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High-Frequency Focused Ultrasound as a Novel Ablative Treatment for Porokeratosis: A Proof-of-Concept Study

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Abstract

Background: Porokeratosis comprises a rare and heterogeneous group of keratinization disorders defined by the presence of a cornoid lamella and an established risk of malignant transformation, particularly into squamous cell carcinoma. Despite its premalignant potential, effective, durable, and cosmetically acceptable treatment options remain limited, especially for patients with multiple lesions or involvement of anatomically challenging sites.

Objectives: To evaluate the feasibility, safety, and dermoscopic outcomes of 20 MHz high-frequency focused ultrasound (HIFU) as a novel, non-invasive ablative treatment for porokeratosis.

Methods: Three porokeratotic lesions exhibiting dermoscopic features suggestive of progression were selected for treatment in a patient with disseminated porokeratosis. All lesions were treated in a single session using a 20 MHz HIFU device, without anesthesia. Clinical and dermoscopic evaluations were performed at baseline and during follow-up, with particular attention to lesion clearance, vascular patterns, pigmentary changes, and healing dynamics.

Results: All treated lesions achieved complete clinical and dermoscopic resolution, with no evidence of recurrence or malignant evolution during follow-up. Post-treatment healing was characterized by reproducible dermoscopic features, including ill-defined homogeneous white structures, isolated white shiny lines, white clods arranged in a square pattern, and transient appearance of a rainbow pattern consistent with dermal collagen remodeling. A marked reduction in vascular density was observed, with only sparse, morphologically non-pathological vessels remaining. The procedure was well tolerated and resulted in excellent cosmetic outcomes, without scarring or persistent pigmentary alterations.

Conclusions: High-frequency focused ultrasound represents a promising, tissue-sparing ablative modality for the treatment of porokeratosis. Its ability to achieve complete lesion clearance with favorable cosmetic outcomes and distinctive, reproducible dermoscopic healing patterns suggests that HIFU may offer a valuable non-invasive alternative for managing premalignant or potentially progressive porokeratotic lesions, particularly in surgically challenging locations. These findings support further prospective studies to validate the oncologic safety and long-term durability of this approach.

Introduction

Porokeratosis comprises a rare and heterogeneous group of cutaneous keratinization disorders characterized by the presence of a cornoid lamella, a column of parakeratotic cells overlying dyskeratotic epidermis [1,2]. Clinically, porokeratotic lesions often begin as small papules that progressively enlarge into annular, atrophic plaques with a raised, hyperkeratotic border corresponding to the histopathological cornoid lamella [2,3]. Several clinical variants exist, including porokeratosis of Mibelli, linear porokeratosis, and disseminated superficial actinic porokeratosis (DSAP), yet all share this distinctive histological and clinical feature [1,4]. Although the precise etiology remains incompletely understood, genetic susceptibility, ultraviolet radiation, and immunosuppression have all been implicated in disease development [2,5]. Importantly, porokeratosis has long been recognized as a premalignant condition, with a documented potential for progression to cutaneous malignancies, particularly squamous cell carcinoma (SCC) [1,6].

The risk of malignant transformation within porokeratotic lesions is well-established and constitutes a major clinical concern in chronic cases [7]. All subtypes are potentially premalignant, with SCC being the most frequently associated malignancy, although basal cell carcinoma has also been reported [8]. The overall risk of transformation across all variants is estimated at approximately 7.5%; this risk is notably lower in DSAP (3.4%) but significantly higher in linear porokeratosis (up to 19%) [9,10]. However, more recent large-scale epidemiological data suggests the actual cancer risk may be higher when assessed through population registries. A 2023 Swedish nationwide study found porokeratosis was associated with hazard ratios of 4.3 for SCC, 2.42 for BCC, and 1.83 for melanoma compared to controls [11]. Factors contributing to malignant progression include lesion size (>1 cm), chronicity (often decades), and anatomical location, particularly sun-exposed areas [12]. Given this oncogenic potential, regular clinical surveillance is essential, and any changes in lesion morphology or ulceration should prompt immediate biopsy to exclude SCC in situ or invasive carcinoma [13]. These risks underscore the therapeutic imperative to treat porokeratosis rather than adopt a passive observational approach.

Despite this, the therapeutic management of porokeratosis remains challenging. A universally effective or standardized treatment protocol has yet to be established, primarily due to the rarity of the disease and the absence of large-scale, randomized controlled trials [14]. Consequently, treatment approaches are highly individualized and depend on variables such as lesion type, distribution, anatomical location, and the availability of therapeutic modalities.

Current treatment strategies can be broadly categorized into destructive and pharmacologic approaches, both of which show variable efficacy. Topical therapies such as keratolytics, 5-fluorouracil, imiquimod, vitamin D analogs, and retinoids have been employed with modest success. Procedural interventions include cryotherapy, dermabrasion, carbon dioxide laser ablation, and surgical excision. However, these methods often result in incomplete or transient responses, with frequent recurrences and the need for prolonged treatment regimens, which may negatively impact patient adherence and quality of life.

In the absence of formal treatment guidelines, therapeutic decisions are generally guided by lesion size, subtype, and anatomical considerations. Nevertheless, the limited efficacy of available options and the potential for malignant degeneration underscore the need for novel, targeted therapies capable of achieving sustained lesion clearance with an acceptable safety and cosmetic profile [14].

