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A Systematic Review of Light Emitting Diode (LED) Phototherapy for Treatment of Psoriasis: An Emerging Therapeutic Modality

Derek Ho BS,[a,b] Eugene Koo MS,[a,b] Andrew Mamalis MD MS,[a,b] and Jared Jagdeo MD MS[a,b,c]

[a]Dermatology Service, Sacramento VA Medical Center, Mather, CA

[b]Department of Dermatology, University of California Davis, Sacramento, CA

[c]Department of Dermatology, State University of New York Downstate Medical Center, Brooklyn, NY

ABSTRACT

Background: Psoriasis is a chronic, inflammatory skin condition. The economic burden of psoriasis is approximately $35.2 billion in the United States per year, and treatment costs are increasing at a higher rate than general inflation. Light emitting diode (LED) phototherapy may represent a cost-effective, efficacious, safe, and portable treatment modality for psoriasis.

Objective: The goal of our manuscript is to review the published literature and provide evidence-based recommendations on LED phototherapy for the treatment of psoriasis.

Methods & Materials: A search of the databases Pubmed, EMBASE, Web of Science, and CINAHL was performed on April 5, 2016. Key search terms were related to psoriasis and LED-based therapies.

Results: A total of 7,793 articles were generated from the initial search and 5 original articles met inclusion criteria for our review. Grade of recommendation: B for LED-blue light. Grade of recommendation: C for LED-ultraviolet B, LED-red light, and combination LED-near-infrared and LED-red light.

Conclusion: We envision further characterizing the effects of LED phototherapy to treat psoriasis in patients may increase adoption of LED-based modalities and provide clinicians and patients with new therapeutic options that balance safety, efficacy, and cost.

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INTRODUCTION

Psoriasis is a chronic, inflammatory skin condition characterized by thick plaques with silvery scale.[1] These psoriatic plaques commonly occur on the scalp, face, hands, feet, nails, genital regions and skin folds, and often cause pruritus and discomfort. Due to the aesthetically unpleasant appearance of psoriatic plaques, patients often feel self-conscious about their appearance, resulting in depression, anxiety, stress and decreased quality-of-life.[2] Comorbidities of psoriasis, such as myocardial infarction, arterial hypertension, dyslipidemia, obesity, and diabetes mellitus, can also negatively impact patient health.[3] Furthermore, psoriasis is a significant socioeconomic burden as it affects more than 3% of the United States (U.S.) population.[1] Studies evaluating the economic burden of psoriasis estimate the cost to be approximately $26,000 per patient per year with a total cost of $35.2 billion in the U.S. per year, due to a combination of incremental medical costs, reduced quality-of-life, and productivity losses.[4,5] Additionally, treatment costs are increasing at a higher rate than general inflation, especially with newer biologic agents compared to traditional treatments.[6,7]

As there is no cure for psoriasis, current treatments are aimed at suppressing the cutaneous and systemic symptoms of psoriasis. The treatment modalities include topical medications (corticosteroids, vitamin D analogues, and calcineurin inhibitors), phototherapies (Psoralen with Ultraviolet A [PUVA] and narrowband ultraviolet B [NB-UVB]), systemic treatments (methotrexate and cyclosporine), and biologic agents (targeting Tumor Necrosis Factor-α [TNF-α], Interleukin 12/23, or Interleukin 17A). However, these treatment modalities are associated with significant side effects, including increased risks of skin atrophy from long-term use of topical corticosteroids, risks of non-melanoma skin cancer (NMSC) from phototherapies, and immune-suppression from systemic treatments. Despite these side effects, phototherapy is commonly performed for treatment of psoriasis due to proven efficacy, moderate cost, and minimal side effects compared to treatments with systemic and biologic agents. A 2015 meta-analysis investigated the efficacy of PUVA and UVB for treatment of psoriasis. This meta-analysis found 77% of PUVA and 61% of UVB studies achieved a 75% or greater reduction in psoriasis area severity index (PASI).[8] However, PUVA and UVB treatment systems are often stationary and require a dedicated physical space, are costly to acquire and maintain, and require patients to frequently visit dermatology offices for treatment (three sessions a week is a standard phototherapy regimen). Thus, there exists a need for

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new psoriasis treatments to balance cost-effectiveness, safety, efficacy, home access, and ease of use.

