.* [29] observed that Brazilian propolis effectively reduced inflammation and accelerated the healing of superficial second–degree burns in humans.

In veterinary medicine, Kalil *et al.* [30] reported that, in sheep, propolis treatment led to reduced healing time, faster hair regrowth, and a notable antibacterial effect. Abu–Seida [31] also demonstrated a significant reduction in lesion size and faster re–epithelialization in dogs treated with propolis.

More recently, El–Kersh *et al.* [32] confirmed in a murine in vivo model that propolis effectively reduced wound size and promoted healing without causing adverse skin effects. In addition, Manginstar *et al.* [33] reviewed the underlying biological mechanisms involved. Propolis exhibits antimicrobial, antioxidant, and anti–inflammatory properties, while also stimulating cell proliferation, neovascularization, and collagen synthesis—key processes for tissue regeneration and remodeling.

Similarly, Akpınar and Özdemir [34], in an experimental rat model, observed a significant improvement in epithelialization and a reduction in the injured area in the group treated with propolis–based care. These positive outcomes are largely attributed to the

high flavonoid content of propolis, compounds well–documented for their wound–healing properties. These flavonoids are known to modulate several key cellular signaling pathways, including TGF–β1, VEGF, NF–κB, MAPK/ERK, and PI3K/Akt, thereby promoting angiogenesis, re–epithelialization, and tissue regeneration [35].

Overall, these experimental and clinical data support the therapeutic potential of propolis in burn treatment, owing to its multifaceted mechanisms of action that promote rapid, effective, and high–quality wound healing.

The analysis of burn wound healing scores highlights the superior effectiveness of the propolis–based treatment compared to silver sulfadiazine and the control group. Although all groups started with an identical score on d 1 (score 5), corresponding to fresh, non–healed burns, significant differences began to emerge by d 20. At this stage, the Propolis group showed an average score of 2, indicating a substantial reduction in lesion size, while the Sulfadiazine and Control groups remained at a score of 3, reflecting slower healing progression.

By d 30, complete healing was observed in all animals of the Propolis group (score 0), whereas the Sulfadiazine and Control groups still presented average scores of 2.5 and 2, respectively. These observations are further supported by the mean cumulative scores over the entire period: 2.79 ± 1.44 for the Propolis group, compared to 3.70 ± 1.16 and 3.74 ± 0.68 for the Sulfadiazine and Control groups, respectively. These findings confirm that propolis, applied using a slightly modified protocol, not only accelerates burn healing, but also improves its overall quality TABLES IV, V, and VI and FIG. 3.

TABLE IV
Burn Healing Scores for the Propolis Group

Lots	PGR1	PGR2	PGR3	PGR4
	Burn Healing Scores for the PG			
Mean ± SD	2.86 ± 1.42	2.9 ± 1.41	2.5 ± 1.4	2.9 ± 1.55
Cumulative scores	2.79 ± 1.44			

PG: Propolis group, SDG: Silver Sulfadiazine group, CG: Control group. Rabbit (1, 2, 3, 4)

TABLE V
Burn Healing Scores for the SilverSulfadiazine group

Lots	SDGR1	SDGR2	SDGR3	SDGR4
	Burn Healing Scores for the SDG			
Mean ± SD	3.79 ± 1.10	3.85 ± 0.99	3.75 ± 1.07	3.44 ± 1.5
Cumulative scores	3.70 ± 1.16			

PG: Propolis group, SDG: Silver Sulfadiazine group, CG: Control group. Rabbit (1, 2, 3, 4)

TABLE VI
Burn Healing Scores for the Control group

Lots	CGR1	CGR2	CGR3	CGR4
	Burn Healing Scores for the CG			
Mean ± SD	3.75 ± 0.75	3.87 ± 0.69	3.68 ± 0.55	3.69 ± 0.74
Cumulative scores	3.74 ± 0.68			

PG: Propolis group, SDG: Silver Sulfadiazine group, CG: Control group. Rabbit (1, 2, 3, 4)

