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Review Article

Synergistic effects of herbal extracts and nanoparticles in skin damage repair: A comprehensive review

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Abstract

Objective: Today, applying herbal extracts to treat skin damage has become widespread and it is supported by numerous studies that confirmed their effectiveness. Due to fewer side effects, diversity of active compounds in them, and lower costs, herbal extracts are an important therapeutic method for skin lesions. additionally, nanoparticles are important for stimulating the body's ability to recover and treat wounds.

Materials and Methods: This review article aims to evaluate how combining herbal extracts with nanoparticles and advanced drug carriers (like liposomes and nanofibers) creates synergistic effects that enhance the treatment of bacterial skin infections and wounds. By improving bioavailability, targeting delivery, and reducing required dosages, these formulated combinations offer a more effective, faster-healing, and potentially safer alternative to conventional therapies.

Results: Based on the discussed studies, therapy using a combination of medicinal herbs and nanotechnology increases the effectiveness of treatment, accelerates recovery, and decreases the use of each material, thereby reducing the toxicity of each in infection and skin damage treatment.

Conclusion: This review conclusively demonstrates that the strategic formulation of herbal extracts with nanoparticles and advanced drug carriers—such as liposomes, nanofibers, and polymeric nanoparticles—unlocks unprecedented synergistic potential for treating bacterial skin infections and accelerating wound and burn healing. By enhancing bioavailability, enabling targeted delivery, and reducing therapeutic doses (thereby minimizing toxicity), these nano-herbal hybrids represent a paradigm shift toward safer, faster, and more cost-effective regenerative therapies that can combat antibiotic resistance and revolutionize modern dermatological care.

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Introduction

Medicinal herbs have long been recognized as a valuable resource in treating a wide range of diseases including infections, inflammatory conditions, and systemic disorders. Their broad-spectrum activity, low cost, and minimal side effects make them a compelling alternative to synthetic drugs, especially as antibiotic resistance becomes increasingly problematic (Uprety, Asselin et al. 2012). Traditional medicine which relies heavily on plant extracts, provides healthcare for over 80% of the global population, particularly in developing nations (Bloemsma, Dokter et al. 2008). In recent years, pharmaceutical companies and researchers have invested significant effort into developing natural products derived from medicinal plants, aiming to create more effective therapeutic solutions (Takasaki, Konoshima et al. 2000). Among their many applications, medicinal plants have shown particular promise in treating injuries and wounds. Skin health which is vital for preventing dehydration, bleeding, and microbial invasion, becomes compromised when injuries occur (Bakhtiyari et al. 2014). Damaged skin presents a complex challenge in medical treatment, requiring prompt intervention to restore the epithelial layer and regenerate the dermal matrix(Ghaderi and Afshar 2015). Since the skin is the body's primary barrier against pathogens, any breach in it increases the risk of infection. Wound infections, especially those caused by antibiotic-resistant strains like *Pseudomonas*, can lead to chronic complications, delayed healing, and tissue necrosis if not treated properly Roberts, Latg et al. 1998, Church et al. 2006).

Burns represent one of the most severe forms of skin injury, often resulting in extensive physical and psychological trauma (Church, Elsayed et al. 2006, Ghaderi and Afshar 2015). The treatment of burns involves multiple stages, including epithelial regeneration, angiogenesis, and cellular interactions with the extracellular matrix and cytokines. Immediate treatment is critical, as delays can hinder healing and increase infection risks (Qu, Diao et al. 2013). Current treatments often rely on topical antimicrobial agents, but many conventional solutions such as betadine, acetic acid, and certain antibiotics, have been found to be toxic to fibroblasts and lymphocytes (Qu, Diao et al. 2013). Given the high costs and prolonged recovery associated with burn and wound care, any method that accelerates healing can significantly reduce the financial and psychological burden on patients and healthcare systems (Bugajski, Nowogrodzka-Zagorska et al. 1989).

Medicinal plants, with their antimicrobial and wound-healing properties, offer a promising solution. Their ability to combat resistant pathogens while promoting tissue repair makes them an attractive option for modern wound management (Seyyednejad and Motamedi 2010, Bahramikia and Yazdanparast 2012, Beiranvand, Bahramikia and Dezfoulian 2021, Bahramikia, Gavyar and Yazdanparast 2022).