Light emitting diode (LED) phototherapy devices generate light at specific wavelengths to treat the skin. LEDs have several advantages compared to fluorescent/halogen bulbs, including a small form factor, long bulb life (>10,000 hours), superior power efficiency, adequate intensity, uniform coverage, and low heat production.[9] In addition, the cost of LEDs has decreased significantly over the past decade, and LED phototherapy for treatment of psoriasis may benefit from reduced production and consumer costs.[10-12] LED phototherapy may represent a cost-effective, efficacious, safe, and portable treatment modality for psoriasis.

The effects of LED light, often referred to as photobiomodulation, can change cell proliferation, cytokine signaling, and many other functions involved in the pathogenesis of psoriasis.[13] LED phototherapy has been shown to improve wound healing, tissue regeneration, and reduce acute inflammation.[14] In principle, the biologic effects of traditional fluorescent/halogen bulb phototherapy and LED phototherapy are likely to be the same when identical fluences and power densities are utilized. However, to our knowledge, no head-to-head comparative clinical trials in dermatology have been performed to evaluate the safety and efficacy between traditional phototherapy and LED phototherapy.

In recent years, there have been several clinical studies evaluating the use of different types of LED phototherapy for the treatment of psoriasis. The goal of our manuscript is to review the published literature and provide evidence-based recommendations on LED phototherapy for the treatment of psoriasis.

METHODS

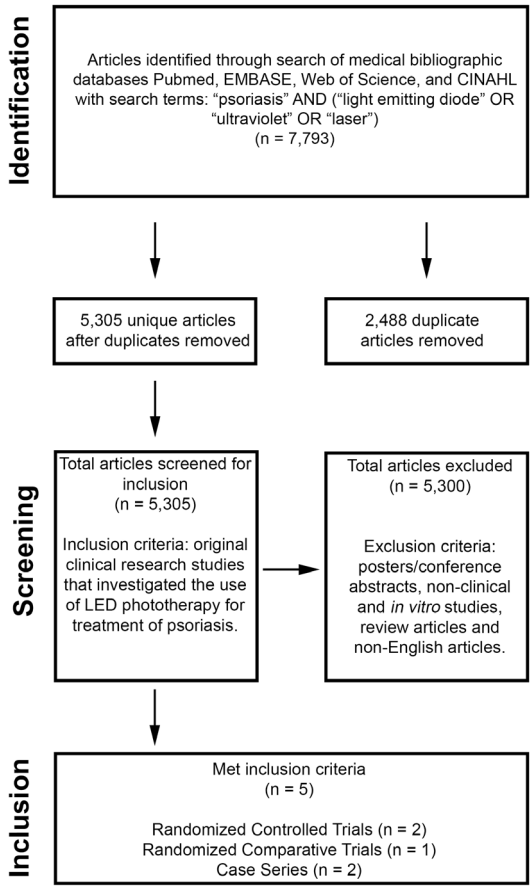
Literature Search Strategy

A search of the computerized bibliographic databases Pubmed, EMBASE, Web of Science, and CINAHL was performed on April 5, 2016. The key terms were: "psoriasis" AND ("light emitting diode" OR "ultraviolet" OR "laser") and all dates were searched in the databases.

Selection Procedure and Inclusion and Exclusion Criteria

The relevant articles that met the following criteria were selected for inclusion: original clinical research studies that investigated the use of LED phototherapy for treatment of psoriasis (Figure 1).[15] Exclusion criteria included: posters/conference abstracts, non-clinical and in vitro studies, review articles, and non-English articles. Titles and abstracts from the electronic search were screened, and full-text articles that met the selection criteria were obtained. Information on study design, sample size, treatment regimen/parameters, follow-up period, assessment methods, treatment outcomes, and adverse events were extracted.

FIGURE 1. Schematic of the search strategy listing the number of articles matching inclusion or exclusion criteria. Adapted from Moher et al.[15]



RESULTS

A total of 7,793 articles were generated from the initial search. Duplicate articles were removed and resulted in 5,305 unique articles. After screening of titles, abstracts and/or full-text, 5 original articles met inclusion criteria for our review. We found 3 articles on LED-Blue Light (LED-BL), 1 article (included with aforementioned articles on LED-BL) on LED-Red Light (LED-RL), 1 article on combination LED-near-infrared (LED-nIR) and LED-RL, and 1 article on LED-UVB. Articles were assigned a level of evidence (LOE) and graded (Table 1).[16] Table 2 details the characteristics of the 5 reviewed articles.

