

Efficacy and safety of microneedling with tacrolimus and tofacitinib on vitiligo patients

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Abstract

Vitiligo is an acquired, chronic pigmentary condition in which melanocytes are progressively destroyed, producing sharply outlined patches of depigmented skin. While it carries no direct threat to physical health, the disorder can take a considerable emotional and social toll on those affected. Standard treatment options — topical steroids, calcineurin inhibitors, light-based therapy, and surgical repigmentation — do not consistently succeed, especially once lesions become long-standing or resistant to therapy. One technique gaining traction as an adjunct is microneedling, a minimally invasive method that improves drug penetration through the skin, triggers local growth-factor release, and encourages melanocytes to migrate and multiply. When paired with topical agents such as the calcineurin inhibitor tacrolimus or the JAK inhibitor tofacitinib, this approach has produced encouraging results in a growing number of clinical reports.

Here we bring together the available evidence on combining microneedling with tacrolimus or tofacitinib for vitiligo management. Studies published from 2015 through 2026 were identified through searches of PubMed, Scopus, Embase, and Google Scholar. Taken together, the literature indicates that microneedling boosts repigmentation chiefly by improving local drug penetration and supporting melanocyte regrowth. Combination therapy with tacrolimus has performed particularly well on the face and in localized disease, whereas tofacitinib — which works by blocking the JAK-STAT pathway responsible for autoimmune melanocyte loss — appears useful even in lesions resistant to other treatments. Both approaches were generally well tolerated, with the main adverse effects being short-lived redness, discomfort, swelling, and irritation after the procedure.

Keywords: Vitiligo, Microneedling, Tacrolimus, Tofacitinib, JAK inhibitor, Repigmentation, Topical therapy, Comprehensive review.

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INTRODUCTION

In vitiligo, melanocytes within the epidermis are gradually lost, leaving behind clearly bordered patches of depigmented skin. The condition is thought to affect roughly 0.5–2% of people worldwide and can develop at any age, in either sex, and across all ethnic backgrounds. It does not shorten life expectancy, but its cosmetic and social consequences are substantial — many patients report anxiety, depressive symptoms, diminished self-esteem, and a reduced quality of life, particularly when depigmentation affects visible sites like the face, hands, or neck (1,2).

How vitiligo develops is still not fully worked out, and most researchers regard it as having several

contributing causes. The leading explanation involves autoimmunity, whereby autoreactive CD8+ T cells target and eliminate melanocytes. Additional proposed contributors include oxidative stress, an inherited predisposition, neurogenic influences, elevated inflammatory cytokines, and impaired melanocyte adhesion. More recently, attention has turned to the JAK-STAT signaling cascade — especially interferon- γ -driven immune activity — as a key driver of disease onset and progression (3–5). Treating vitiligo is not straightforward, since outcomes depend heavily on how active the disease is, how long it has been present, where lesions are located, and individual patient factors. The standard

toolkit includes topical steroids, calcineurin inhibitors like tacrolimus, vitamin D derivatives, narrowband UVB phototherapy, excimer laser, systemic immunosuppressants, and surgical grafting for disease that has stabilized. Even so, many patients — especially those with lesions on the hands and feet or with treatment-resistant disease — do not achieve full or lasting repigmentation with these options (6–8).

Among newer options, microneedling — the creation of tiny, controlled punctures in the skin using fine sterile needles — has drawn interest as a low-risk dermatologic procedure. The micro-injuries it produces allow topical drugs to penetrate more effectively while also setting off wound-healing processes such as collagen formation, new blood vessel growth, and the release of several growth factors. In the context of vitiligo, this is thought to help melanocytes migrate in from nearby pigmented skin and hair follicles, working alongside improved drug delivery to support repigmentation (9–11).

Tacrolimus, applied topically, dampens T-cell activity and reduces output of the inflammatory cytokines implicated in melanocyte loss. It has an advantage over prolonged corticosteroid use in that it does not thin the skin, making it a reasonable choice for delicate regions such as the face, neck, and skin folds. A number of trials have found that pairing tacrolimus with microneedling yields better repigmentation than tacrolimus used alone (12–15).

Tofacitinib, a JAK1/JAK3 inhibitor, has been increasingly explored for autoimmune skin conditions because it interrupts interferon- γ signaling and thereby limits the immune attack on melanocytes.

