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Review Article

A review of the dermatologic activity and applications of *Centella asiatica*

Natalie M. Soliman, BS[1], Maithili Bhagat, MBA[1], Alejandra Segarra Ponce, MD[2], Andrea M. Rustad, MD[3], Trisha Khanna, MD[4]

[1] Ohio University Heritage College of Osteopathic Medicine, [2] Independent researcher, San Luis Potosí, Mexico, [3] Dermatology, University of Wisconsin, [4] Premier Dermatology, Orlando, FL

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Centella asiatica (also known as cica or Gotu Kola) is a medicinal herb in the Apiaceae family, long used in Ayurvedic, Chinese, and Unani medicinal traditions for wound healing and treatment of skin conditions. Its active compounds—asiaticoside, madecassoside, asiatic acid, and madecassic acid—have demonstrated anti-inflammatory, antioxidant, and regenerative effects, making it an increasingly popular ingredient in dermatology and skin care products. To summarize its current role in skin health, we performed a literature review over the past decade using PubMed and Google Scholar. Search terms included "Centella asiatica," "Gotu Kola," "cica," "skin," "wound healing," and "dermatology." Preclinical and early clinical data indicate that *C. asiatica* enhances fibroblast proliferation, collagen synthesis, and angiogenesis, thereby improving healing in acute wounds, chronic ulcers, and surgical scars, while reducing hypertrophic and keloid scar formation. *C. asiatica* also demonstrated anti-inflammatory and antioxidant activity, mediated through NF-κB, JAK/STAT, COX-2, and LOX pathways, suggesting a role in the management of acne, rosacea, psoriasis, and photoaging. Aesthetic applications include striae and anti-aging therapies, with studies reporting improvements in pigmentation, elasticity, and fine lines. Recent small studies also suggest potential benefits for hair loss and vitiligo through follicle stimulation and melanocyte protection. Topical *C. asiatica* is generally well tolerated. Adverse reactions are uncommon, with rare case reports describing allergic contact dermatitis after use. Although larger-scale clinical studies are needed, existing evidence suggests that *C. asiatica* is a versatile and well-tolerated botanical with growing importance in dermatology and skin care.

INTRODUCTION

Centella asiatica, also known as "cica" or "Gotu Kola" among other names, is a medicinal herb widely used in Ayurvedic, Chinese, and Unani traditions. It belongs to the Apiaceae family, which includes about 20 species.[1] Native to tropical and subtropical regions, including Southeast Asia, India, South America, and parts of Africa, it has been traditionally used for wound healing and treating skin conditions like lupus, eczema, and psoriasis.[1] Its long-standing presence in traditional medicine underscores its growing relevance in modern dermatologic and integrative therapies.

BOTANICAL AND CHEMICAL PROFILE OF CENTELLA ASIATICA

The dermatologic activity of *C. asiatica* is mediated by multiple classes of bioactive phytochemicals. The most extensively studied constituents are pentacyclic triterpenoids—collectively referred to as centelloids—including asiaticoside, madecassoside, asiatic acid, and madecassic acid (Table 1).[2] These compounds drive the wound-healing, anti-inflammatory, antifibrotic, and barrier-repair effects of *C. asiatica* through well-described molecular pathways, including stimulation of fibroblast proliferation, upregulation of collagen synthesis, enhancement of angiogenesis, and modulation of pro-inflammatory cytokine signaling.[2] Collectively, these mechanisms form the pharmacologic basis for the widespread use of *C. asiatica* in dermatologic and cosmeceutical formulations.

In addition to triterpenoids, *C. asiatica* contains polyphenolic compounds, particularly flavonoids, which contribute to its antioxidant, anti-inflammatory, anti-microbial, and photoprotective properties.[20] One key anti-inflammatory mechanism involves the inhibition of eicosanoid-generating enzymes, such as phospholipase A2, cyclooxygenases, and lipoxygenases, which reduces the concentrations of pro-inflammatory prostanoids and leukotrienes.[21] The antibacterial effects of flavonoids include disrupting bacterial cell membranes, inhibiting key enzymatic processes, and suppressing efflux pumps, thereby impeding bacterial growth and causing cell death in both Gram-positive and Gram-negative bacteria.[22] The conjugated double bonds of flavonoids enable them to ab-

Table 1. Key Active Compounds in *Centella asiatica* and Their Dermatologic Effects