DISCUSSION

Based upon published literature, there is a lack of clinical trials evaluating the safety and efficacy of LED phototherapy for treatment of psoriasis (we only found 2 randomized controlled trials [RCT], 1 randomized comparative trial, and 2 case

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TABLE 1.

Level of Evidence (LOE) and Grades of Recommendation (GOR)
Level of Evidence (LOE)
1a. Systematic review of RCTs
1b. Individual RCT
2a. Systematic review of cohort studies
2b. Individual cohort study (including low-quality RCT)
3a. Systematic review of case-control studies
3b. Individual case-control study
4b. Case series
5. Case reports, expert opinion, bench research
Grades of Recommendation (GOR)
A. Consistent level 1 studies
B. Consistent level 2 or 3 studies or extrapolations from level 1 studies
C. Level 4 studies or extrapolations from level 2 or 3 studies
D. Level 5 evidence or troublingly inconsistent or inconclusive studies of any level

RCT, Randomized controlled trial.
LOE, Level of evidence.
Data from Oxford Center for Evidence-based Medicine Levels of Evidence[16]

series [CS]). The challenge of conducting double-blind RCTs using LED phototherapy for treatment of psoriasis is the inherent difficulty in blinding patients and LED device operators.

In the studies reviewed, post-treatment outcome measures varied and were mostly evaluated through subjective measures and clinician assessment. Most studies used the Local Psoriasis Severity Index (LPSI) to grade the severity of erythema, induration, and scaliness of the treated psoriatic plaques (graded on a scale of 0-12). Additional measures of outcome included the visual analogue scale (VAS), the Dermatology Life Quality Index (DLQI), and/or patient satisfaction. Non-universal usage of a standardized objective assessment scale as the primary outcome measure in the included LED-related studies limits interstudy comparisons.

UV-based LED devices likely function similarly to traditional UV units, and therefore may also cause DNA damage that is associated with NMSC. However, UV-based LED devices have the advantage of being more cost-effective and portable than traditional UV units.

Blue light, red light, and near-infrared are common commercially available wavelengths for LED devices. These wavelengths function through photobiomodulatory effects by directly stimulating chromophores, such as cytochrome c oxidase, and are not known to be associated with DNA damage or skin cancer. Therefore, LED devices at these wavelengths may represent safer alternatives to UV light. In vitro studies demonstrate that LED-BL has anti-inflammatory properties due to downregulation of inflammatory mediators such as dendritic cells and IL-6/TNF-α.[17-23] Due to the role of immune cells in the pathogenesis and maintenance of psoriasis, the photobiomodulatory effects of LED-BL, LED-RL, and LED-nIR on keratinocytes, dendritic cells, and fibroblasts demonstrate the potential for LED phototherapy as a promising treatment option for psoriasis.[24]

LED-BL Phototherapy for Treatment of Psoriasis

We identified 2 RCTs and 1 randomized comparative trial evaluating LED-BL for the treatment of psoriasis. One RCT investigated two different peak power densities (200 mW/cm^2 [Group 1] and 100 mW/cm^2 [Group 2]) of LED-BL (435±5 nm) in 47 patients with mild psoriasis.[25] Mild psoriasis was determined by PASI ≤ 10, body surface area (BSA) ≤ 10, and DLQI ≤ 10. Treatment regimen was once daily for four weeks at home (100% compliance in both groups), and continued at least three times weekly for eight weeks at home (100% and 95.65% compliance in Groups 1 and 2, respectively). Patients from both treatment groups achieved a significant improvement in the treated plaque compared to the control plaque, and Group 1 achieved a greater improvement from baseline compared to Group 2 based upon the LPSI. Melanin skin content measurement did not reveal a significant increase in melanin.[25]

The second RCT investigated two wavelengths of LED-BL (420 nm and 453 nm with 20 patients in each group) in 40 patients with mild to moderate psoriasis as graded by PASI.[26] Patients received once daily treatment for four weeks ("excellent" compliance, data not reported). Results demonstrated a significant improvement based upon the LPSI for both treatment groups, and there was no significant difference of improvement between treatment with 420 nm and 453 nm LED-BL.