A limited case reports and early clinical studies point to meaningful repigmentation when topical tofacitinib is used — especially alongside microneedling or phototherapy — in patients whose vitiligo is stable but has not responded to other treatments (16–19). Vitiligo is an autoimmune, disfiguring skin disease that manifests as a non-scaly, amelanotic, chalky-white macule with distinct margins.(20)

According to the international consensus, vitiligo is classified into two major classes: nonsegmental vitiligo (NSV) and segmental vitiligo (SV), as they differ in their prognostic implications.¹ Worldwide, vitiligo is a common disease with an estimated prevalence of 0.5-2% in both the adult and pediatric populations.(21)

Pairing microneedling with either drug makes sense both in theory and in practice: by bypassing the outermost skin barrier, microneedling lets more of the topical drug reach its target, while at the same time it drives epidermal renewal and promotes melanocytes to proliferate and move into depigmented areas. Together, these effects may improve outcomes

without raising the amount of drug absorbed systemically (22).

Still, the published data are far from uniform — studies differ in design, treatment protocol, needling depth, session frequency, follow-up length, and how outcomes are measured. Sample sizes tend to be small, and few studies directly compare the tacrolimus- and tofacitinib-based combinations against each other. Pulling this evidence together is therefore useful, both to guide current practice and to point toward gaps that future research should address (23–25).

The aim of this review is to bring together what is currently known about combining microneedling with topical tacrolimus or tofacitinib for vitiligo, covering mechanism of action, clinical results, safety, practical advantages, the limitations of the existing literature, and directions for future work on optimizing this combined approach (26–30).

MATERIALS AND METHODS

Study Design

This narrative review set out to bring together current evidence on the efficacy and safety of combining microneedling with topical tacrolimus or tofacitinib for vitiligo.

Data Sources

Literature was identified through structured searches of the following databases:

- PubMed/MEDLINE
- Scopus
- Embase
- Google Scholar
- Cochrane Library

Search Strategy

Searches were limited to articles published from January 2015 through June 2026, using the following MeSH terms and free-text keywords, alone and in combination:

- "Vitiligo"
- "Microneedling"
- "Percutaneous collagen induction"
- "Tacrolimus"
- "Topical tacrolimus"
- "Tofacitinib"
- "Topical tofacitinib"
- "JAK inhibitor"
- "Repigmentation"
- "Combination therapy"
- "Vitiligo treatment"

These terms were combined using the Boolean operators AND and OR to sharpen the search.

Inclusion Criteria

Studies were eligible for inclusion if they met the following criteria:

- Original clinical research assessing microneedling used with topical tacrolimus and/or tofacitinib in vitiligo patients.
- Randomized controlled trials.
- Prospective and retrospective observational studies.
- Comparative clinical studies.
- Pilot studies and case series with adequate clinical outcome data.
- Studies published in English.
- Human studies involving patients of any age and either sex.

Exclusion Criteria

Studies were excluded if they were:

- Conducted in animals or in vitro.
- Reviews, editorials, letters, or opinion pieces.
- Conference abstracts lacking full data.
- Duplicate reports of the same dataset.
- Missing clinical outcome or safety data.
- Published in a language other than English.

Study Selection

Titles and abstracts retrieved from the searches were screened, and full texts of potentially eligible articles were then reviewed in detail; studies meeting the inclusion criteria were retained for qualitative synthesis.

Data Extraction

For each included study, the following data were recorded:

- Patient characteristics
- Type of vitiligo
- Treatment protocol
- Microneedling device and treatment interval
- Duration of follow-up
- Degree of repigmentation
- Adverse events
- Major conclusions

Outcome Measures

Primary outcomes of interest were:

- Percentage of repigmentation
- Improvement in Vitiligo Area Scoring Index (VASI)
- Time to onset of repigmentation
- Patient satisfaction
- Clinical response rate

Secondary outcomes were:

- Local adverse effects
- Treatment tolerability
- Disease recurrence
- Overall safety profile

Data Synthesis

Given wide variation across studies in design, treatment protocol, and outcome measures, the findings were synthesized narratively rather than pooled statistically. Studies were compared on

efficacy, safety, clinical response, and adverse events, with the goal of highlighting overall trends, therapeutic benefits, current limitations, and priorities for future research.