High-intensity focused ultrasound (HIFU) has recently emerged as a promising non-invasive therapeutic modality in dermatology, offering precise ablation of pathological tissue while preserving the surrounding epidermis. By concentrating acoustic energy at a defined focal point within the skin, HIFU induces rapid localized heating—reaching approximately 65°C—resulting in thermal coagulative necrosis of the target tissue [15]. Unlike laser or cryotherapy, HIFU enables controlled-depth ablation with minimal collateral damage. The development of 20 MHz high-frequency HIFU devices has further expanded their applicability to superficial dermatologic lesions, with real-time dermoscopic or ultrasound-guided visualization allowing for tailored energy delivery based on lesion morphology and depth [16].

Early clinical studies support the efficacy and safety of this approach. In a prospective open-label trial evaluating actinic keratosis (AK), high-frequency HIFU achieved approximately 97% lesion clearance after one to three treatment sessions, with rapid re-epithelialization and no scarring observed [17]. Building upon these findings, Wozniak et al. reported the successful application of 20 MHz HIFU for the treatment of cutaneous neurofibromas in patients with neurofibromatosis type 1, achieving complete or substantial lesion reduction in five out of seven cases, without anesthesia and with minimal side effects [18]. In parallel, Zawada and Bove demonstrated, through acoustic modeling and engineering optimization, that 20 MHz HIFU transducers can confine thermal energy within submillimeter focal zones, permitting precise ablation of dermal targets while sparing superficial skin layers [19].

Furthermore, a prospective study by Calik et al. examined healing kinetics following HIFU treatment of 233 benign lesions, including seborrheic keratoses, sebaceous hyperplasia, and vascular nevi, demonstrating lesion-specific fibrosis patterns and consistent post-treatment evolution. These insights support individualized treatment planning and patient education regarding healing trajectories [20]. Collectively, these data establish high-frequency HIFU as a selective, well-tolerated, and cosmetically favorable treatment modality for various dermatologic conditions.

Given the superficial localization and oncogenic potential of porokeratotic lesions, HIFU presents a compelling therapeutic alternative capable of achieving full-thickness lesion clearance without surgical morbidity. In light of this, we systematically assessed the feasibility, procedural safety, and dermoscopic outcomes of 20 MHz HIFU as a novel, non-invasive ablative treatment for porokeratosis, focusing on lesion response, epidermal remodeling, and the evolution of characteristic dermoscopic features over time (Figure 1).

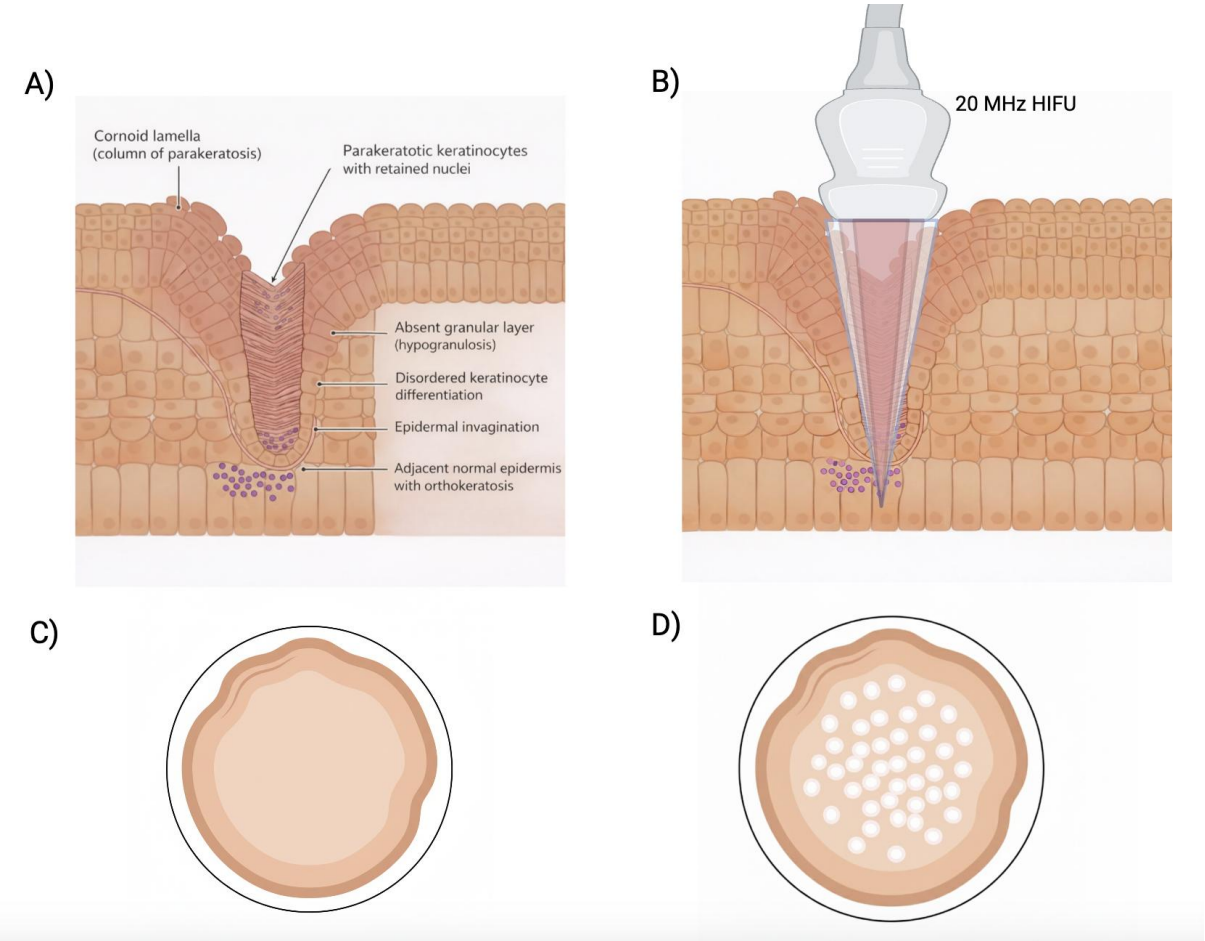


Figure 1. Schematic representation of porokeratosis and its treatment with high-intensity focused ultrasound (HIFU). **(A)** Schematic illustration of porokeratosis with a characteristic cornoid lamella. **(B)** Application of 20 MHz high-intensity focused ultrasound (HIFU) targeting the porokeratotic lesion. **(C)** Top-view schematic of the porokeratotic lesion prior to treatment. **(D)** Top-view schematic after HIFU treatment, showing discrete HIFU shots applied at **2-mm intervals** across the lesion.