The randomized comparative trial evaluated LED-BL (420 nm) and LED-RL (630 nm) in 20 patients with mild psoriasis.[27] Each patient received treatment with each wavelength on two separate psoriatic plaques three times weekly for four weeks (compliance not reported). There was significant improvement based upon the global sum score (assessment of clinical plaque severity - erythema, induration, and desquamation) recorded at baseline, two-, and four-week observations from LED-BL treated plaques.

All 3 clinical trials reported temporary hyperpigmentation of the area surrounding the treated psoriatic plaque as an adverse event. However, no patients reported long-lasting side effects.

Grade of recommendation: B for LED-BL phototherapy for treatment of psoriasis (2 LOE 1b RCTs and 1 LOE 2b randomized comparative trial). These studies demonstrate promising findings that LED-BL may be able to effectively treat mild to moderate

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TABLE 2.

Summary of Clinical Studies Meeting Inclusion Criteria for the Treatment of Psoriasis Using Light Emitting Diode (LED) Phototherapy

#	Authors	Study Type	LOE	Sample Size	Treatment Regimen/ Parameters	Follow-up Period	Assessment Methods	Treatment Outcomes	Adverse Events
					LED-BL Phototherapy; GOR: B				
1	Pfaff et al,[25] 2015	Double blind RCT	1b	47 (High intensity: 24, Low intensity: 23), with mild psoriasis as determined by PASI.	LED-BL (Philips Light and Health, Eindhoven, The Netherlands): 435±5 nm peak wavelength, treatment area 7x5 cm (oval shaped), 30 mins, 50 mW/cm^2, 90 J/cm^2. Group 1: 200 mW/cm^2. Group 2: 100 mW/cm^2. (Device operated with 2 different peak power densities) Initiation treatment: 5 to 7 times per week at home for 4 weeks. Maintenance treatment: at least 3 times per week at home for 8 weeks. Total of 12 weeks of treatment. *Daily application of 10% urea cream at treated and control psoriatic plaques.	4 weeks	1. LPSI (0 to 12) – sum of 3 scales (erythema [0 to 4], scaling/ desquamation [0 to 4], and induration [0 to 4] of the psoriatic plaque. 2. Mexameter® – evaluate pigmentation and erythema of the plaque. 3. DLQI 4. Patient questionnaire on device usability and thermal comfort.	Both Group 1 and Group 2 patients achieved a significant improvement of the treated plaque compared to the control plaque at end of treatment. Group 1 patients consistently reported a higher degree of reduction in change from baseline compared to Group 2 patients. The patient questionnaires recorded high user acceptance of the treatment and high patient satisfaction from the improvement.	50% of patients reported slight hyperpigmentation of the area surrounding the treated plaque, but the Mexameter® did not show significant increase in melanin levels for both groups.
2	Weinstabl et al,[26] 2011	Double blind RCT	1b	40 (Group 1: 20, Group 2: 20), with mild to moderate psoriasis as determined by PASI.	LED-BL (Philips Light and Health, Eindhoven, The Netherlands): 15 mins, 100 mW/cm^2, 90 J/cm^2. Group 1: LED-BL device with 420 nm peak wavelength. Group 2: LED-BL device with 453 nm peak wavelength. Daily irradiation at home for 15 mins for 4 weeks. *Daily application of 10% urea cream at treated and control psoriatic plaques.	2 weeks	1. LPSI 2. DLQI 3. VAS	37 patients completed the study. The LPSI improved significantly post-treatment in both groups of the treated plaques compared to the control plaques. Patients in both groups described an "improvement trend" of the treated plaques based on the VAS. The improvement with the treated plaques diminished after end of treatment.	Total of 20 patients in both groups had "significant increase" in pigmentation as assessed by patients after 3 weeks of treatment. Pigmentation decreased within 2 weeks post end of treatment. No patient reported persistence of hyperpigmentation.
3	Kleinpenning et al,[27] 2011	Double blind, randomized comparative trial	2b	20 (each patient received LED-BL and LED-RL on 2 different psoriatic plaques), with mild psoriasis as determined by PASI.	LED-BL (Philips Light and Health, Eindhoven, The Netherlands): 420 nm peak wavelength, 20 mins, 100 mW/cm^2, 120 J/cm^2. LED-RL (Philips Light and Health, Eindhoven, The Netherlands): 630 nm peak wavelength, 20 mins, 50 mW/cm^2, 60 J/cm^2. Irradiation for 20 minutes, 3 times weekly for 4 weeks. *Daily application of 10% salicylic acid in petrolatum at treated and control psoriatic plaques (to remove excessive scaling that may block light penetration).	0	LPSI	Clinical improvement (desquamation and induration) was identical and significant for both LED-BL and LED-RL treated plaques. Improvement of erythema was significant for both light sources, but was more noticeable from LED-BL treatment. The clinical improvement of erythema persisted with LED-BL treated plaques while improvement with LED-RL treated plaques discontinued after 2 weeks.	16/20 patients reported hyperpigmentation with LED-BL treatment, while 1/20 reported hyperpigmentation with LED-RL.
					LED-RL Phototherapy; GOR: C				
3	Kleinpenning et al,[27] 2011	Double blind, randomized comparative trial	2b	20 (each patient received LED-BL and LED-RL on 2 different psoriatic plaques), with mild psoriasis vulgaris as determined by PASI.	LED-BL (Philips, Eindhoven, the Netherlands): 420 nm peak wavelength, 20 mins, 100 mW/cm^2, 120 J/cm^2. LED-RL (Philips, Eindhoven, the Netherlands): 630 nm peak wavelength, 20 mins, 50 mW/cm^2, 60 J/cm^2. Irradiation for 20 minutes, 3 times weekly for 4 weeks. *Daily application of 10% salicylic acid in petrolatum at treated and control psoriatic plaques (to remove excessive scaling that may block light penetration).	0	LPSI	Clinical improvement (desquamation and induration) was identical and significant for both LED-BL and LED-RL treated plaques. Improvement of erythema was significant for both light sources, but was more noticeable from LED-BL treatment. The clinical improvement of erythema persisted with LED-BL treated plaques while improvement with LED-RL treated plaques discontinued after 2 weeks.	16/20 patients reported hyperpigmentation with LED-BL treatment, while 1/20 reported hyperpigmentation with LED-RL.