The main goal of this review article is to examine the synergistic therapeutic effects of combining formulated herbal extracts with nanoparticles for the treatment of skin damage, particularly bacterial infections in wounds and burns. It aims to compile and analyze existing research on how these combinations enhance healing, reduce treatment duration, and lower the required dosage (and thus potential toxicity) of individual components compared to their use alone. Furthermore, the article explores how formulating these active agents with advanced drug carriers, like liposomes and nanofibers, can improve their stability, bioavailability, and targeted delivery, thereby offering more effective and safer alternatives to conventional treatments.

Materials and Methods

Acknowledging the critical role infections play in complicating skin injuries and given the global surge in research on herbal medicines this review, adopts a narrative approach to explore how formulated herbal extracts, nanoparticles, and advanced drug delivery systems can be harnessed to effectively treat bacterial skin damage, including burns, wounds, and related infections.

To achieve this objective, we conducted a search through various scientific databases, including PubMed, Web of Science, Scopus, and Google Scholar along with Iranian databases such as SID (Scientific Information Database) and Magiran covering the period from 2000 to 2024**.** We utilized Mesh terms-based Keywords including: "herbal extracts", "medicinal plants", "nanoparticles", "nanotechnology", "burn infection", "drug delivery", "skin damage", "bacterial skin infection", and various combinations of these terms employing Boolean operators (AND/OR). The search included original research articles, governmental and the WHO reports, case reports, review articles, and relevant grey literature. Subsequent to selecting an article, articles' topics were identified and required information was extracted. We ignored Non-English publications, abstracts without full texts, and studies unrelated to skin damage, reviews without original data and studies using synthetic compounds alone (no herbal/nano components). Furthermore, this review seeks to avert redundant studies and motivate new research avenues for individuals actively engaged in the field.

Results

Herbal extracts effective in the treatment of skin damage

The activity of different species of plants and their derivatives derivation in treating skin damage has been documented by numerous researchers.

A study on the microscopic effects of kiwifruit on wound healing in a rat model showed that debridement, formation of new epithelium, and wound contraction were faster and better in the experimental group compared to the control group. Following rapid enzymatic debridement, wound healing progressed well, and no healthy tissue damage was observed(Hafezi, Elmirad and Pedram 2009). Similarly, the extract of *Fagonia indica* Burm F. had the same effects on burns in rats. Based on the results, this extract accelerates skin epithelium formation and decreases treatment duration(Rasool, Shehab et al. 2014).

Herbal extracts effective in the treatment of skin damage

Numerous studies have reported the activity of different plant species and their derivatives in treating skin damage. Table 1 summarizes the findings, highlighting the factors measured and the observed changes after treatment.

Synergistic effect of herbal extracts and nanoparticles in the treatment of skin damage

Today, nanotechnology is extensively used in electronic, environmental, agricultural, and other domain's , and medicine is no exception. In recent years, this technology has been incorporated mainly in regenerative medicine with novel advances in this domain (Kalashnikova, Das and Seal 2015). Recently, nanotechnology has started a wound treatment and management revolution by introducing new solutions (Bahramikia and Izadi 2023).

The application of nanotechnology in medicine and the unique properties of nanostructures have received considerable attention. Compared to regular antibiotics, microbial nanoparticles have advantages such as less toxicity for the host, dominance over microorganism resistance, and lower costs. Compared to the smallest antibiotic particles, these nanoparticles have more long-lasting effects on the body. Therefore, they are called a miracle of modern medicine. Due to the new properties of nanoscale materials, their production and use are widespread today (Safari, Bahramikia and Dezfoulian 2023, Mostaed, Bahramikia et al. 2024).

Nanoparticles are important tools for stimulating the recovery and healing of wounds caused by burns. Silver, gold, platinum, selenium, copper, zinc oxide, tantalum, iron, and titanium oxide have shown therapeutic solid potential in treating wounds. These functional nanoparticles are used extensively as nanocomposites in ointments and bandages (Cortivo, Vindigni et al. 2010, Li, Wang et al. 2015, Rahimnejad, Derakhshanfar and Zhong 2017).

Several researchers (Figure 1) have reported the effects of herbal extracts combined with nanoparticles for the treatment of skin damage.