The primary objective of this study was to evaluate the feasibility and safety of 20 MHz HIFU as an ablative treatment option for porokeratosis. Secondary objectives included the assessment of dermoscopic changes following treatment, with particular attention to the evolution of disease-specific structures, lesion clearance dynamics, and early indicators of therapeutic response during follow-up. Additionally, we aimed to explore the potential role of dermoscopy as a non-invasive tool for monitoring treatment efficacy and tissue response after HIFU-based ablation.

Methods

Study Design and Clinical Setting

This study was conducted as a prospective, single-patient, proof-of-concept clinical observation evaluating the feasibility and dermoscopic outcomes of high-frequency focused ultrasound (HIFU) for the treatment of porokeratosis. The procedure and follow-up assessments were performed within routine dermatologic care at a tertiary referral center, without deviation from approved clinical practice.

Patient Characteristics and Diagnostic Work-Up

A female patient with a complex dermatologic history was referred for dermoscopic evaluation due to concern for malignant transformation of a facial lesion. The patient had a prior histopathological diagnosis of trichoepithelioma on the right cheek. Dermoscopy revealed blue-grey clods and branched linear vessels—features commonly associated with basal cell carcinoma—however, repeat histopathological examination confirmed trichoepithelioma. The patient's medical history was notable for a previously excised basal cell carcinoma on the left upper arm and two additional lesions on the lower extremities, both histologically confirmed as squamous cell carcinoma in situ (Bowen's disease), which were surgically removed.

Comprehensive skin examination revealed the presence of multiple annular, hyperkeratotic plaques distributed across the extremities. Based on clinical morphology and dermoscopic features, a diagnosis of disseminated porokeratosis was established. The patient was subsequently enrolled in a structured videodermoscopy surveillance program, including standardized clinical and dermoscopic imaging of all lesions at six-month intervals.

Lesion Selection and Anatomical Localization

For detailed analysis and presentation, the three lesions—each demonstrating dermoscopic features suggestive of progression—were selected for HIFU treatment description. The treated lesions were anatomically located as follows: 1) Posterior aspect of the left calf (regio surae posterior sinistra), 2) Posterior aspect of the right calf (regio surae posterior dextra), 3) Anterior aspect of the left thigh (regio femoris anterior sinistra). These lesions were chosen based on dermoscopic evolution rather than size or symptomatology.

Baseline Dermoscopic Assessment

Clinical and dermoscopic evaluation of each lesion was performed using a digital videodermatoscopy system (FotoFinder Medicam 1000®, FotoFinder Systems GmbH, Bad Birnbach, Germany), enabling high-resolution image acquisition under both non-polarized and polarized light. At baseline, dermoscopic examination of the selected lesions revealed features consistent with porokeratosis, including a hyperkeratotic ridge corresponding to the cornoid lamella. Initially stable lesions demonstrated central dotted vessels within the keratotic ridge. Progressive lesions exhibited the emergence of branched linear vessels, looped vessels, and structureless white areas accompanied by white shiny lines under polarized light—features suggestive of early malignant transformation toward squamous cell carcinoma. These dermoscopic changes constituted the primary indication for intervention.

Treatment Modality and Procedure

Given the multiplicity of lesions and their localization on the lower extremities—where surgical excision carries an increased risk of delayed wound healing, scar formation, or the need for skin grafting—high-frequency focused ultrasound (HIFU) was selected as a non-invasive ablative alternative. HIFU therapy was performed using the TOOsonix System ONE-M® (TOOsonix A/S, Hoersholm, Denmark), operating at a frequency of 20 MHz. This CE-marked medical device enables precise delivery of focused acoustic energy to superficial skin layers, resulting in localized thermal coagulative necrosis while sparing surrounding tissue. Prior to treatment, high-frequency ultrasound skin imaging was performed using the Dermascan®C system (Cortex Technology ApS, Aalborg, Denmark) to accurately assess lesion thickness and depth. This step was essential for selecting the appropriate HIFU handpiece according to the required focal penetration depth. The TOOsonix ONE-M® system offers four interchangeable handpieces with focal depths of 0.8, 1.3, 1.8, and 2.3 mm. Based on ultrasound assessment, a handpiece with a focal depth of 0.8 mm was selected for all treated lesions.

Before each procedure, the transducer chamber was filled with deionized (DI) water and sealed with a polyethylene membrane. Acoustic coupling between the transducer and the skin surface was achieved using Parker Aquasonic 100® ultrasound gel (Parker Laboratories Inc., Fairfield, NJ, USA). Each lesion was treated in a single session without anesthesia. Based on prior clinical experience with HIFU, neither topical anesthetics nor intralesional anesthesia were used. Energy delivery parameters were standardized across lesions, with an energy

output of approximately 1 J per exposure, a focal depth of 0.8 mm, and an exposure duration of 150 ms per shot. Individual exposures were applied in a contiguous pattern with a spacing of approximately 1–2 mm to ensure complete lesion coverage, while maintaining a minimal circumferential safety margin of approximately 1 mm. The interval between successive exposures was maintained at 1–2 seconds. Pain during the procedure was mild and well tolerated, rated by the patient as 3 out of 10 on a numerical rating scale. Throughout the procedure, real-time dermoscopic monitoring was performed using the integrated imaging system, allowing continuous visual control of tissue response and accurate coverage of the target area.