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TABLE 2. *Continued*

Summary of Clinical Studies Meeting Inclusion Criteria for the Treatment of Psoriasis Using Light Emitting Diode (LED) Phototherapy

#	Authors	Study Type	LOE	Sample Size	Treatment Regimen/ Parameters	Follow-up Period	Assessment Methods	Treatment Outcomes	Adverse Events
					Combination LED-nIR and LED-RL Phototherapy; GOR: C				
4	Ablon et al,[28] 2010	CS	4b	9, all had BSA involvement of 5% to 80%.	LED-nIR and LED-RL (Omnilux, PhotoTherapeutics, Carlsbad, CA) delivers - LED-nIR: 830 nm, 20 mins, 50 mW/cm^2, 60 J/cm^2. LED-RL: 633 nm, 20 mins, 105 mW/cm^2, 126 J/cm^2. 20 mins treatment session. Week 1: 2 sessions of LED-nIR treatment, 48 hours apart. Week 2: 2 sessions of LED-RL treatment, 48 hours apart. Week 3, 4, 5: 1 session each of LED-nIR and LED-RL treatment, 48 hours apart. Total of 10 treatments for 5 weeks for 1 regimen. Regimen could be stopped if 100% resolution was achieved. A second regimen could be performed due to insufficient clearance of plaque psoriasis or due to patient request.	3 to 8 months	Subjective physician and patient assessment	5 patients required two regimens, and 4 patients required one regimen. Psoriasis resolution rates ranged from 60% to 100%. All patients with long follow-up periods reported "high" satisfaction rates.	None.
					LED-UVB Phototherapy; GOR: C				
5	Kemény et al,[29] 2010	CS	4b	20 (Regimen 1: 10, Regimen 2: 10), all had mild to moderate psoriasis involving <20% BSA.	LED-UVB (Allux Medical Inc., Menlo Park, CA): peak wavelength 310±15 nm, treatment area 12.8x9x3.8 cm, 5 mins 50 secs, 1 mW/cm^2, 3.5 J/cm^2. Regimen 1: Starting dose of 1 MED and dose increased at every visit by 20% to 50% from the previous dose up to 5 MED, and continued until end of treatment period. Regimen 2: Starting dose of 0.7 MED and dose increased at every visit by 0.1 MED for the whole treatment period. Treatments occurred 4 times weekly up to 8 weeks or until complete clearance, whichever occurred first. *Application of 10% salicylic acid 2 to 3 days before first treatment, mineral oil applied at plaque surface pre-treatment (to increase penetrance of UV into skin with less scatter), and topical emollients post-treatment.	6 months	1. LPSI 2. Skin biopsy and immunohistochemistry	Patients from both treatment regimens had significant improvement compared to baseline starting at 2 weeks post first treatment. At the 6-month follow-up, 6 and 5 patients from regimen 1 and 2, respectively, were still in remission.	2 patients experienced small blister formation (both after 50% increase of the previous dose) from regimen 1. Blisters resolved "rapidly" and one treatment session was skipped.