Table 1. Summary of herbal extracts used for skin damage and their effects

Plant/Extract	Study/Year	Measured Factors	Effect After Treatment
Actinidia deliciosa	(Hafezi, Elmirad and Pedram 2009)	Wound contraction, epithelialization, debridement	Faster healing, no healthy tissue damage
Fagonia indica	(Rasool, Shehab et al. 2014)	Epithelial regeneration, healing duration	Accelerated epithelial formation, reduced healing time
Alcea	(Miroliaei, Chelongar et al. 2017)	Dermis and epidermis healing, inflammation	Most effective among tested herbs; anti-inflammatory and antioxidant properties
Achyranthes aspera	(Barua, Talukdar et al. 2012)	Wound surface area, recovery speed	Significant reduction in wound size and faster recovery
Scrophularia striata	(Azhdari-Zarmehri, Nazemi et al. 2014)	Healing time, tissue regeneration	Accelerated wound healing
Allium sativum	(Nidadavolu, Amor et al. 2012)	Bacterial infection (burn wound)	Prevented infection; antimicrobial activity
Bowdichia virgilioides	(Agra, Pires et al. 2013)	Collagen deposition, fibroblasts, inflammatory cells, bacteria load	Enhanced healing, antibacterial against *S. aureus*
Otostegia persica	(Ganjali, Sotoudeh et al. 2013).	Inflammatory cell count	Significant reduction of inflammation
Aloe vera	(Shahzad and Ahmed 2013)	Healing rate, cost comparison	Faster healing than silver sulfadiazine, more economical
Cinnamomum spp.	(Buru, Pichika et al. 2014)	Antibacterial activity, Methicillin-resistant Staphylococcus aureus inhibition zone	*Cinnamomum impressicostum* showed largest inhibition (21 mm zone); strong effect on MRSA
Coriander sativum	(Zadeh, Mahzooni et al. 2015)	Burn healing, comparison with silver sulfadiazine	Superior healing with coriander ointment
Cyclotides (*cyO2*, *KB2*)	(Fensterseifer, Silva et al. 2015)	MIC values, phagocytosis, bacterial load	Reduced bacterial load; cyO2 lowered phagocytosis
Origanum vulgare	(Rahmani Gohar, Moslemi et al. 2016)	*S. aureus* wound infection	Significant antibacterial effect in vivo
Salvia multicaulis	(Salimikia, Aryanpour et al. 2016)	Wound size, healing effect at different concentrations	All concentrations significantly effective

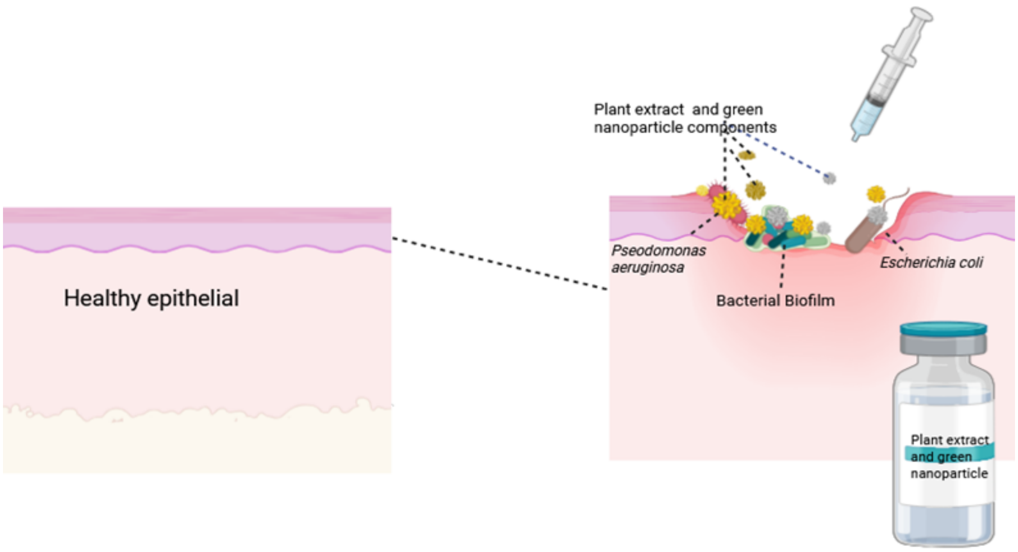

Figure 1. The effects of herbal extracts combined with nanoparticles for the treatment of skin damage

For instance, Suganya et al. employed nanofibers carrying the methanolic and chloroformic extract of *Tecomella undulata* for wound treatment. Results revealed that nanofibers loaded with herbal extract act as a drug delivery system and an effective therapeutic method for treating wounds and the bacterial infection resulting from it (Suganya, Senthil Ram et al. 2011).

Leu et al. (2012) reported that gold nanoparticles, epigallocatechin gallate, and alpha lipoic acid antioxidants accelerate wound treatment through their anti-inflammatory and antioxidant activities. They also showed that, after treatment with gold nanoparticles and antioxidants, the expression of CD68 protein decreased and that of copper-zinc superoxide dismutase considerably increased, leading to wound treatment on mouse skin (Leu, Chen et al. 2012).