Compound	*Mechanism of Action*	*Key Benefits*
Asiaticoside[3]	Promotes collagen synthesis, wound healing	Wound healing, anti-inflammatory
Madecassoside[4]	Reduces inflammation, anti-oxidant, improves skin barrier	Anti-acne, anti-inflammatory
Asiatic acid[5]	Stimulates fibroblast proliferation and collagen I/III	Wound healing, scar modulation
Madecassic acid[6]	Reduces oxidative stress	Anti-aging, antioxidant

Table 2. In vitro and preclinical studies of *Centella asiatica* in dermatology

Study Type/ Model	*Relevant Dermatologic Condition*	*Main Outcomes*	*Key Mechanisms*
Imiquimod mouse, cell models[7]	Psoriasis	Increased antioxidant enzymes (glutathione, superoxide dismutase), reduced pro-inflammatory cytokines (IFN-γ, IL-6, TNF-α), improved skin barrier proteins (aquaporin-3, filaggrin)	Antioxidant effects, barrier restoration, inhibition of JAK/STAT3 and NF-κB pathways
Phthalic anhydride[8]**– and DNCB–induced mouse models**[9]	Atopic dermatitis	Reduced epidermal thickness and mast cell infiltration; decreased inflammatory cytokines (TNF-α, IL-6)	NF-κB inhibition, anti-inflammatory and immunomodulatory effects
In vitro cell models, UVB guinea pig[10,11]	Skin Lightening	Reduced tyrosinase activity (IC_{50} 18.85 μg/mL), decreased melanin content, lowered MITF expression	Tyrosinase inhibition, melanogenesis modulation
In vitro[12]	Hair Loss	Increased human dermal papilla cell viability and volume, upregulated hair follicle-related genes in 3D cultures	Follicle stimulation, gene expression enhancement
Guinea pig[13]	Vitiligo	10% cream increased epidermal melanin in guinea pigs; madecassoside protected human melanocytes from oxidative damage	Antioxidant activity, autophagy support, mitochondrial protection

IFN-γ: Interferon gamma, IL-6: Interleukin 6, TNF-α: Tumor necrosis factor alpha, JAK: Janus kinase, STAT3: Signal transducer and activator of transcription 3, NF-κB: Nuclear factor kappa-light-chain-enhancer of activated B cells, DNCB: 2,4-dinitrochlorobenzene, UVB: Ultraviolet B, IC_{50}: Half maximal inhibitory concentration, MITF: Microphthalmia-associated transcription factor, 3D: Three-dimensional

sorb UV-A and UV-B radiation.[22] In addition to UV absorption, flavonoids act as direct and indirect antioxidants, scavenging reactive oxygen species generated by UV exposure—mechanisms particularly relevant to photoaging, and pigmentary disorders.[23] Understanding these mechanisms of action helps to contextualize the diverse observed clinical and preclinical effects of *C. asiatica* across dermatologic indications.

METHODS

This manuscript is a narrative literature review examining the dermatologic activity and applications of *C. asiatica.* A literature review was conducted using the PubMed and Google Scholar databases to identify relevant studies published from January 2014 through September 2025. Search terms included "*Centella asiatica,*" "Gotu Kola," and "cica," combined with "dermatology," "skin," and "wound healing." Eligible articles included human clinical studies, animal models, and in vitro investigations evaluating dermatologic outcomes or relevant mechanisms of action of *C. asiatica* or its bioactive compounds. Only English-language, peer-reviewed publications were included. Studies focusing exclusively on non-cutaneous indications or lacking primary experimental or clinical data were excluded. Titles and abstracts were screened for relevance, and full texts were reviewed when appropriate. Given the narrative design of this review, no formal risk-of-bias or quality assessment was performed. Funding sources were not consistently reported across the included studies.

BENEFITS OF CENTELLA ASIATICA IN SKINCARE

WOUND HEALING

Asiaticoside is one of the key compounds involved in wound healing. Preclinical studies suggest asiaticoside and asiatic acid promote wound healing by enhancing fibroblast proliferation and collagen synthesis.[24] In diabetic and ischemic wound models, *C. asiatica* compounds improved vascularization and reduced inflammation.[25] While most data are from in vitro or animal models, emerging evidence supports its use in post-procedural wound care and chronic ulcers.

