Wearable devices for photodynamic therapy – A systematic review

To the Editor: Photodynamic therapy (PDT) is a non-invasive treatment for premalignant and non-melanoma skin cancers.[1] PDT is an effective treatment modality, shown to have superior cosmetic outcomes and less morbidity compared to other non-surgical alternatives.[2] Conventional PDT involves the use of a photochemical reaction generated from the interaction of a photosensitizing agent, visible light, and oxygen to selectively destroy diseased tissues. However, the inconvenience of hospital-based treatment and associated discomfort are significant

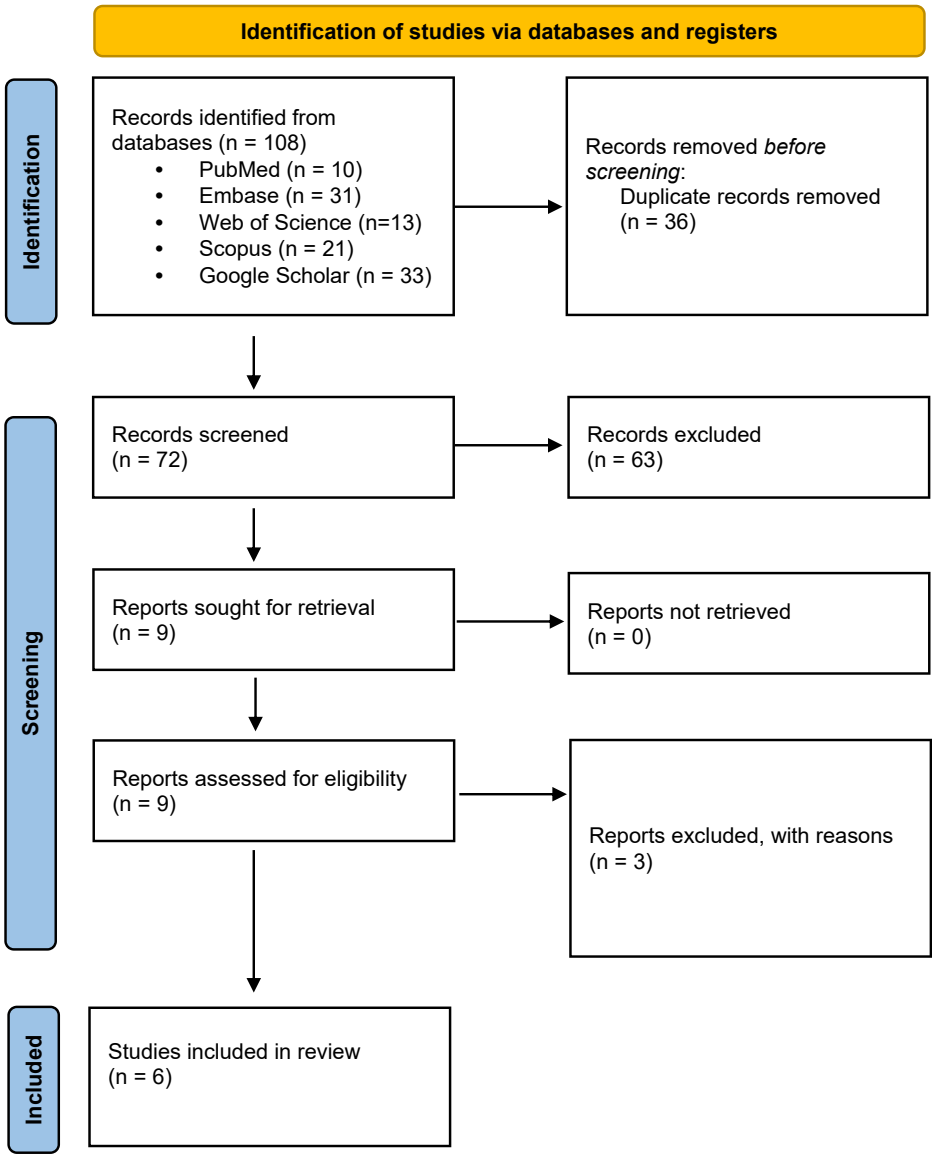

Fig 1. Summary of systematic review performed according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines.

Table I. Studies reporting on the use of wearable devices for delivery of photodynamic therapy*

Reference & location of Study	Study design	No. of patients	Skin disease	Device/type of light	Treatment protocol	Outcome measures	Clearance	Adverse effects	limitations
Fonda-Pascual et al,[4] 2019 Spain	Pilot	27	Actinic keratosis (AK)	Wearable cap-like device/ light-emitting diode	Single cycle of 15 min (total light dose 4.59 J/cm^2)	Reduction in number of lesions; AK Quality of Life (AKQOL) score	71% reduction in number of lesions at 2 mo	Pain: None reported Other adverse effects: Mild heat (25%), mild paraesthesia (7%)	Small sample size; no control group Short follow up time (2 mo) No blinded assessment Wearable device but not portable
Kessels et al,[1] 2017 Netherlands	Retrospective	125	Superficial BCC	Ambulight device/ inorganic light-emitting diode	3 h per cycle (total light dose 75 J/ cm^2); total number of cycles not specified	Primary outcome measure: 1-y probability of remaining tumour-free Secondary outcome measures: (1) cumulative probability of recurrence-free survival at 6 and 18 mo (2) Incidence of adverse events	100% complete clearance (no residual tumour) at 3 mo 93.6% no recurrence at 6 mo, 89.9% at 12 mo, and 87.6% at 18 mo	Not reported Pain: None reported Other adverse effects: Blistering and erosions (1 patient), bacterial skin infection (1 patient)	Retrospective study with no control group; available information limited in some cases Device unable to treat tumours on convex or concave areas Limited to tumours <2 cm
Moseley et al,[2] 2006 United Kingdom	Pilot	5	Bowen's Disease	Prototype device/light-emitting diode	2 cycles (duration not specified, total light dose 75 J/ cm^2), 4 wk apart	Clearance and pain	80% complete clearance at 6-13 mo follow-up time (median 9 mo)	Pain: No pain in 10%, mild in 70%, moderate in 20% Other adverse effects: Mild oedema and erythema	Small sample size; no control group