Post-Treatment Monitoring and Follow-Up

Treated lesions were monitored clinically and dermoscopically at predefined time points: at baseline (prior to treatment), immediately after HIFU application, at 2 weeks, at 3 months, at 6 months, and at 12 months post-treatment. Follow-up assessments included standardized clinical photography and digital videodermoscopic imaging using the FotoFinder Medicam 1000® system, with evaluation focused on lesion clearance, vascular patterns, pigmentary changes, and features of tissue remodeling.

Ethical Considerations

The procedure was performed strictly within the approved registration scope of the medical device used. The TOOsonix System ONE-M® is a CE-marked medical device classified as Medical Device Regulation (MDR) class IIa, and its use in the treatment of superficial benign and premalignant epidermal lesions falls within its registered indications. As the intervention was conducted in accordance with the device's intended use, without off-label application, experimental modification, or deviation from standard clinical practice, approval from an institutional ethics committee was not required. The absence of prior peer-reviewed publications addressing this specific clinical application does not constitute investigational use under MDR regulations. Written informed consent was obtained from the patient prior to treatment, including consent for anonymized clinical and dermoscopic image acquisition and publication. All procedures complied with the principles of the Declaration of Helsinki and were conducted in accordance with applicable institutional and national ethical standards. All personal identifiers were removed to ensure full compliance with data protection regulations.

Results

Macroscopic (Clinical) Outcomes

All treated porokeratotic lesions were successfully ablated using a single-session HIFU procedure and remained clinically stable throughout the entire follow-up period. No immediate or delayed procedural complications were observed.

Immediately after HIFU application, treated areas demonstrated discrete, well-demarcated treatment fields corresponding to the applied acoustic exposures, without excessive surrounding erythema or tissue disruption. At the two-week follow-up, all lesions exhibited hemorrhagic crusts, consistent with the expected post-ablative healing response following HIFU therapy. Re-epithelialization progressed gradually, and in several lesions crust detachment occurred only after approximately four weeks.

At the three-month follow-up, lesions appeared flattened, with resolution of the previously elevated hyperkeratotic border. Residual erythema was minimal and limited to the former lesion sites. No ulceration, infection, or hypertrophic scarring was observed.

At six months post-treatment, the treated areas presented as subtle, scar-like macules with preserved skin contour. No clinically apparent recurrence, hyperkeratosis, or nodular regrowth was detected. By the one-year follow-up, the treated sites demonstrated near-complete clinical normalization of the skin, with only minimal residual

hyperpigmentation in some areas. The original lesion margins were no longer clinically distinguishable from the surrounding healthy skin.