Naghsh et al. (2013) examined a novel nano-compound of pumpkin and silver nanoparticles for treating skin burns in male mice. It was shown that the effects of silver nanoparticles-pumpkin hydroethanolic extract were more significant than each agent alone for treating burns, indicating the regenerative synergistic impact of these two materials in herbal nanocomposites (Naghsh, Aboutalebi and Karam Seychani 2013).

Krychowiak et al. revealed that secondary metabolites produced in *Drosera binata* have strong antimicrobial effects when tested in laboratory culture media. Results also showed that the combination of silver nanoparticles with the extracts of this plant or with pure 3-chloro-plumbagin compound significantly increases antimicrobial properties against *Staphylococcus aureus* in wounds and infection caused by burns (Krychowiak, Grinholc et al. 2014).

Sheikholeslami et al. reported that a combination of silver nanoparticles and the methanolic extract and oil of *Zataria multiflora* increases the effects and decreases the use of each agent alone, thereby reducing the toxicity of each in the treatment of infections caused by *Staphylococcus epidermidis* and *Staphylococcus aureus* (Sheikholeslami, Mousavi et al. 2016).

Yousefpoor et al. reported that *Aloe Vera* gel accelerates wound healing at the site of infection with *Staphylococcus aureus*, *Pseudomonas aeruginosa*, and *Escherichia coli*, while silver nanoparticles alone delayed burn wound treatment. This study also showed that the synergistic effect of plant gel and silver nanoparticles is similar to the mean effect of both gels and silver nanoparticles in treating burn wounds (Yousefpoor, Bolouri et al. 2016).

Numerous studies have been conducted on the effects of herbal extracts in combination with nanoparticles on bacteria in skin wounds and infections, considering the increase in diseases caused by different bacteria, especially drug-resistant ones in hospitals and healthcare centers.

For instance, Mirzaei et al. examined the antimicrobial effect of silver nanoparticles, Allisin (an antimicrobial compound in garlic extract), and a combination of both in the form of ointment on treating skin infection caused by *Staphylococcus aureus* in a rat model. Results showed that the minimum inhibitory concentration MIC and minimum bactericidal concentration (MBC) of silver nanoparticles against *Staphylococcus aureus* was 6.25 and 12.5 ppm, and the MIC and MBC of Allisin on the noted bacterium were 10.68 and 21.37 µg/ml, respectively. MIC and MBC of the silver nanoparticles-Allisin combination against *Staphylococcus aureus* were 1.33 µg/ml and 3.12 ppm and 2.67 µg/ml and 6.25 ppm, respectively. Based on these results, the combination of Allysine and silver nanoparticles synergizes against skin infection caused by *Staphylococcus aureus* (Mirzaei, Salouti and Shapouri 2015).

A similar experiment was performed by Sharifi-Rad et al.. They explored the effects of silver nanoparticles, Allisin and their combination against skin infection based on Methicillin-resistant Staphylococcus aureus (MRSA) strains *in vitro* and *in vivo*. Results of MIC and MBC of the combination of silver nanoparticles and Allisin confirmed that the synergistic effect of the resulting compound accelerates the healing of skin infection caused by MRSA strains. Therefore, this combination can be used as a medicine to treat wounds caused by *Staphylococcus aureus* in the future (Sharifi-Rad, Hoseini-Alfatemi et al. 2014).

Salouti et al. assessed the synergistic effect of an MBP-1 plant peptide with silver nanoparticles to treat the skin infection caused by *Staphylococcus aureus*. Based on the results, the amount of MIC and MBC for the MBP-1 peptide is 0.6 and 0.7 mg/ml. Also, the amounts of MIC and MBC for silver nanoparticles against *Staphylococcus aureus* were 6.25 and 12.5 mg/ml, respectively. Furthermore, the MIC and MBC of silver nanoparticles and MBP-1 against *Staphylococcus aureus* were 3.125 and 0.5 mg and 6.25 and 0.6 mg, respectively. According to these results, silver nanoparticles and the MBP-1 plant peptide alone did not significantly affect wound treatment. However, the synergistic effect of the MBP-1 plant peptide and silver nanoparticles was considerably higher in accelerating wound treatment (Salouti, Mirzaei et al. 2016).

In 2017, an Egypt-based microbiological research team performed extensive experiments on the effects of combining thymol (a secondary metabolite in plants) and silver nanoparticles against *Staphylococcus aureus*. Results revealed that silver nanoparticles act as a strong promoter, disrupting the bacterium's cell wall and assisting the entrance of thymol into the bacterium. By this entrance, it disrupts and inactivates important biomolecules in the bacterium's cell cycle. Consequently, combining thymol and silver nanoparticles is an effective medication for treating wounds caused by *Staphylococcus aureus* (Abdelhamid and El-Hosseiny 2017).