RESULTS

This review drew on published clinical research evaluating microneedling combined with either topical tacrolimus or topical tofacitinib in vitiligo, published between 2015 and 2026. The evidence base was dominated by randomized controlled trials, prospective comparative studies, observational cohorts, pilot studies, and case reports, most enrolling patients with stable, non-segmental disease.

Across studies, adding microneedling to topical tacrolimus consistently boosted its clinical effect, apparently by improving transdermal delivery and encouraging melanocyte migration; repigmentation was better than with tacrolimus alone, most notably on the face and neck. Combination therapy was also linked to earlier visible repigmentation, larger gains on VASI scoring, and higher patient satisfaction in several studies.

A similar pattern emerged for microneedling combined with topical tofacitinib, with encouraging results even in lesions that were resistant to other treatments. By enhancing tofacitinib's penetration into the skin, microneedling appeared to speed the clinical response and produce more pigmentation than topical tofacitinib alone, with the benefit becoming more apparent after several months of continued treatment.

Regardless of which topical agent was used, facial lesions responded best, followed by those on the neck and trunk; lesions on the hands and feet lagged behind. Repeated sessions tended to produce cumulative improvement over time.

Both combinations were generally safe. Reported side effects were mostly limited to brief redness, mild procedural discomfort, a burning sensation, localized swelling, and temporary irritation, all of which resolved on their own.

Taken as a whole, the evidence suggests microneedling is a useful adjunct that strengthens the effect of both tacrolimus and tofacitinib without compromising safety. That said, the literature remains constrained by small cohorts, inconsistent protocols, and relatively short follow-up.

DISCUSSION

Vitiligo can be understood as an autoimmune process that selectively eliminates epidermal melanocytes, producing patches of depigmentation that may enlarge with time. It rarely causes physical impairment, yet the psychosocial burden can be significant: patients commonly describe distress, lowered self-esteem, anxiety, and depressive symptoms tied to the visible nature of the

disfigurement, particularly when the face, hands, or neck are affected (1,2). For this reason, modern treatment goals extend beyond restoring pigment to also addressing patients' emotional wellbeing and overall quality of life.

A growing understanding of what drives vitiligo has pushed treatment away from broad immunosuppression and toward more targeted immune modulation. The autoimmune model — involving autoreactive CD8⁺ T cells, interferon- γ , the chemokines CXCL9 and CXCL10, oxidative stress, and JAK-STAT pathway activation — continues to be the dominant explanatory framework. This mechanistic insight has spurred development of targeted agents like JAK inhibitors, alongside growing interest in procedural adjuncts such as microneedling to improve treatment response (3–5).

Also called collagen induction therapy, microneedling was originally developed to treat scars and rejuvenate skin, but its use has since broadened to alopecia, enhancing drug delivery, and pigmentary conditions like vitiligo. Fine sterile needles create numerous tiny channels across the epidermis; these transiently breach the stratum corneum, allowing topical medications to reach deeper skin layers far more effectively than they otherwise would. The procedure also sets off a wound-healing response — platelet activation, fibroblast growth, collagen deposition, new vessel formation, and release of assorted cytokines and growth factors — that supports tissue regeneration (6).

Microneedling's benefit in vitiligo is not limited to better drug absorption. Deliberately injuring the epidermis appears to trigger release of several growth factors — PDGF, TGF- β , VEGF, EGF, and FGF — which together drive keratinocyte growth, pull melanocytes in from adjacent pigmented skin and hair follicles, and help rebuild the epidermal pigment unit. Because hair follicles house a reservoir of melanocyte stem cells, areas rich in follicles — such as the face — tend to repigment more readily than follicle-sparse regions like the hands and feet (7,8).

A key strength of microneedling is that it gets around the stratum corneum's natural barrier function, which otherwise limits how well topical drugs penetrate intact skin. The temporary microchannels it creates raise local drug availability without meaningfully increasing systemic absorption — a distinction that matters for agents like tacrolimus and tofacitinib, whose effectiveness hinges on reaching adequate concentrations locally. This is likely why combination regimens have outperformed topical monotherapy in numerous published studies (9,10).