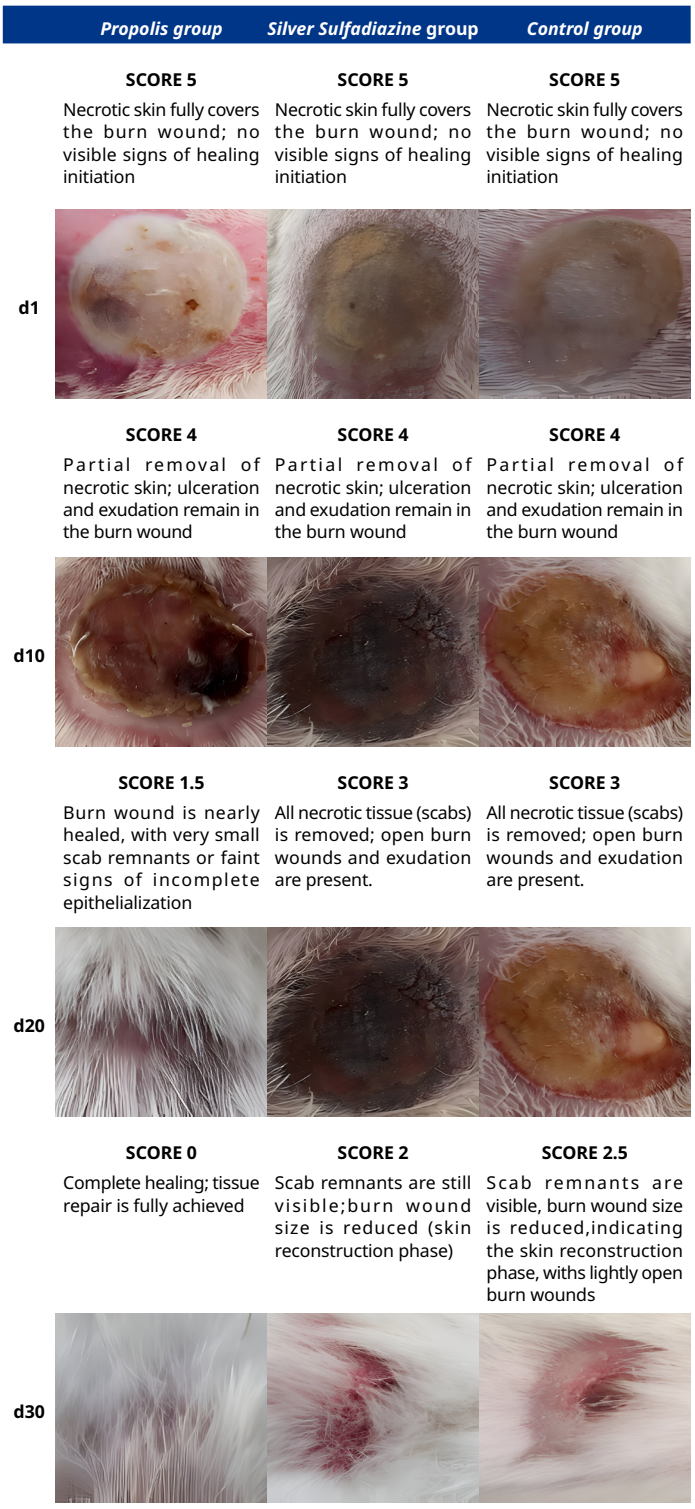

FIGURE 3. Burn healing dynamics over time across treatment group

Propolis actively contributes to skin repair by promoting granulation tissue development, activating cutaneous regeneration and regulation of the extracellular scaffold [36]. Furthermore, Salrian *et al.* [37] reported that the synergistic application of propolis and honey enhances wound contraction and significantly

improves the healing of burn injuries, particularly through increased fibroblast proliferation and angiogenesis.

In contrast, the daily application of sulfadiazine over a 33-d period did not result in complete healing of burn wounds. These results are in correlation with those reported by Sene *et al.* [18], who noted that the absence of healing after four weeks of sulfadiazine treatment suggests that the induced burns were at least of deep second–degree severity, which are difficult to heal with this treatment alone.

Another noteworthy observation concerns hair regrowth, which appeared earlier in the (PG) compared to the (SDG) or left untreated. This phenomenon, also reported by Boudra *et al.* [13], reflects a faster and more complete recovery of the burned skin. Thus, propolis not only accelerates tissue regeneration but also seems to improve the quality of healing at the macroscopic level, including fur restoration.

CONCLUSION

The formulation used in this research appears to demonstrate its effectiveness in the treatment of burn lesions. Although its antibacterial activity is moderate, Algerian propolis exhibited superior healing effects under experimental conditions compared to silver sulfadiazine and the control group. It promoted faster and more complete skin regeneration without affecting thermal homeostasis. The early onset of hair regrowth further supports its regenerative capacity. Given its natural origin and ease of topical application, propolis represents a valuable candidate for burn wound care. Moreover, the absence of adverse effects highlights its safety for clinical use. Further investigations are warranted to standardize its formulations and optimize dosage for human applications.

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Conflict of interest

The authors declare no conflicts of interest related to this report.

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