Ranjbar et al. concluded that the combination of *Aloe Vera* and chitosan thin films (a nanoparticle synthesized from the skin of crustaceans) accelerates wound treatment at the site of infection with MRSA bacteria, while chitosan alone delayed wound treatment. These results reveal that the combination of *Aloe Vera* and chitosan nanoparticles has considerable synergistic effects in treating infections caused by MRSA (Ranjbar and Yousefi 2018).

In a review study, Rai et al. extensively studied the essential oils (EOs) of citral, citronellal, cinnamaldehyde, benzaldehyde, vanillin thymol, and carvacrol, and their combination with nanoparticles. Results showed an antimicrobial solid synergistic effect. For instance, when combined with EOs, gold nanoparticles can disrupt the cell cycle of *Staphylococcus* and *Pseudomonas*, thus proving effective in treating infected wounds caused by these bacteria (Rai, Paralikar et al. 2017) (Figure 2).

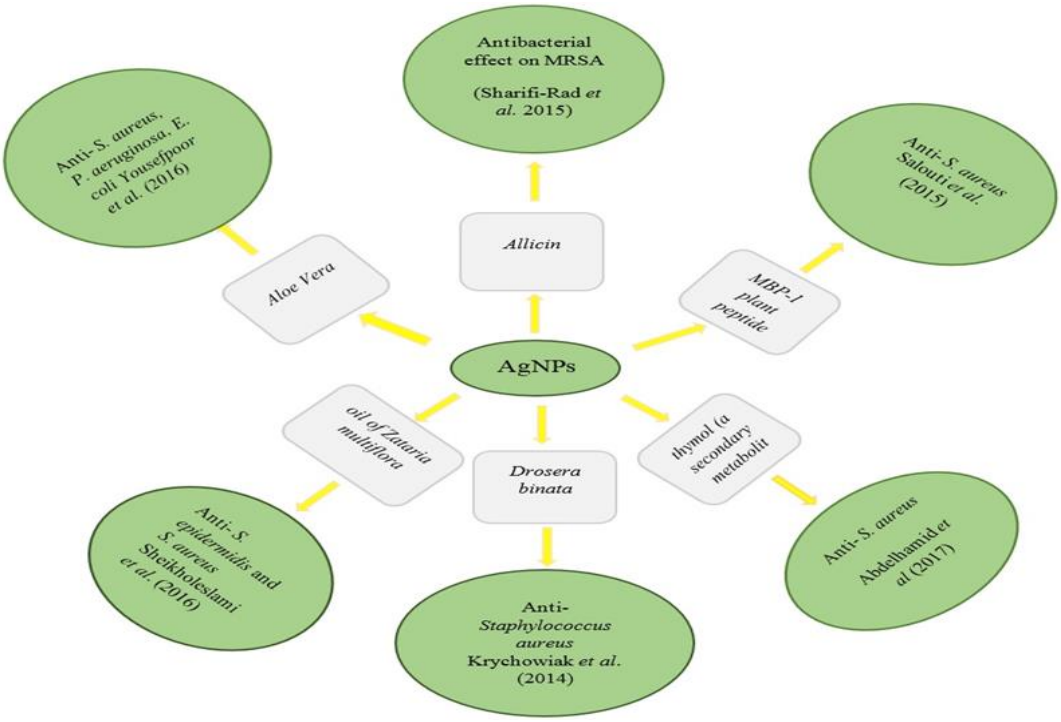

Figure 2. The effects of Ag nanoparticles synthesized from different plants on different bacteria in wound. .

Effects of the formulation of herbal extracts with drug carriers in the treatment of skin damage

Encapsulation is the entrapment of solids, liquids, or gases in capsules, which release their content at a controlled speed and under specific conditions. This process includes the following stages: formation of a wall around the bioactive compound, ensuring the lack of leakage of these compounds, and ensuring the lack of entrapment of unfavorable compounds in the capsule (Fang and Bhandari 2010). The efficiency of phenolic compounds depends on their activity, stability, and bioavailability. The little absorption of phenolic compounds in the intestine, stability during the process, and protection of nutrients against environmental factors such as oxygen, temperature, chemical and biological agents, low water solubility, and bitter taste have limited the application of these compounds. These problems can potentially be resolved by encapsulation (Munin and Edwards-Lévy 2011).