Among non-steroidal options for localized vitiligo, topical tacrolimus stood out in the reviewed literature, particularly when combined with

microneedling. As a calcineurin inhibitor, it blocks calcineurin from dephosphorylating NFAT, which in turn curbs T-cell activation and lowers output of inflammatory mediators such as IL-2, interferon- γ , and TNF- α — reducing the immune assault on melanocytes. Because it avoids the skin thinning, visible blood vessels, and stretch marks associated with long-term corticosteroid use, tacrolimus is well suited to prolonged treatment of sensitive areas like the face, eyelids, neck, and skin folds (11–13).

A number of investigators have found that microneedling plus tacrolimus outperforms tacrolimus alone, an effect attributed mainly to better drug penetration through the induced microchannels, along with a wound-healing environment conducive to melanocyte growth and movement. Studies in this review consistently reported that combination-treated patients repigmented sooner, achieved a greater percentage of repigmentation, and reported higher satisfaction than those on tacrolimus monotherapy (14,15).

How well microneedling-plus-tacrolimus worked depended heavily on lesion site: facial lesions did best, often reaching near-complete repigmentation after multiple sessions, followed by neck and trunk lesions, while acral sites — hands, feet, fingers, toes — proved more stubborn. This gradient likely reflects regional differences in melanocyte stem-cell density, blood supply, and follicular density, since dormant melanocytes housed in hair follicles migrate outward during successful treatment, favoring follicle-dense regions (16,17).

JAK inhibitors have become a major focus of vitiligo research since the recognition that interferon- γ -driven activation of the JAK-STAT pathway is central to melanocyte destruction. Tofacitinib, which selectively blocks JAK1 and JAK3, interrupts the intracellular signaling that activates autoreactive cytotoxic T cells; this eases the immune attack on melanocytes and allows repigmentation to proceed wherever surviving melanocytes or their stem cells remain (18).

Combining topical tofacitinib with microneedling looks promising, especially for stable, treatment-resistant vitiligo, even though far fewer studies exist for this pairing than for tacrolimus. Microneedling helps tofacitinib penetrate the skin more effectively, achieving higher local concentrations while keeping systemic exposure low, and several authors described gradually increasing pigmentation with repeated sessions extended over several months (19).

A recurring theme in the literature is the complementary relationship between microneedling and immunomodulatory drugs: microneedling drives epidermal repair and melanocyte movement, while tacrolimus and tofacitinib dampen the autoimmune

processes destroying melanocytes in the first place. Because this covers both the regenerative and immunological sides of vitiligo, combination approaches tend to outperform single-pathway interventions — a pattern increasingly seen as important across chronic autoimmune skin diseases generally (20).

Combination-treated patients also tended to see visible pigment return sooner than those on topical treatment alone. That earlier response matters practically, since it builds patient confidence, supports adherence, and boosts satisfaction — important given that vitiligo treatment typically stretches over many months, and early visible progress helps keep patients from abandoning therapy prematurely (21).

Reported patient satisfaction with either combination was consistently high, and gains in pigmentation were often paired with improved confidence, less social discomfort, and better overall quality of life. These psychological gains carry particular weight since vitiligo frequently affects young adults and people whose work involves regular public contact, and restoring pigment in visible areas like the face can meaningfully improve emotional and social functioning (22).

The reviewed studies repeatedly stressed that disease should be stable before microneedling-based treatment begins, since stable vitiligo responds better than actively progressing disease. Stable lesions are more likely to retain functioning melanocyte reservoirs and face less ongoing immune attack, creating a more favorable setting for repigmentation — making careful patient selection a key factor in outcomes (23).

On a practical level, microneedling is technically simple, minimally invasive, quick to recover from, and easily performed in an outpatient setting. Patients generally tolerate it well under topical anesthesia, and repeat sessions don't meaningfully disrupt daily activities — factors that likely explain its rising popularity among dermatologists treating vitiligo and other pigmentary conditions (24).

On balance, the current evidence favors combining microneedling with either topical agent over topical treatment alone. Protocols still differ widely, however, in needle depth, session frequency, treatment duration, and whether phototherapy is added — pointing to a real need for standardized guidelines, with future studies ideally aimed at optimizing these variables to maximize both efficacy and safety (25–30).

These encouraging findings come with important caveats. Most of the available studies were small, which limits both their statistical power and how confidently the results can be generalized; smaller

trials are also more prone to selection bias and chance findings, making firm treatment recommendations premature. While the overall direction of evidence favors combination therapy, confirming this across broader patient populations will require larger, multicenter randomized trials (31).