Abbreviations: BSA: body surface area, cm: centimeters, CS: case series, DLQI: Dermatology Life Quality Index, GOR: Grade of Recommendation, LED-BL: Light emitting diode-blue light, LED-nIR: Light emitting diode-near infrared, LED-RL: Light emitting diode-red light, LED-UVB: Light emitting diode-ultraviolet B, LOE: level of evidence, LPSI: Local Psoriasis Severity Index, MED: minimal erythema dose, mins: minutes, mW: milliwatts, nm: nanometers, PASI: Psoriasis Area and Severity Index, RCT: randomized controlled trial, s: seconds, VAS: Visual analog scale.

psoriasis. However, additional clinical trials are needed to fully establish the safety and efficacy of LED-BL in comparison to other LED wavelengths and current PUVA and UVB treatment systems.

LED-RL Phototherapy for Treatment of Psoriasis

As previously described, one randomized comparative trial evaluated LED-BL (420 nm) and LED-RL (630 nm) in 20 patients with mild psoriasis.[27] Clinical improvement of induration and desquamation from treatment with LED-BL and LED-RL were similar. However, clinical improvement of erythema from LED-BL treatment was greater than improvement with LED-RL. These findings suggest that LED-RL effects may require more regularly scheduled treatment sessions for clinical benefit.

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Grade of recommendation: C for LED-RL phototherapy for treatment of psoriasis (1 LOE 2b randomized comparative trial). One study reported improvements of psoriatic lesions post LED-RL phototherapy, however, the benefits to erythema reduction were quickly lost after six treatments. Additional RCTs are required to evaluate long-term safety and efficacy of LED-RL.

Combination LED-nIR and LED-RL Phototherapy for Treatment of Psoriasis

We found one CS that evaluated combination LED-nIR and LED-RL phototherapy for treatment of psoriasis. This article investigated an LED device that outputs nIR (830 nm) and red light (633 nm) for 9 patients with psoriasis involving 5% to 80% BSA.[28] Based upon physician and patient assessment, after a minimum of ten treatments over five weeks with both LED-nIR and LED-RL, there was a 60% to 100% improvement of psoriasis. No permanent adverse events were reported. These results are promising, however, RCTs using objective outcome measures are needed to fully establish efficacy and compare combination therapy with LED-nIR and LED-RL monotherapy.

Grade of recommendation: C for combination LED-nIR and LED-RL phototherapy for treatment of psoriasis (1 LOE 4b CS). RCTs are required to demonstrate safety, efficacy, and benefits of combination LED-nIR and LED-RL phototherapy compared to monotherapy.

LED-UVB phototherapy for treatment of psoriasis

Our search identified a CS demonstrating significant improvement from four weekly treatments for up to eight weeks with an LED-UVB device (310±15 nm) in 20 patients with mild to moderate psoriasis involving ≤ 20% BSA, and greater than 50% of the patients were symptom free at six months post-treatment.[29] No permanent adverse events were reported.