ANTIMICROBIAL ACTIVITY

With rising antimicrobial resistance, interest in plant-based alternatives has grown, including *C. asiatica*. Preliminary in vitro studies show ethanol extracts of *C. asiatica* have

Table 3. Clinical and in vivo studies of *Centella asiatica* in dermatology

Dermatologic Condition	*Intervention*	*Control/Placebo*	*Main Outcomes*	*Adverse Events*
Keloids[14]	Prospective study (n = 129): oral Centellicum® 225 mg BID × 4 weeks + standard care	Standard care alone	Smoother, more uniform scars on ultrasound ($p < 0.05$)	None reported
Acne[15]	Meta-analysis of 875 patients: topical and/or oral *C. asiatica* formulations	Placebo and/or standard therapy in most trials	Reduced lesion counts (mean difference −0.54)	Mild irritation, redness
Rosacea[16]	Randomized controlled trial (n = 64): topical *C. asiatica* facial mask 3×/week + oral minocycline and hydrating cream for 6 weeks	Standard therapy alone	Improved dryness, flushing, and lesion counts ($p < 0.05$)	None reported
Stretch Marks[17]	Controlled studies: postpartum women using topical *C. asiatica* powder; fractional CO_2 laser combined with *C. asiatica* cream (n = 22)	No-treatment control (powder study); laser alone (combination study)	Powder: marks faded in 90% vs 30% controls; laser + cream improved severity, QoL, and pain ($p < 0.05$)	Mild irritation possible
Photoaging[18]	Clinical trials: topical ampoule containing *C. asiatica*-derived exosomes for 15 days	Not specified	Reduced pore size (−17.9%), wrinkle depth (−18.8%), increased hydration and dermal density	None reported
Nonscarring Hair Loss[19]	Controlled study: daily *C. asiatica* lotion applied for 4–8 weeks in mild-to-moderate AGA and telogen effluvium	Not specified	Decreased hair shedding by 41%, improved hair strength	None reported

AGA: androgenic alopecia, BID: Twice daily, *C. asiatica*: *Centella asiatica*, CO_2: Carbon dioxide, n: Sample size, p: Probability value (statistical significance), QoL: Quality of life, RCT: Randomized controlled trial.

antibacterial properties against several human pathogens, with notable potency against certain Gram-negative species, but also—of particular relevance to dermatology—against Gram-positive organisms including *Staphylococcus aureus* and *Streptococcus pyogenes*. Additionally, aqueous extracts have demonstrated antifungal effects against species such as *Cladosporium*, *Aspergillus,* and *Penicillium*.[26]

ANTIOXIDANT ACTIVITY

As discussed above, *C. asiatica* is rich in flavonoids, which exert potent antioxidant effects against free radicals. In vitro, aqueous extracts effectively scavenge DPPH (2,2-diphenyl-1-picrylhydrazyl) free radicals.[27] However, ethanol extracts often show stronger antioxidant activity.[28] These antioxidants act by reducing reactive oxygen species, neutralizing free radicals, and chelating metal ions. Such mechanisms are particularly relevant in skin aging, photodamage, and inflammatory dermatoses, where oxidative stress plays a key pathogenic role.

ANTI-INFLAMMATORY ACTIVITY

C. asiatica has shown anti-inflammatory effects in preclinical models by reducing levels of pro-inflammatory mediators such as interleukin-1β (IL-1β), interleukin-6 (IL-6), tumor necrosis factor-α (TNF-α), prostaglandin E2 (PGE2), and by inhibiting cyclooxygenase-2 (COX-2) and lipoxygenase (LOX) activity.[29] These actions could explain reported clinical benefits in inflammatory skin disorders, including acne, psoriasis, and eczema.

KELOIDS

Traditionally, *C. asiatica* has been used in the treatment of keloid scars. *C. asiatica* may modulate excessive collagen production in keloids by inhibiting transforming growth factor β1 (TGF-β1) and plasminogen activator inhibitor 1, factors involved in fibrosis and scar persistence.[29]

A prospective study of 129 patients with a history of hypertrophic or keloid scars following abdominal or knee surgery compared oral Centellicum® (225 mg twice daily) plus standard care to standard care alone for four weeks after surgery.[14] Patients receiving Centellicum® developed significantly smoother and more uniform scars on ultrasound assessment ($p < 0.05$), with no reported side effects. These findings suggest that oral *C. asiatica* may be a safe and effective option to improve scar healing in at-risk patients.