Nanoencapsulation is a novel method for increasing the physical stability of bioactive compounds, protecting these compounds against unfavorable environmental factors and the interfering effects of nutrients. This method includes the manipulation of atoms and molecules, leading to nano-sized structures (mostly 100 nm or smaller) while maintaining their properties. Nanoencapsulation is a novel technology for packaging active materials in small sizes. To this end, nanocomposite, nano-emulsification, and nanostructures are used. Finally, a functional final product with controlled release is produced. Nanoencapsulated compounds have a higher bioactivity because of their smaller cell size. This method is also used to protect active compounds against environmental factors such as oxygen, light, and humidity (Figure 3) (Takahashi, Inafuku et al. 2007).

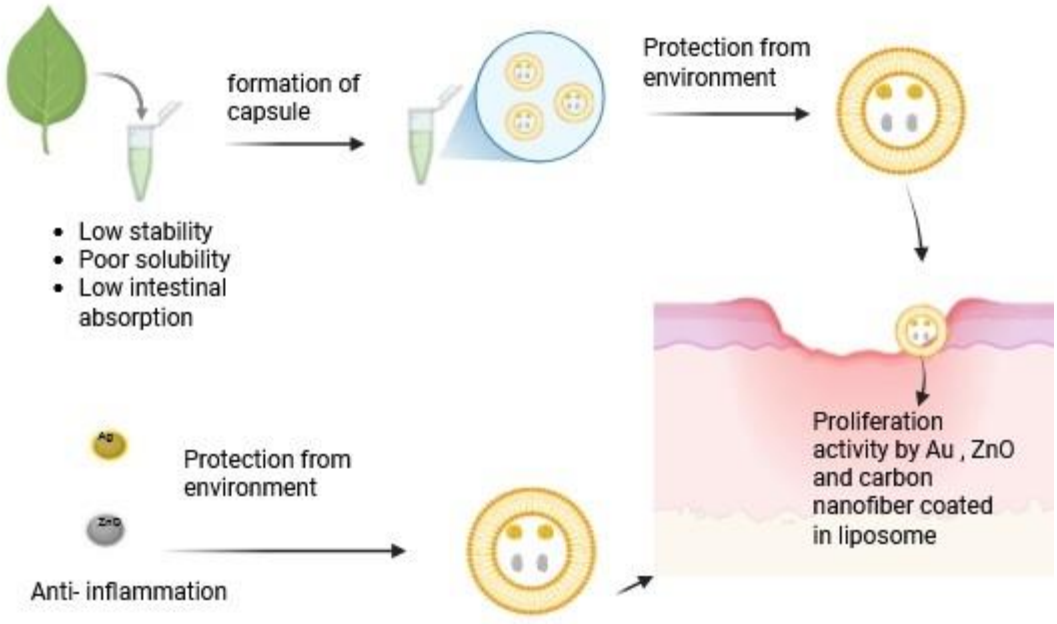

Figure 3. Effects of the formulation of herbal extracts with drug carriers in the treatment of skin damage

Accordingly, studies have been conducted to examine the effects of encapsulated herbal extracts for treating skin damage.

For example, Takashi et al. used aloe leaf gel extract (AGE) encapsulated inside the liposome, which increased collagen synthesis by 23%. However, this increase was very small when AGE was used alone. Furthermore, the use of liposomes containing 4 and 20 µg/ml of AGE increased the production and proliferation of normal human epidermal keratinocytes (NHEK) by 77% and 101%. On the other hand, this increase was only 41% and 60% following the use of 4 and 20 µg/mL of AGE alone, respectively. It is concluded that bioactivity and skin protection are significantly enhanced by encapsulating AGE (Takahashi, Kitamoto et al. 2009).

Pinsuwan et al. entered *Hibiscus sabdariffa* Linn extract inside a liposome containing phosphatidylcholine and deoxycholic and performed skin treatment experiments on rabbits. Results showed that applying the encapsulated extract of the mentioned plan is far more effective on skin irritability than using the extract alone (Pinsuwan, Amnuaikit et al. 2010).

Kwon et al. encapsulated *Centella asiatica* extract in a nano-liposome. This nano-encapsulated extract reduced toxicity against fibroblasts by 10% compared to pure extract. It also decreased the level of metalloproteinase from 136% to 77.6%. Moreover, the encapsulated extract reduced hyaluronidase compared to the pure extract. In addition, the penetration of extract in rabbit skin was much higher in the encapsulated form than in the pure form (Kwon, Choi et al. 2012).