Attili et al,[3] 2009 United Kingdom	Pilot	12	Bowen's disease, superficial BCC <2 cm diameter	Prototype device/ organic light-emitting diode	2 cycles of 3 h each (total light dose 45-60 J/cm^2 per cycle), 1 mo apart	Efficacy of treatment at 3, 6, 9, and 12 mo; pain and discomfort	58.3% complete clearance at 1 y	Pain: Pain score ≤2 on numeric rating scale (NRS) Other adverse effects: Nil reported	Small sample size; no control group
Ibbotson et al,[5] 2022 Ninewells Hospital, United Kingdom	Pilot	53	Bowen's disease, superficial BCC (<2 mm thickness), AK ≤2 cm diameter	Ambulight device/ inorganic light-emitting diode	2 cycles of 3 h each (total light dose 75 J/cm^2 per cycle), 1 wk apart for BCC/bowen's 1 cycle of 3 h for actinic keratosis, second cycle given only if no clearance at 3 mo	Pain and efficacy	84% complete clearance at 1 y	Pain: Median NRS pain score 2 for first treatment; 4 for second treatment Other adverse effects: Nil reported	Small sample size Device unable to treat tumours on convex or concave areas
Ibbotson et al,[5] 2022 Ninewells Hospital, United Kingdom	Randomized controlled	32	Bowen's disease, superficial BCC (≤2 cm diameter)	Ambulight device/ inorganic light-emitting diode	2 cycles of 3 h each (total light dose 75 J/cm^2 per cycle), 1 wk apart. second cycle given at 12 wk if no clearance	Primary outcome measure: pain Secondary outcome measures: efficacy, erythema, patient satisfaction	77.8% complete clearance with Ambulight vs 84.4% with conventional PDT at 1 y	Pain: 1.25 for Ambulight vs 5.26 for conventional PDT on VAS Other adverse effects: Erythema (slightly greater with Ambulight compared to conventional PDT)	Small sample size Device unable to treat tumours on convex or concave areas

AK, Actinic keratosis; *BCC*, basal cell carcinoma; *PDT*, photodynamic therapy; *VAS*, visual analog scale.
*Non-malignant skin conditions are out of scope in this review.

drawbacks.[3] While daylight PDT circumvents the inconvenience of conventional PDT, it is limited by several variables including patient compliance and dependence on weather conditions. As such, great interest has been placed in developing wearable devices, which can potentially provide more consistent irradiation[4] and on-demand treatment. Recent studies have emerged to evaluate novel protocols and light sources to improve the delivery of PDT, including wearable devices. To evaluate the usefulness of such devices in the treatment of premalignant and nonmelanoma skin cancers, a literature search was conducted (Fig 1). We report 6 studies involving 274 participants that explored the use of wearable devices to deliver PDT (Table I).

Pilot studies using the Ambulight device (Ambicare Health) for the treatment of superficial basal cell carcinoma, Bowen's disease and actinic keratoses, have reported up to 77.8% to 89.9% clearance at 1 year.[1,5] Preliminary studies suggest that the efficacy of these novel devices can be explained by the use of light sources that provide lower irradiance over a longer period. However, this has greater photobleaching efficacy and is potentially more cytotoxic.[1] The lower irradiance may also account for the lower pain scores reported with such wearable devices. Ibbotson et al reported a lower pain score of 1.25 with ambulatory PDT, compared to 5.26 with conventional PDT on the visual analog scale.[5] This was consistent with the overall low pain scores reported across the identified studies. Other reported symptoms include mild oedema and erythema,[2,5] while Fonda et al reported mild heat in 25% and mild paraesthesia in 7% of patients with their cap-like device.[4] Devices such as Ambulight are designed to turn on and off automatically, providing greater ease of use for patients and potentially improving compliance.[1,5]

However, findings are limited to mostly pilot studies with a short follow-up time, and a lack of control for comparison. Current wearable devices have significant drawbacks—these can only be used on flat body surfaces, limited to small lesions (less than 2 cm),[1] and peripheral margin failure.[3] More data regarding cost are also required, as this can significantly influence patients' decisions on treatment options. Further refinements on the design of such devices should be considered, with the aim of creating a lightweight, comfortable device that delivers consistent irradiation for remote PDT.

In conclusion, given the significant burden of disease of premalignant and malignant skin diseases, delivery of ambulatory PDT via wearable devices can potentially be a feasible, convenient, and more comfortable method of treatment. Future efforts may be devoted to the development of devices that allow for remote and reliable delivery of PDT.

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Conflicts of interest

None disclosed.

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