ACNE

Acne is one of the most common skin conditions worldwide, and *C. asiatica* is gaining attention for its potential as a natural treatment. Its effectiveness is largely attributed to its anti-inflammatory, antibacterial, and skin-regenerating properties. Key bioactive compounds in *C. asiatica*, such as asiatic acid and madecassic acid, have been shown to inhibit the growth of *Cutibacterium acnes* (formerly *Propioni-*

bacterium acnes), a key contributor to acne development. A recent meta-analysis reported a pooled mean difference of −0.54 (95% CI: −0.67 to −0.41) in acne lesion counts, favoring *C. asiatica.*[15] However, differences in how lesions were measured across studies and the use of varying control groups make the practical significance of this estimate uncertain.[15] Minimal side effects were reported: primarily mild irritation and redness.

Madecassoside and asiatic acid reduce inflammatory signaling via toll-like receptor 2 (TLR2) and nuclear factor kappa B (NF-κB) pathways. Several in vitro studies demonstrate *C. acnes* bacterial suppression at concentrations ranging from 31.25 μg/mL to 15 mg/mL.[27-29] A meta-analysis of 875 patients involving both topical and oral formulations reported modest but statistically significant reduction in acne lesion count, though heterogeneity in study design and outcome measures limits definitive conclusions regarding clinical efficacy.[15] Formulations combining *C. asiatica* with cannabidiol have shown enhanced anti-acne effects in skin models.[30]

Overall, current evidence supports *C. asiatica* as a potentially useful adjunctive therapy rather than a stand-alone acne treatment.

PSORIASIS

Preclinical studies suggest *C. asiatica* may benefit psoriasis by enhancing antioxidant defenses, reducing inflammation, and restoring the skin barrier. In in vitro and imiquimod-induced mouse models, the ethyl acetate extract increased glutathione and superoxide dismutase levels, reduced reactive oxygen species, and downregulated key pro-inflammatory mediators such as IFN-γ, IL-6, and TNF-α.[7] It also boosted skin barrier proteins, including aquaporin-3 and filaggrin. These effects were linked to inhibition of NF-κB and JAK/STAT3 signaling, resulting in less scaling, erythema, and crusting. While promising, these findings are from experimental models and require confirmation in human trials.

ROSACEA

In a six-week randomized controlled trial of 64 rosacea patients, incorporating a *C. asiatica* facial mask three times a week with standard therapy (oral minocycline plus hydrating cream) led to significantly greater reductions in overall severity, dryness, flushing, and lesion counts at 3 and 6 weeks compared to standard therapy alone ($p < 0.05$).[16] Improvement in flushing was particularly marked ($p = 0.037$), and no adverse effects were reported. These results suggest that topical *C. asiatica* may be a safe, well-tolerated adjunct for enhancing skin hydration and reducing inflammation in rosacea.

ECZEMATOUS DERMATITIS

C. asiatica has shown potential benefit in eczematous conditions, including atopic dermatitis, largely through its anti-inflammatory effects and support of the skin barrier. In a phthalic anhydride–induced mouse model—using a chemical sensitizer to trigger allergic, eczema-like skin inflammation—topical *C. asiatica* reduced epidermal thickening and inflammatory cell infiltration, along with decreased NF-κB activity and lower levels of iNOS, COX-2, TNF-α, IL-1β, and IgE.[8] In a DNCB (2,4-dinitrochlorobenzene)–induced mouse model, another commonly used chemical allergen model of atopic dermatitis, treatment with *C. asiatica* ethanol extract reduced ear swelling and inflammatory infiltrates, with associated reductions in TNF-α and IL-6.[9] However, evidence is limited to preclinical models, and *C. asiatica* should currently be viewed as a potential adjunctive, not primary, therapy in atopic dermatitis.

STRETCH MARKS

C. asiatica, alone or with procedural therapy, can improve the appearance of striae, skin texture, and comfort. Boira et al demonstrated that topical *C. asiatica* extract restores dermal architecture in stretch marks by promoting fibroblast migration, downregulating fibrosis markers, reorganizing collagen fibers, and enhancing elastin synthesis.[31] These findings suggest a mechanistic basis for the clinical improvements in stretch mark appearance and skin elasticity observed with Centella-based formulations.