Recent studies have shown that curcumin affects the treatment of acute wounds. However, it is not widely used today due to its high photosensitivity and low stability. To resolve these problems, Chereddy et al. encapsulated curcumin inside a material called poly lactic-co-glycolic acid(PLGA). Then, they evaluated the release of PLGA-encapsulated curcumin (PLGA-CC). In the first 24 hr, a burst release (40%) was observed, and sustained release was seen over the next eight days. lactate dehydrogenase leakage assay LDH and methyl tetrazolium MTT evaluation showed that PLGA-CC at 100 μg/mL concentrations was not toxic against skin keratinocytes. Under laboratory conditions, using PLGA-CC leads to the full recovery of the wound. However, using PLGA or curcumin alone led to a 75% wound recovery. Moreover, histological observations showed that applying PLGA-CC led to re-epithelialization and connective tissue formation (Chereddy, Coco et al. 2013).

Photodynamic therapy (PDT) is an appropriate method for treating infected wounds. In PDT, a photo-sensitive material is injected and then activated by light. The photo-sensitive material is activated, creating active oxygen molecules that destroy microbes. Hypericin is a novel photo-sensitive material extracted from *Hypericum perforatum* with antimicrobial properties (Kadam, Chaudhari et al. 2010). Hypericin has limited therapeutic use due to its hydrophobic properties. To resolve this issue, Nafee et al. encapsulated hypericin in polycaprolactone-poly ethylene glycol PCL-PEG, which showed a pulsatile release over 48 hr. This photo-sensitive nanoparticle produced reactive oxygen species 100 times more than the hypericin dissolved in dimethyl sulfoxide DMSO and effectively prevented the growth of MRSA strains. This study used Wistar rats to examine wound healing, creating deep wounds on their backs. Wounds were infected with *S. aureus*. Then, they were treated with hypericin encapsulated in PCL-PEG and phosphate-buffered saline PBS, and hypericin was dissolved in DMSO. Examinations on day 10 revealed that the highest degree of wound healing had occurred in the group treated with hypericin encapsulated in PCL-PEG. At the same time, abscess extension and edema were observed in the group treated with hypericin dissolved in DMSO. Also, 100% of rats treated with hypericin encapsulated in PCL-PEG survived, while approximately 50% to 75% of those treated with PBS and hypericin dissolved in DMSO survived (Nafee, Youssef et al. 2013).

Castangia et al. showed that using nanovesicles (liposome and penetration enhancer containing vesicles PEVs) containing curcumin and quercetin prevents skin damage or promotes healing. The manufactured nanovesicles contained a combination of phospholipid and natural polyphenols such as curcumin and quercetin. In this study, the skin of mice was smeared with 12-O-tetradecanoylphorbol-13-acetate TPA compound dissolved in acetone (243 μM, 3 μg/20 μl). Then, in all groups, 20 μl of nano-compounds was used on the wound for 2-3 days. Based on the results, treatments managed to decrease the extent of the damage. Moreover, myeloperoxidase activity, which causes skin inflammation, was reduced by 59% using liposome quercetin and by 68% using liposome curcumin (Castangia, Nácher et al. 2014).

The combination of epigallocatechin gallate EGCG, alpha lipoic acid, and gold nanoparticles facilitated the healing of diabetic wounds in diabetic rat models through increased angiogenesis and reduced oxidation and inflammation (Leu, Chen et al. 2012). Better effects were observed when these materials were used in the topical form. However, better results were possible when release occurred at the deep region of the skin so that the noted materials would be protected from enzymes on the skin's surface (Huang, Chen et al. 2014). That is why Demir et al. encapsulated *Calendula officinalis* extract with liposome, and better effects were observed when this extract was prescribed with gold nanoparticles (Demir, Barlas et al. 2014).

Also, Pereira et al. used a combination of Aloe Vera/vitamin E/chitosan to treat burn wounds. Results were examined in the form of tissue sections to observe wound healing. In this experiment, rats received this combination in the topical form. A significant burn wound recovery was observed in the experimental group over time (Pereira, Santos-Oliveira et al. 2014).

Rijo et al. (2014) assessed the antimicrobial effect of 5 species of *Plectranthus*. Extraction was performed using infusion, decoction, and microwave extractions. In this study, the microwave extract of *P. madagascariensis* had superior antimicrobial effects compared to other species. Rosmarinic acid is the main compound in this extract. To enhance the stability of this extract, they successfully encapsulated it with alginate. This property improved the stability and bioactivity of this extract (Rijo, Matias et al. 2014).