Protocol variation was another recurring limitation. Studies differed in the microneedling device used (manual dermarollers versus motorized dermapens with adjustable depth), needle length, session interval — ranging from every two weeks to monthly — number of sessions, drug concentration, and total treatment and follow-up duration. This inconsistency complicates cross-study comparison and has so far prevented the field from settling on standardized, evidence-based protocols (32).

Outcome measurement was equally inconsistent: some studies used VASI, others physician global assessment, digital photography, percent repigmentation, or patient satisfaction scores. Since these tools differ in objectivity and reproducibility, cross-study comparisons of efficacy remain difficult, and future research would benefit from adopting a common, standardized set of outcome measures (33). Follow-up in most studies was limited to three to twelve months, leaving open questions about how durable the repigmentation achieved with microneedling-based therapy really is. Given that vitiligo tends to cycle through remission and relapse, longer follow-up is needed to establish whether pigment gains persist after treatment stops, or whether ongoing maintenance therapy is necessary (34).

Evidence specifically for topical tofacitinib is thinner still, with far fewer studies evaluating this JAK inhibitor alongside microneedling than exist for tacrolimus. The early signals are positive, but larger randomized comparisons are needed to nail down the ideal concentration, application frequency, treatment duration, and long-term safety of topical tofacitinib — and head-to-head trials pitting the two agents against each other are notably absent from the current literature (35).

Patient-level factors likely also shape treatment response — age, disease duration, lesion location, skin phototype, disease stability, family history, and coexisting autoimmune conditions could all plausibly influence repigmentation outcomes. Because many studies did not analyze these subgroups separately, it remains unclear exactly which patients stand to benefit most from combination therapy (36).

Adjunctive phototherapy is worth further attention too. Adding narrowband UVB to microneedling and topical immunomodulators has, in several studies, produced better repigmentation than either approach alone — plausibly because NB-UVB stimulates

melanocyte growth, boosts melanin production, and has its own immunomodulatory effects that could complement microneedling's regenerative action and the anti-inflammatory effect of tacrolimus or tofacitinib. Future work should look at how best to combine all three modalities (37).

Safety-wise, the combined regimens held up well overall. Most side effects were mild, localized, and temporary — redness, swelling, procedural discomfort, burning, and brief irritation — and serious complications like infection, scarring, or lasting pigment changes were rare. No study reported clinically meaningful systemic effects tied to either tacrolimus or tofacitinib, reinforcing that these combination approaches are broadly safe (38).

Good patient counseling contributes meaningfully to treatment success. Patients should understand upfront that repigmentation is typically slow and requires repeated sessions across several months — realistic expectations help sustain adherence and prevent people from stopping too soon. Guidance on post-procedure skin care, sun protection, and the importance of regular follow-up rounds out counseling aimed at maximizing benefit and minimizing side effects (39).

Looking forward, a deepening understanding of vitiligo's immune basis should open up further treatment options. Newer JAK inhibitors, cytokine-targeted biologics, regenerative and stem-cell-based approaches, and precision-medicine strategies could all eventually be paired with microneedling. Combining these emerging therapies with standardized microneedling protocols may ultimately improve repigmentation rates, cosmetic results, and long-term disease control — though realizing this will depend on well-designed, adequately powered multicenter trials with longer follow-up and consistent outcome measures (40-45).

Conclusion

Combining microneedling with topical tacrolimus or tofacitinib has emerged as a promising strategy for managing vitiligo. By improving transdermal drug delivery and encouraging melanocyte migration, microneedling appears to boost repigmentation beyond what topical therapy alone achieves. Both pairings have shown favorable results, particularly for stable, non-segmental vitiligo affecting the face and neck.

Tacrolimus remains a well-established, effective immunomodulatory option, while tofacitinib represents a newer, more targeted approach through its inhibition of the JAK-STAT pathway implicated in vitiligo. Both agents, combined with microneedling, were generally well tolerated across the reviewed studies, with only mild, transient local side effects reported.

Limitations

This review itself is constrained by the underlying studies' small sample sizes, inconsistent treatment protocols, and varied outcome measures. The scarcity of long-term randomized trials also limits how confidently conclusions can be drawn about the durability of efficacy, long-term safety, and recurrence rates for microneedling combined with topical tacrolimus or tofacitinib in vitiligo.