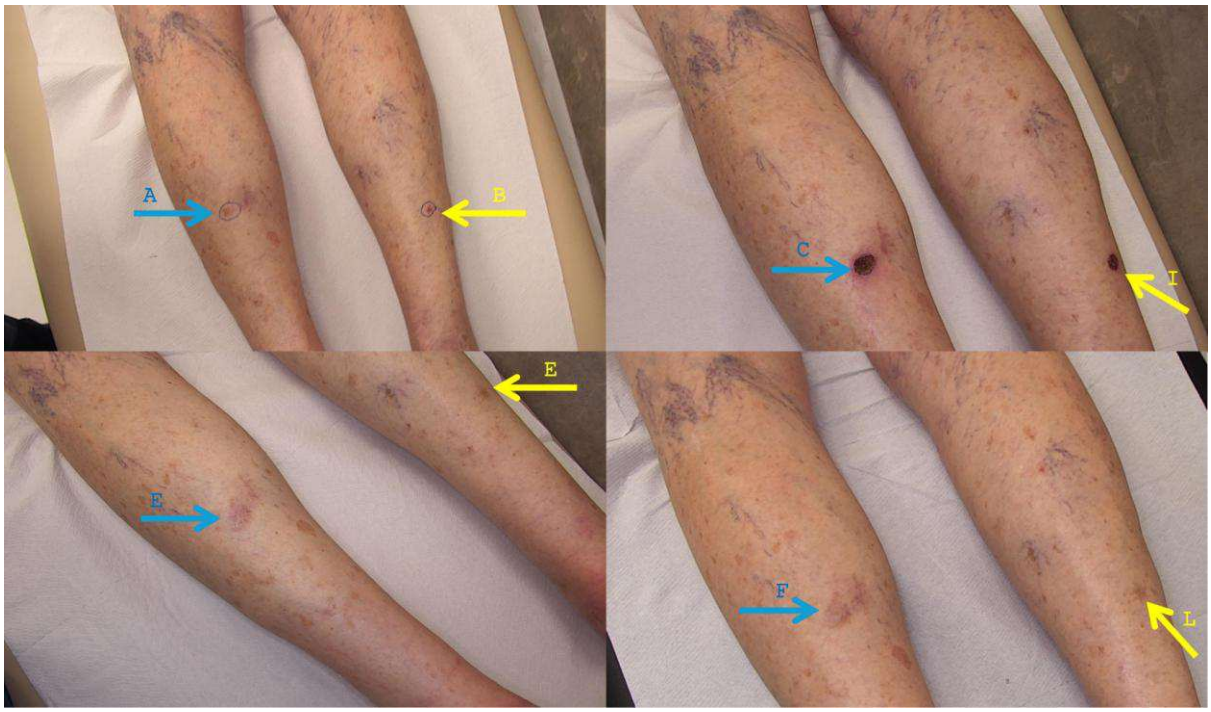


Figure 2. Macroscopic evolution of porokeratotic lesions treated with high-frequency focused ultrasound (HIFU) with corresponding dermoscopic references. The figure presents macroscopic (clinical) images of representative porokeratotic lesions at successive time points following HIFU treatment. Alphabetical labels indicate correspondence with dermoscopic images shown in the subsequent figure, allowing direct clinicodermoscopic correlation at each stage of treatment and healing. Images labeled A and B depict the lesions before HIFU treatment. Images labeled C and I show the lesions at 2 weeks post-treatment, characterized clinically by the presence of hemorrhagic crusts. Images labeled E and K represent the lesions at 6 months post-HIFU, demonstrating lesion flattening with scar-like resolution and post-inflammatory changes. Images labeled F and L illustrate the lesions at 12 months post-treatment, showing near-complete clinical normalization of the skin. Corresponding dermoscopic images for each time point are provided in the subsequent figure, enabling detailed assessment of structural and vascular changes throughout the healing process.

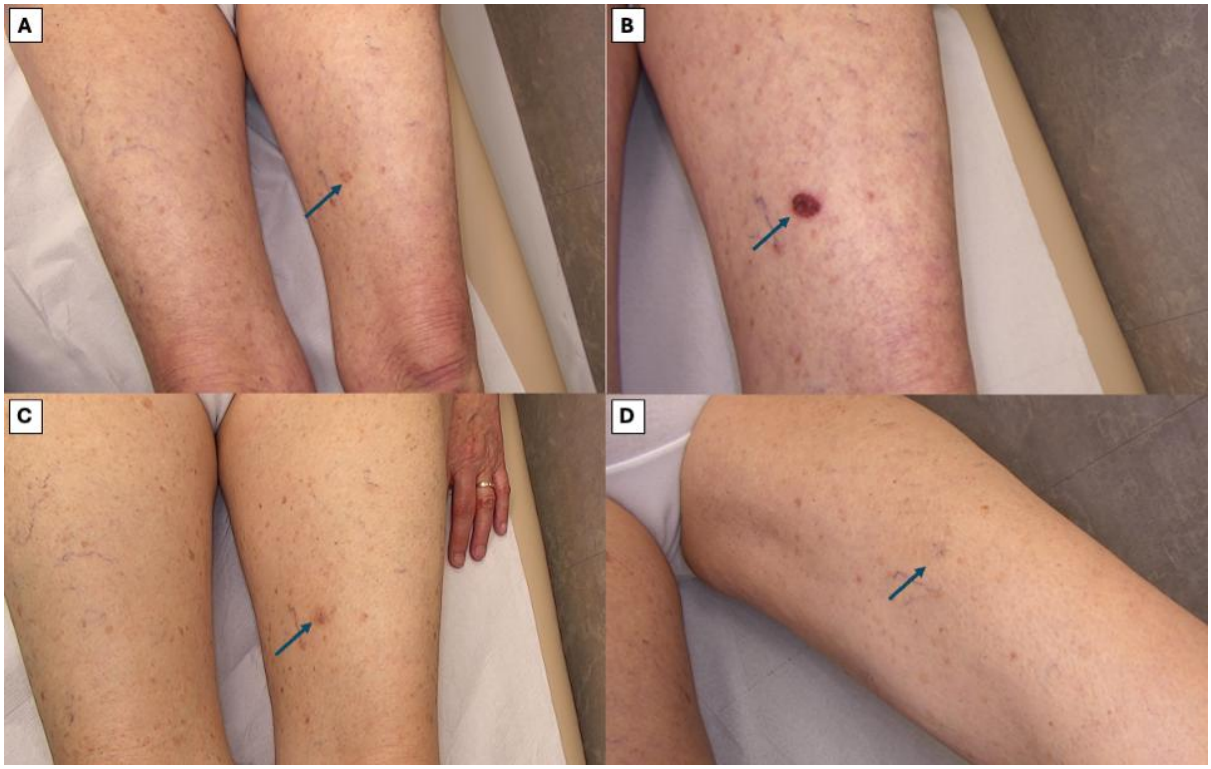


Figure 3. Macroscopic evolution of porokeratotic lesions on the left thigh treated with high-frequency focused ultrasound (HIFU) with corresponding dermoscopic references. The figure presents macroscopic (clinical) images of representative porokeratotic lesions located on the left thigh at successive time points following HIFU treatment. Image A depicts the lesion before HIFU treatment. Image B shows the lesion at 2 weeks post-treatment, characterized clinically by the presence of hemorrhagic crusts. Image C represents the lesion at 6 months post-HIFU, demonstrating lesion flattening with scar-like resolution and post-inflammatory changes. Image D illustrates the lesion at 12 months post-treatment, showing near-complete clinical normalization of the skin. Corresponding dermoscopic images for each time point are provided in the subsequent figure, enabling detailed assessment of structural and vascular changes throughout the healing process.

Dermoscopic Outcomes

At baseline, the initial dermoscopic pattern of the treated lesions included central dotted vessels within the keratotic ridge, a pattern consistent with stable porokeratosis. Lesions selected for intervention demonstrated dermoscopic progression, characterized by the emergence of branched linear vessels, looped vessels, and structureless white areas accompanied by white shiny lines under polarized light, suggesting early transformation toward squamous cell carcinoma (Figure 4A, 4G and 5A).

Immediately following HIFU treatment, dermoscopic examination revealed instantaneous whitening of the treated area (blanching), corresponding to protein denaturation and coagulative necrosis induced by the thermal effects of focused ultrasound energy. This finding was consistently accompanied by localized edema, representing an acute inflammatory response to thermal injury. At this stage, pre-existing vascular structures were no longer discernible within the treated fields, and thermal coagulation artifacts were clearly visible (Figure 4B, 4H and 5B).