Grade of recommendation: C for LED-UVB phototherapy for treatment of psoriasis (1 LOE 4b CS). This article reported significant improvement with LED-UVB, which is anticipated and similar to the well-established efficacy seen with traditional UV phototherapy. Future RCTs are needed to establish safety and efficacy, and to compare LED-UVB devices with traditional UV phototherapy units that utilize fluorescent/halogen bulbs.

Limitations and Future Directions

Currently, there are several clinical trials evaluating LED phototherapy for treatment of psoriasis. Based upon the 5 reviewed clinical studies (2 RCTs, 1 randomized comparative trial, and 2 CS), we found support for LED phototherapy (BL, RL, nIR, and UVB) treatment of mild to moderate psoriasis with no long-term adverse events.

Several limitations were identified in the 5 reviewed clinical studies. One limitation was the concurrent use of exfoliants (10% salicylic acid and/or 10% urea-based cream) to help reduce thickened epidermis during the study. The advantage of using exfoliants with LED phototherapy is to improve light penetration deep into the basal layer of the epidermis and potentially even targeting cells in the dermis. However, other medications can affect study outcome measures and concurrent use of topical and systemic medications should be avoided during LED phototherapy trials. In future studies, a stringent washout period and treatment regimen and dosing should be standardized. Another limitation is that the anatomic locations of the psoriatic plaque differed in the reviewed studies. Ideally, the treatment area should be sun-protected and from a similar location to improve interstudy comparisons. Future researchers may consider investigating LED phototherapy treatment of psoriasis on the trunk with subgroup classifications of mild, moderate, and severe psoriasis based upon a standardized grading system such as the PASI.

LED phototherapy is an emerging therapeutic modality for treatment of psoriasis and other dermatological conditions. In addition to the treatment of psoriasis, LED phototherapy currently has several known therapeutic uses in dermatology, including wound healing, acne treatment, sunburn prevention, facial rhytides, and skin rejuvenation.[30] Other medical fields, such as pediatrics, have already adopted LED-BL phototherapy in place of traditional blue light fluorescent light-based phototherapy for treatment of neonatal hyperbilirubinemia, and a Cochrane review has reported similar efficacy comparing the two types of phototherapy devices for the treatment of neonatal hyperbilirubinemia.[9,31]

Although LED phototherapy has the advantage of a small form factor, a full-body photobooth is often required to treat psoriasis that affects a large BSA – as is currently performed with UVB or PUVA phototherapy. Therefore, in addition to advancement in the scientific community to provide high quality evidence of the safety and efficacy of LED phototherapy, medical device manufacturers must advance in parallel to supply dermatologists with more cost-effective and energy-efficient LED phototherapy devices. There is a need for both hand-held and full-body LED-devices and device trackers to record and avoid over-use at home. We foresee these advances in the device market supporting the increasing demands of LED phototherapy treatment of psoriasis and other skin conditions.

CONCLUSION

There exists an unmet need for more cost-effective treatment options for psoriasis with improved safety and efficacy. Based upon the published literature, LED-BL phototherapy demonstrates the strongest benefit for treatment of psoriasis, without any known long-term adverse events. The use of LEDs, compared to fluorescent/halogen bulbs, as a light source for phototherapy has enabled the use of many wavelengths of light

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for the treatment of psoriasis, including ultraviolet, blue, red, and nIR light. Continued research into the mechanism on how LED phototherapy (in particular red and near-infrared light due to a paucity of basic science and clinical data) can affect the cells and molecular pathways responsible for the pathogenesis of psoriasis may help improve adoption by both dermatologists and patients, as LED phototherapy can be a cost-effective, safe, efficacious, easy-to-use, at-home therapeutic modality requiring minimal training and supervision. LED phototherapy is an important emerging therapeutic modality as the cost for treatment of psoriasis continues to increase at a rate that may limit patient access to many treatment options. We envision further characterizing the effects of LED phototherapy to treat psoriasis in patients may increase adoption of LED-based modalities and provide clinicians and patients with new therapeutic options that balance safety, efficacy, and cost.

DISCLOSURES

The authors have no conflicts of interest to disclose. The contents do not represent the views of the U.S. Department of Veterans Affairs or the United States Government.

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AUTHOR CORRESPONDENCE

Jared Jagdeo MD MS
E-mail:..... jrjagdeo@gmail.com

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