In a 2023 study of postpartum women, applying *C. asiatica* powder visibly faded stretch marks in 90% of the intervention group versus 30% of controls who received only health education. Combining fractional CO_2 laser with topical *C. asiatica* in 22 patients with stretch marks produced significant improvements in severity scores ($p = 0.014$), quality of life ($p < 0.001$), and pain ($p < 0.001$) over 12 weeks.[17]

HYPERPIGMENTATION

Although no human studies have been identified in the literature, multiple in vitro studies have shown promise for the application of *C. asiatica* in disorders of hyperpigmentation. Asiaticoside-rich extracts of *C. asiatica* may reduce pigmentation by inhibiting tyrosinase activity (IC_{50} 18.85 μg/mL) and modulating melanin pathways in keratinocytes, melanocytes, fibroblasts, and endothelial cells.[10] In a UVB-induced hyperpigmentation model in guinea pigs, 10% *C. asiatica* cream significantly lowered melanin content and Microphthalmia-associated Transcription Factor—a key regulator of melanogenesis—expression compared to controls (both $p < 0.001$).[11] While these results suggest potential skin-lightening effects through multiple steps in melanin synthesis, clinical trials in humans are needed for further characterization.

ANTI-PHOTOAGING

Multiple human trials and in vitro studies support the anti-photoaging and regenerative potential of *C. asiatica*. A systematic review of five double-blind randomized controlled trials (172 women) found that *C. asiatica*-based creams and gels, including asiaticoside formulations, reduced periorbital and lip wrinkles, improved hydration, and caused fewer adverse events than tretinoin.[32] In a recent trial, a

topical ampoule containing *C. asiatica*-derived exosomes was used for 15 days, reducing pore size by 17.9%, wrinkle depth by up to 18.8%, and increasing dermal hydration and density, with excellent tolerability.[18] These outcomes were objectively measured using 3D imaging (Antera 3D®), tissue dielectric constant probes (MoistureMeter D®), and ultrasound devices (Ultrascan UC22®, DUB® SkinScanner).

Mechanistic studies show strong antioxidant activity measured by DPPH and ABTS antioxidant capacity assays, inhibition of collagenase (78%) and elastase (12%), as well as protection of fibroblasts from oxidative stress and reduced matrix metalloproteinase-9 expression.[33,34] Together, these findings suggest *C. asiatica* can protect skin structure, enhance barrier function, and improve visible signs of photoaging.

Many commercially available products marketed as "cica," the common cosmetic industry term for *C. asiatica*, vary substantially in composition, concentration, and extraction methods, and may not be directly comparable to standardized pharmacologic extracts such as titrated extract of *C. asiatica* (TECA) used in experimental studies. Accordingly, reported cosmetic and anti-aging benefits should be interpreted with caution, and outcomes may not be generalizable across different formulations.

HAIR GROWTH

C. asiatica has garnered attention for its potential to nourish hair follicles and the scalp, strengthening hair fibers and reducing hair loss and breakage.[35] In a controlled study involving individuals with mild-to-moderate androgenic alopecia and telogen effluvium, daily application of a *C. asiatica*-based lotion for 4 to 8 weeks led to a 41% reduction in hair shedding and significant improvements in hair strength, as measured by pull and wash tests.[19] This early clinical data is supported by cellular and molecular findings.

One study investigated the effects of the titrated extract of *C. asiatica* (TECA) on human dermal papilla (HDP) cells, key regulators of hair follicle development, suggesting that TECA significantly enhanced HDP cell viability and volume in 3D cultures, which better simulate in vivo conditions.[12] Simultaneously, it upregulated several genes involved in promoting hair follicle function and regeneration. These findings highlight *C. asiatica* and its active components as a botanical agent with potential in improving scalp health, reinforcing hair structure, and as a natural adjunctive therapy for androgenic alopecia and telogen effluvium, acting through multiple synergistic pathways to enhance follicle vitality and hair regrowth. However, while early clinical and mechanistic data are encouraging, available studies are limited by short duration and small sample sizes, and the role of *C. asiatica* in hair loss should currently be considered adjunctive and investigational.

VITILIGO

While direct clinical evidence is not yet available, preclinical data suggest that *C. asiatica*, specifically its active compound madecassoside, may support melanocyte health and mitigate oxidative stress in vitiligo. In a guinea pig vitiligo model, a 10% *C. asiatica* extract cream significantly increased epidermal melanin compared to controls ($p < 0.05$).[13] In vitro, madecassoside protected human melanocytes from H_2O_2-induced damage by preserving dendrite morphology, stabilizing mitochondrial membrane potential, reducing intracellular calcium accumulation, and enhancing autophagy, as indicated by increased LC3-II/LC3-I ratio and ultrastructural evidence of mitochondrial integrity.[13] Together, these findings suggest a potential adjunctive role in vitiligo management pending confirmation in human clinical studies.