The healing process was prolonged compared with that typically observed after HIFU treatment of other benign lesions. In some cases, crust detachment occurred only after approximately one month. At the two-week follow-up, dermoscopy demonstrated central hemorrhagic crusts with peripheral clearing, representing a characteristic early post-HIFU healing pattern (Figure 4C, 4I and 5C).

At six months post-treatment, dermoscopic evaluation revealed scar-like areas with complete loss of pathological vascular structures. Characteristic post-ablative features included pale yellow structureless areas, white clods arranged in a square or polygonal pattern, and isolated white shiny lines. In addition, a distinct rainbow pattern was observed under polarized light, consistent with optical interference phenomena within remodeled dermal collagen, indicative of late-stage healing following successful HIFU ablation of porokeratotic tissue (Figure 4E, 4K and 5E).

After a one-year follow-up, the area previously occupied by a hyperkeratotic plaque demonstrated a region of clinically and dermoscopically near-normal skin (Figure 4F, 4L and 5F). Within this area, ill-defined homogeneous white structures were present, accompanied by isolated white lines, consistent with residual stromal remodeling. In the central portion of the lesion, increased pigmentation was observed; however, the pigment intensity was more pronounced at the periphery, forming a subtle peripheral accentuation rather than a focal central structure. Evaluation of the lesion margin, at the interface between the former hyperkeratotic area and adjacent healthy skin, revealed color harmonization without evident disruption of keratinization. No signs of abnormal cornification were present, indicating excellent tissue regeneration and healing. Compared with baseline imaging, there was a marked reduction in vascular density. Only isolated, well-focused vessels remained visible, displaying no morphological features suggestive of atypia. These vessels were sparse, evenly distributed, and lacked architectural distortion. A notable finding was the complete resolution of polychromia, including the disappearance of the so-called “rainbow pattern”, alongside the loss of sharp lesion demarcation and the absence of a plaque-like structure. In comparison with the initial dermoscopic presentation, the central area no longer exhibited vascular patterns typical of porokeratotic lesions, such as dotted, linear, or branching vessels. The few remaining vessels did not demonstrate pathological configurations. At approximately one year post-intervention, only minimal residual hyperpigmentation persisted within the former lesion site. This pigment alteration was expected to resolve completely over time, likely resulting in fully restored skin, with the original lesion location becoming clinically and dermoscopically indistinguishable.

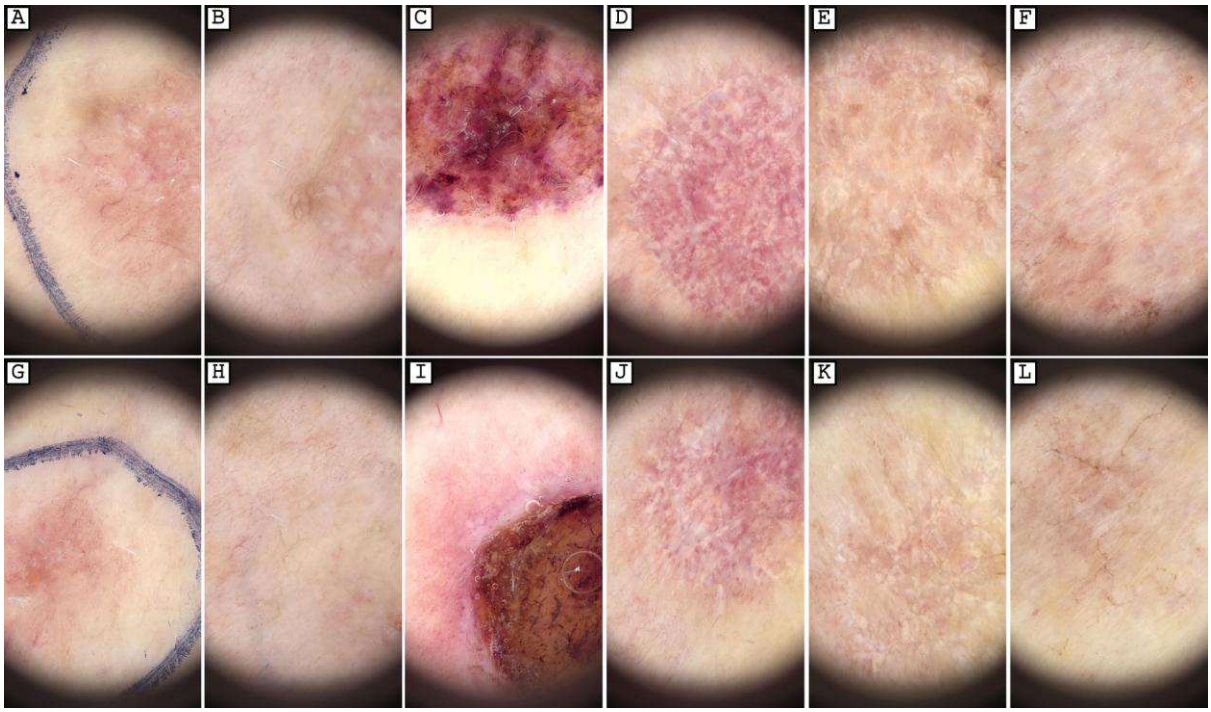


Figure 4. Dermoscopic evolution of porokeratotic lesions on the lower extremities treated with high-frequency focused ultrasound (HIFU). Panels A–F present the dermoscopic features of the lesion located on the posterior aspect of the left calf (regio surae posterior sinistra) at consecutive time points: before treatment (A), immediately after HIFU application (B), at 2 weeks post-treatment (C), at 3 months (D), at 6 months (E), and at 12 months follow-up (F). Panels G–L show the dermoscopic features of the lesion located on the posterior aspect of the right calf (regio surae posterior dextra) at the corresponding time points: before treatment (G), immediately

after HIFU application (H), at 2 weeks post-treatment (I), at 3 months (J), at 6 months (K), and at 12 months follow-up (L).