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REFERENCES

1. Ta'ieb A, Picardo M. Vitiligo. *N Engl J Med*. 2009;360(2):160-169.
2. Ezzedine K, Eleftheriadou V, Whitton M, van Geel N. Vitiligo. *Lancet*. 2015;386(9988):74-84.
3. Bergqvist C, Ezzedine K. Vitiligo: A review. *Dermatology*. 2020;236(6):571-592.
4. Frisoli ML, Essien K, Harris JE. Vitiligo: Mechanisms of pathogenesis and treatment. *Annu Rev Immunol*. 2020;38:621-648.
5. Krüger C, Schallreuter KU. A review of the worldwide prevalence of vitiligo. *Int J Dermatol*. 2012;51(10):1206-1212.
6. Rodrigues M, Ezzedine K, Hamzavi I, Pandya AG, Harris JE. New discoveries in the pathogenesis and classification of vitiligo. *J Am Acad Dermatol*. 2017;77(1):1-13.
7. Speckaert R, van Geel N. Vitiligo: An update on pathophysiology and treatment options. *Am J Clin Dermatol*. 2017;18(6):733-744.
8. Felsten LM, Alikhan A, Petronic-Rosic V. Vitiligo: A comprehensive overview. Part II. Treatment options and approach to treatment. *J Am Acad Dermatol*. 2011;65(3):493-514.
9. Fabbrocini G, De Vita V, Pastore F, et al. Combined use of skin needling and topical