REGULATORY AND FORMULATION CONSIDERATIONS

Botanical products such as *C. asiatica* are chemically complex and naturally variable, making standardization difficult. Oral formulations are commonly marketed as dietary supplements and may be sold without pre-market demonstration of efficacy, leading to variability in extraction methods and active compound content.[36] Topical formulations, typically regulated as cosmetic products, also vary widely in concentration and formulation.[36] These regulatory and formulation differences may contribute to inconsistent clinical outcomes and should be considered when interpreting study results.

ADVERSE EFFECTS AND SAFETY CONSIDERATIONS

Topical *C. asiatica* is generally well tolerated, with low rates of irritation or sensitization reported in human studies using low-concentration extracts (0.018–0.2%).[37] Rare cases of allergic contact dermatitis with positive patch testing have been described, suggesting potential sensitization to extract components; clinicians should consider this in patients presenting with dermatitis temporally associated with "cica"-containing products.[37] Product variability remains an important consideration. Commercial "cica" formulations differ substantially in extract composition, triterpenoid concentration, vehicle, and purity, whereas pharmacologically studied preparations such as titrated extracts of *Centella asiatica* (TECA) are standardized to defined triterpenoid fractions.[12,35] Such heterogeneity may influence both efficacy and tolerability and limit extrapolation of clinical trial findings to all marketed products. Additionally, as with other herbal preparations, heavy-metal contamination has been reported in some plant-derived supplements, highlighting the importance of reputable sourcing and regulatory oversight, particularly for oral formulations.[35]

LIMITATIONS AND FUTURE DIRECTIONS

The current evidence supporting dermatologic applications of *C. asiatica* has several important limitations. Many studies involve small sample sizes, short treatment durations,

or rely on in vitro and animal models, which may not fully translate to clinical practice. Substantial heterogeneity exists across studies regarding extract type, triterpenoid concentration, formulation, route of administration, and outcome measures, complicating direct comparisons and the interpretation of pooled analyses.

Future research should prioritize well-designed, adequately powered randomized controlled trials using standardized extracts and clinically meaningful endpoints. Longer-term safety data and clearer regulatory standards for both topical and oral formulations will be essential to better define the therapeutic role of *C. asiatica* in dermatology.

CONCLUSION

C. asiatica is packed with potentially beneficial compounds—asiaticoside, madecassoside, and asiatic acid—that modulate inflammation, combat free radicals, and promote tissue repair. Clinical and preclinical studies illustrate growing evidence for its potential role in diverse dermatologic conditions, including acne, rosacea, psoriasis, stretch marks, vitiligo, photoaging, and nonscarring hair loss. Its mechanisms of action include stimulating collagen synthesis, enhancing skin barrier function, soothing irritation, and protecting melanocytes from oxidative stress. Widely and increasingly recognized in modern skincare (particularly in Korean skincare and beauty) as "cica," it is gaining a reputation as a calming and repairing agent for sensitive skin. While further human studies are needed, scientific investigations are unraveling the mechanistic details to support this centuries-old ingredient. We predict *C. asiatica* will continue to grow in popularity and applications in dermatology; awareness of its expanding evidence-based benefits is key for dermatologists.

ABBREVIATIONS

C. asiatica: Centella asiatica, CICA: Centella asiatica (skincare term), DPPH: 2,2-diphenyl-1-picrylhydrazyl, IL-1β: Interleukin-1 beta, IL-6: Interleukin-6, TNF-α: Tumor necrosis factor alpha, PGE2: Prostaglandin E2, COX-2: Cyclooxygenase-2, LOX: Lipoxygenase, TGF-β1: Transforming growth factor beta-1, CI: Confidence interval, TLR2: Toll-like receptor 2, NF-κB: Nuclear factor kappa-light-chain-enhancer of activated B cells, IFN-γ: Interferon gamma, JAK/STAT3: Janus kinase / Signal transducer and activator of transcription 3, CO_2 laser: Carbon dioxide laser, IC_{50}: Half maximal inhibitory concentration, UVB: Ultraviolet B, RCTs: Randomized controlled trials, 3D: Three-dimensional, ABTS: 2,2′-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid), TECA: Titrated extract of Centella asiatica, HDP: Human dermal papilla (cells), H_2O_2: Hydrogen peroxide, LC3-II/LC3-I: Microtubule-associated protein 1A/1B-light chain 3.

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CONFLICTS OF INTEREST

None declared.

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