All treated lesions remained clinically and dermoscopically stable, with no further evolution of vascular structures or emergence of malignant criteria. This case illustrates the utility of descriptive dermoscopic terminology in accurate monitoring of porokeratotic lesions and supports the potential role of HIFU as an organ-sparing treatment for premalignant and early malignant epidermal neoplasms, especially in surgically challenging locations.

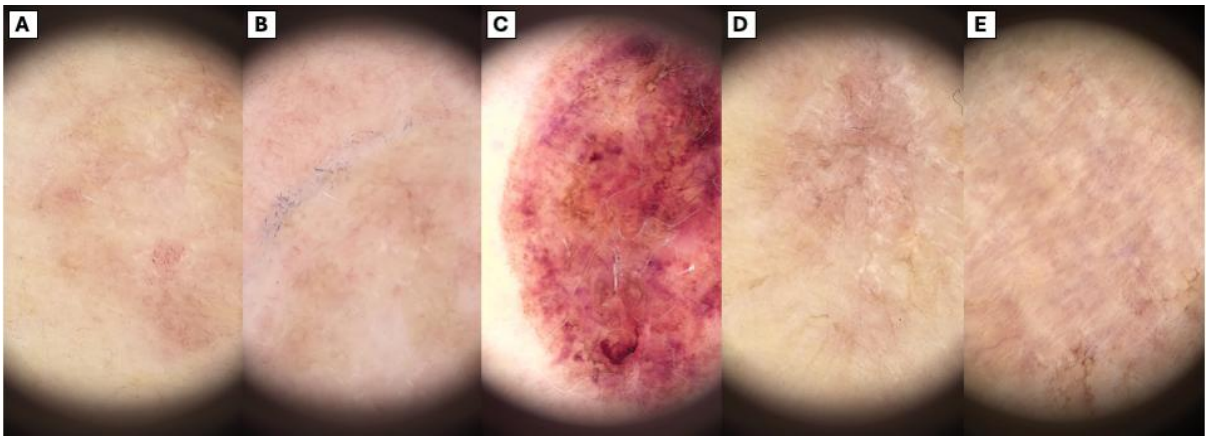


Figure 5. Dermoscopic evolution of porokeratotic lesions on the lower extremities treated with high-frequency focused ultrasound (HIFU). Panels A–F illustrate the dermoscopic features of the lesion located on the posterior aspect of the left thigh (*regio femoris posterior sinistra*) at consecutive time points: before treatment (A), immediately after HIFU application (B), at 2 weeks post-treatment (C), at 3 months (D), at 6 months (E), and at 12 months follow-up (F).

Discussion

Our treatment experience illustrates that high-frequency focused ultrasound (HIFU) can achieve effective ablation of porokeratotic lesions with outcomes that compare favorably to conventional therapies. All treated lesions were eradicated without clinical or dermoscopic evidence of recurrence at 12 months, an encouraging result given the historically variable success of standard treatments. Importantly, beyond demonstrating therapeutic feasibility, this study provides a structured clinicodermoscopic framework for monitoring tissue response and healing following HIFU-based ablation in porokeratosis.

An intriguing dermoscopic finding observed at the 6-month follow-up was the presence of the rainbow pattern, characterized by multicolored iridescence within the previously treated lesion. Although initially described in vascular tumors and fibrous lesions, this optical phenomenon has also been reported in inflammatory and neoplastic dermatoses [21]. In the context of post-HIFU healing, the rainbow pattern likely results from dermal collagen remodeling and light interference phenomena occurring within the reorganized extracellular matrix. This observation suggests that the rainbow pattern may not only reflect structural changes in collagen but could potentially serve as a dermoscopic marker of successful tissue remodeling following ablative therapy. Further research is warranted to determine whether this feature can reliably indicate treatment efficacy or tissue regeneration across different lesion types.

Porokeratosis exemplifies the concept of a premalignant field and field cancerization, in which genetically or epigenetically altered keratinocytes form a contiguous area of skin with an increased risk of malignant transformation, rather than isolated lesions [22]. This field effect is characterized by clonal expansion of atypical keratinocytes, frequently associated with molecular alterations such as p53 mutations, and may give rise to multiple primary keratinocyte carcinomas within the affected area [23]. Conceptualizing porokeratosis within this framework provides important implications for therapeutic strategy selection.

In this context, field-directed therapies are particularly relevant, as they target both clinically apparent lesions and subclinical atypia across the entire cancerized field [24]. High-frequency focused ultrasound represents a novel, non-invasive field-directed modality that enables precise ablation of multiple lesions while minimizing collateral damage to surrounding healthy tissue. HIFU has demonstrated efficacy in the treatment of premalignant and malignant cutaneous lesions, and its ability to address multifocal disease aligns closely with the biological behavior of field cancerization [25].

Conversely, focal surgical excision is inherently limited in the management of porokeratosis, as it removes only individual lesions while leaving the underlying field of genetically altered keratinocytes intact. This residual field predisposes to the development of new primary tumors or lesion recurrence, underscoring the need for treatment strategies that extend beyond lesion-directed surgery and instead address the broader cancerized area whenever feasible [23].