Agnes Mary et al. employed a combination of *Aloe Vera* and nanofibers. They showed that this compound can be used for wound treatment as it increases cell proliferation at the wound site. Based on the results, these herbal nanofibers can be utilized in skin tissue engineering (Agnes Mary and Giri Dev 2015).

Faezizadeh et al. evaluated nanoliposomes containing silymarin extract against MRSA strains in the wound. Results showed that this extract's MIC amount is 500 and 125 mg/L in the free and nano-encapsulated forms, respectively. Moreover, bactericidal speed was much higher using a nanoliposome extract than pure extract (Faezizadeh, Gharib and Godarzee 2015).

Krausz , Adler et al. reported that curcumin loaded on a silane-hydrogel nanoparticle inhibits the growth of MRSA and *Pseudomonas aeruginosa* and accelerates wound healing *in vitro* (Krausz, Adler et al. 2015).

In addition, Moulaoui et al. evaluated the effects of encapsulated *Fraxinus angustifolia* extract on skin damage caused by H2O2. They concluded that this extract alone has little effect on skin recovery, while the encapsulated extract significantly improves skin due to its higher cell absorption. Moreover, after using the extract alone, its side effects on the skin were observed, while the encapsulation from did not cause these (Moulaoui, Caddeo et al. 2015).

The roots of *Zingiber cassumunar* are rubbed on the skin to treat muscle pains, rheumatism, and topical infections. Its anti-inflammatory activity results from Compound D, which is shown to permeate the skin easily. Priprem et al. encapsulated *Zingiber cassumunar* in a niosome material, resulting in *Zingiber cassumunar* niosomal gel. This study evaluated Compound D stability and skin permeation in this plant's niosomal gel and extract gel. Based on the results, the permeation and stability of the material are higher in the plant's niosomal gel. Moreover, the anti-inflammatory and analgesic effects of the plant's niosomal gel were compared with those of piroxicam gel. The plant's niosomal gel showed faster analgesic and anti-inflammatory effects and higher stability due to a quicker permeation (Priprem, Janpim et al. 2016).

Yulianti et al. (2017) entered the ethanolic extract of *Centella asiatica* in chitosan nanostructures and evaluated its effects on cell proliferation. Results showed that the synthesis of type I and III collagen had no significant difference across control and treatment groups. However, the proliferation of normal human dermal fibroblasts (NHDF) and NHEK showed a considerable increase, which can prevent skin aging and promote wound healing. A plant that is used explicitly for the treatment of various infections is Plectranthus spp. (Yulianti, Bramono et al. 2016).

In a study examining the effects of encapsulated extracts on wound healing, Saporito et al. (2018) entered olive and eucalyptus extracts into nanostructures and evaluated their impact on skin structure. Results revealed that these manufactured structures have antimicrobial effects on two *Staphylococcus* strains called *S. aureus* and *S. pyogenes*. Moreover, 20 μL of these olive oil- and eucalyptus-containing nanostructures increased cell proliferation at the damaged and burnt site, reduced wound size, and improved physical and chemical tissue properties (Saporito, Sandri et al. 2018).

Discussion

As the resistance caused by the overuse of synthetic chemical antibiotics and the side effects of drugs used to treat skin damage increase, it becomes more necessary to find alternative medications that have antibacterial effects with the least side effects for humans. Recent studies show that medicinal herbs have bio-activities such as anti-inflammatory, antimicrobial, and antioxidant activities, confirming the relationship between these activities and their therapeutic properties for treating skin wounds and damage. Medicinal herbs are usually inexpensive and available with easier application. Based on the reports reviewed in this article, it can be concluded that medicinal herbs are a good source of new and effective agents for treating skin damage. Moreover, nanotechnology has overcome obstacles to treating severe and chronic wounds such as burns and diabetic foot ulcers, and the therapeutic use of nanotechnology-based drugs will increase extensively. This is because nano-sized particles are biodegradable, do not damage healthy neighboring cells, and are not toxic to the host. In addition, it seems that the encapsulation of phenolic compounds in herbal extracts protects them against harsh environmental conditions and improves their therapeutic properties. Therefore, this technique is a good choice for treating skin damage using formulated medicinal herbs. Consequently, based on the discussed studies, therapy using a combination of medicinal herbs and nanotechnology increases the effectiveness of treatment, accelerates recovery, and decreases the use of each material, thereby reducing the toxicity of each in infection and skin damage treatment. The studies reported in this review article can provide a good source for future studies on treating skin damage.

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Not applicable' for that section.

Conflicts of interest

The authors declare that there is no conflict of interest.

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