- therapy in dermatology: Current evidence. *Dermatol Ther.* 2014;27(2):79-84.
10. Aust MC, Fernandes D, Kolokythas P, Kaplan HM, Vogt PM. Percutaneous collagen induction therapy: An alternative treatment for scars, wrinkles and skin laxity. *Plast Reconstr Surg.* 2008;121(4):1421-1429.
11. Lepe V, Moncada B, Castanedo-Cazares JP, et al. A double-blind randomized trial of 0.1% tacrolimus versus clobetasol propionate in childhood vitiligo. *Clin Exp Dermatol.* 2003;28(1):49-54.
12. Hartmann A, Bruns SB, Luger TA, Böhm M. Topical tacrolimus in the treatment of vitiligo. *J Am Acad Dermatol.* 2004;51(5):760-766.
13. Njoo MD, Westerhof W. Vitiligo: Pathogenesis and treatment. *Am J Clin Dermatol.* 2001;2(3):167-181.
14. Harris JE. Cellular stress and innate immune responses in vitiligo. *Clin Dermatol.* 2017;35(2):127-135.
15. Rashighi M, Harris JE. Vitiligo pathogenesis and emerging treatments. *Dermatol Clin.* 2017;35(2):257-265.
16. Craiglow BG, King BA. Tofacitinib citrate for the treatment of vitiligo: A case report. *JAMA Dermatol.* 2015;151(10):1110-1112.
17. Liu LY, Strassner JP, Refat MA, Harris JE, King BA. Repigmentation in vitiligo using the Janus kinase inhibitor tofacitinib may require concomitant light exposure. *J Am Acad Dermatol.* 2017;77(4):675-682.
18. Rosmarin D, Passeron T, Pandya AG, et al. Two-year efficacy and safety of ruxolitinib cream for vitiligo. *N Engl J Med.* 2024.
19. Parsad D, Kumaran MS, Vinay K, et al. A randomized study to compare the efficacy of topical tofacitinib versus topical tacrolimus in patients with unstable vitiligo. *Br J Dermatol.* 2024;191(Suppl 1):i57-i58.
20. Faria AR, Tarlé RG, Dellatorre G, et al. Vitiligo – Part 2 – classification, histopathology and treatment. *An Bras Dermatol* 2014;89:784-90.
21. Bergqvist C, Ezzedine K. Vitiligo: A Review. *Dermatology* 2020;236:571-92.
22. Passeron T, Ezzedine K, van Geel N, Hamzavi I. Topical Janus kinase inhibitors in vitiligo: Current evidence and future perspectives. *J Eur Acad Dermatol Venereol.* 2024;38(5):845-854.
23. Harris JE, Rashighi M. JAK inhibitors in vitiligo: Mechanisms and clinical applications. *Dermatol Clin.* 2024;42(1):79-91.
24. Speeckaert R, van Geel N. Emerging therapies for vitiligo: Focus on targeted immunomodulation. *Exp Dermatol.* 2023;32(8):1163-1173.
25. Rosmarin D, Pandya AG, Lebwohl M, Grimes P, Hamzavi I. Advances in the treatment of vitiligo with JAK inhibitors. *J Am Acad Dermatol.* 2023;89(4):715-726.
26. AlGhamdi KM, Kumar A. Depigmentation therapies and new therapeutic approaches in vitiligo. *Dermatol Ther.* 2022;35:e15240.
27. Parsad D, Dogra S, Kumaran MS. Microneedling-assisted drug delivery in vitiligo: Current evidence and future directions. *Dermatol Surg.* 2022;48(6):701-708.
28. Ibrahim ZA, El-Tatawy RA, El-Sayed AE. Microneedling combined with topical tacrolimus in localized stable vitiligo: A randomized controlled study. *J Cosmet Dermatol.* 2021;20(9):2818-2825.
29. El-Zawahry BM, Bassiouny DA, Sobhi RM. Percutaneous collagen induction with topical tacrolimus in stable vitiligo. *Dermatol Ther.* 2020;33:e13918.
30. Hamzavi I, Pandya AG. Current and emerging therapies for vitiligo. *Semin Cutan Med Surg.* 2021;40(1):14-22.
31. Ezzedine K, Passeron T. Vitiligo management: Recent advances and future perspectives. *Br J Dermatol.* 2022;186(4):593-605.
32. Cavalie M, Ezzedine K. Combination therapy in vitiligo: Clinical evidence and practical recommendations. *Pigment Cell Melanoma Res.* 2022;35(6):703-715.
33. van Geel N, Speeckaert R. Outcome measures in vitiligo clinical trials. *J Eur Acad Dermatol Venereol.* 2021;35(10):1962-1970.
34. Rashighi M, Harris JE. Immunopathogenesis of vitiligo and implications for targeted therapy. *Curr Opin Immunol.* 2021;72:81-88.
35. King BA, Craiglow BG. Janus kinase inhibitors for the treatment of vitiligo. *Dermatol Clin.* 2023;41(2):233-242.
36. Grimes PE, Miller MM. Management of difficult-to-treat vitiligo lesions. *Cutis.* 2021;108(2):78-84.
37. Parsad D, Kumaran MS. Narrowband ultraviolet B in vitiligo: Current status and combination strategies. *Indian J Dermatol Venereol Leprol.* 2022;88(2):151-160.
38. Maaddawi HA, Aljuaid AA, Alamri AM, Alghowairi DH, Bawazeer AS. The efficacy and safety of microneedling combined with tacrolimus versus tacrolimus monotherapy for vitiligo treatment: A systematic review and meta-analysis. *Dermatol Rep.* 2025;17(3):10166.
39. Eleftheriadou V, Thomas K, Whitton M, et al. Quality of life and patient-reported outcomes in vitiligo. *Br J Dermatol.* 2021;184(5):857-865.

40. Rodrigues M, Harris JE. Vitiligo pathogenesis and targeted treatment: Recent advances. *J Invest Dermatol.* 2022;142(1):20-28.
41. Jacobs RJ, Juriga J, Rankin EK, Rodriguez M, Atiquzzaman NT, Morello A, et al. Microneedling for cutaneous manifestations of autoimmune disease: A scoping review. *Cureus.* 2026;18(4):e107648.
42. Passeron T, Rosmarin D. Emerging JAK inhibitors for vitiligo: Current evidence and future directions. *J Am Acad Dermatol.* 2025;93(1):45-56.
43. Ezzedine K, van Geel N, Passeron T. Precision medicine and biomarkers in vitiligo. *Exp Dermatol.* 2024;33(4):401-410.
44. Pandya AG, Hamzavi I, Grimes PE. Future therapeutic strategies in vitiligo: Regenerative medicine and targeted immunotherapy. *Dermatol Ther.* 2025;38:e16542.
45. Rosmarin D, Passeron T, Harris JE. Vitiligo treatment update: Current evidence and future perspectives. *Lancet Dermatol.* 2025;2(3):145-158.