Destructive modalities such as cryotherapy, laser ablation, and surgical excision often yield only incomplete or transient remission of porokeratosis, with lesions frequently relapsing after initial treatment [26,27]. These therapies also carry the risk of adverse effects such as scarring, pigmentation changes, or persistent erythema. Moreover, the efficacy of several treatments—including topical retinoids, imiquimod, photodynamic therapy, and other topical agents—is limited, and lesion recurrence is common after treatment discontinuation [28]. Although topical statin/cholesterol combination therapy has recently emerged as a promising pathogenesis-directed approach, current evidence is derived from small studies and underpowered meta-analyses, with no randomized controlled trials available to date [29]. Consequently, no standardized treatment algorithm for porokeratosis has been established.

Against this backdrop of modest efficacy and frequent relapse with standard care, the durable lesion clearance observed with HIFU in our patient suggests a meaningful therapeutic advance. Beyond its efficacy, HIFU offers distinct safety and cosmetic advantages. Unlike cryosurgery or ablative lasers, which cause non-specific tissue destruction and may result in pigmentary or textural changes, HIFU concentrates thermal energy at a controlled depth, selectively targeting the pathological epidermal focus while sparing surrounding tissue [30]. This depth-selective “inside-out” ablation likely underpins the favorable cosmetic outcome observed, consistent with prior reports that HIFU-treated keratoses heal rapidly without lasting scars [17].

The procedure was well tolerated and did not require local anesthesia or analgesia, a finding consistent with other dermatologic applications of HIFU. This favorable tolerability profile, combined with the absence of an open wound and minimal downtime, allows treatment of multiple lesions in a single session—an important practical advantage in disseminated porokeratosis, where numerous lesions may require intervention [16, 31-34]. In contrast to therapies requiring repeated clinic visits or prolonged topical application, HIFU offers the potential for durable clearance with limited treatment burden.

An additional consideration is the role of non-invasive monitoring following ablative therapy. In the absence of residual clinical or dermoscopic abnormalities after HIFU, post-treatment biopsy is neither indicated nor technically feasible, as HIFU ablates the target tissue without leaving material suitable for histopathological assessment (25). Dermoscopy is increasingly recognized as a reliable non-invasive follow-up tool in dermatologic oncology, offering high sensitivity and specificity for detecting recurrence or residual disease and guiding further management decisions [35]. This approach aligns with contemporary trends favoring imaging-based surveillance modalities, including dermoscopy and high-frequency ultrasound, particularly in post-ablative settings [36].

Interestingly, beyond its local ablative effect, HIFU may exert immunomodulatory effects. Preclinical studies have shown that thermal injury induced by focused ultrasound can trigger immune activation through the release of damage-associated molecular patterns, leading to enhanced antigen presentation and cytotoxic T-cell infiltration [37–41]. In melanoma and breast cancer models, this phenomenon has been associated with reduced metastatic potential and improved responses to immunotherapy [40,41]. Although immunologic mechanisms were not evaluated in the present study, these findings raise the possibility that HIFU could contribute not only to lesion eradication but also to enhanced local immune surveillance in porokeratosis. The ability of high-frequency focused

ultrasound to induce complete and spatially confined ablation of premalignant and early malignant epidermal lesions suggests that this modality may be capable of curing early-stage squamous cell carcinoma. This hypothesis provides a strong biological and translational rationale for future studies investigating the effects of HIFU on squamous cell carcinoma in tissue-engineered and cell culture models.

Several limitations must be acknowledged. This study represents a single-patient proof-of-concept observation and therefore cannot provide generalizable evidence of efficacy. The absence of a control group precludes quantitative comparison with established therapies, and longer follow-up is required given the chronic nature of porokeratosis and its risk of late malignant transformation. Furthermore, the findings are limited to disseminated porokeratosis in an adult patient, and responses in other clinical subtypes remain to be determined.

Despite these limitations, this study introduces a novel therapeutic and monitoring paradigm for porokeratosis, integrating depth-selective ablation with structured dermoscopic follow-up. These findings support further prospective studies to evaluate the oncologic safety, durability of response, and reproducibility of dermoscopic healing patterns following HIFU treatment in premalignant keratinization disorders.

Conclusions

This proof-of-concept study demonstrates that 20 MHz high-frequency focused ultrasound (HIFU) may be a feasible, well-tolerated, and tissue-sparing modality for the treatment of porokeratosis with dermoscopic features suggestive of progression. Depth-selective thermal ablation enabled complete clinical and dermoscopic clearance of treated lesions, with favorable cosmetic outcomes and no evidence of recurrence during follow-up. Importantly, this study highlights the value of structured dermoscopic monitoring as an integral component of HIFU-based therapy, providing non-invasive assessment of treatment response, healing dynamics, and oncologic safety. The reproducible sequence of post-treatment dermoscopic changes observed in this study suggests that dermoscopy may serve as a reliable surrogate endpoint for evaluating ablative efficacy in premalignant keratinization disorders. While larger prospective studies with longer follow-up are required to confirm durability of response and oncologic adequacy across different porokeratosis subtypes, the present findings support HIFU as a promising field-directed therapeutic approach for patients with disseminated or surgically challenging lesions. This integrated strategy of precision ablation combined with longitudinal dermoscopic surveillance may represent a meaningful advance in the management of porokeratosis and other premalignant epidermal conditions.

Conflicts of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Author Contributions

Jacek Calik: Conceptualization, Clinical Investigation, Methodology, Visualization, Writing – Original Draft. Natalia Sauer: Conceptualization, Methodology, Literature Review, Data Curation, Formal Analysis, Visualization, Writing – Original Draft, Review & Editing, Figure Preparation, Project Administration, Supervision.

All authors have read and approved the final version of the manuscript.

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