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Journal of Dermatology & Cosmetology

Review Article

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An evaluation of minimally invasive laser approaches for cosmetic removal of pearly penile papules

Abstract

Pearly penile papules (PPPs) are benign angiofibromatous proliferations characterized by ectopic sebaceous gland hyperplasia and stromal fibrosis, classically arranged in a dome-shaped distribution around the corona of the glans. Despite their non-infectious and physiologic nature, PPPs are frequently mistaken for sexually transmitted infections, contributing to heightened patient concern and demand for cosmetic intervention. Laser therapy has emerged as the leading treatment modality, offering precise ablation with controlled thermal confinement and favorable cosmetic outcomes. Ablative fractional carbon dioxide (CO_2) lasers (10,600 nm) deliver deep dermal penetration with marked coagulation, facilitating complete lesion removal but at the cost of longer re-epithelialization times and greater risk for pigmentary alteration. In contrast, Erbium-doped Yttrium Aluminum Garnet (Er:YAG) lasers (2940 nm) provide more superficial ablation with minimal collateral thermal damage, supporting faster healing and reduced downtime, though often necessitating multiple sessions for optimal efficacy. Emerging technologies, including picosecond-domain lasers, thulium fiber lasers, and fractional radiofrequency microneedling, are being investigated for their potential to selectively target papular structures with enhanced precision and reduced recovery times. Integration of real-time thermal feedback systems, robotics-assisted guidance, and AI-optimized energy delivery parameters may further advance procedural accuracy and safety. With advances in laser physics, device miniaturization, and precision energy delivery, cosmetic treatment of pearly penile papules reflects a convergence of aesthetic intent and microsurgical control, demonstrating how targeted technologies can refine tissue interaction in anatomically delicate, highly specialized procedures.

Keywords: pearly penile papules (PPPs), Er:YAG lasers, pulsed dye lasers, non-ablative lasers, sexually transmitted infection, microsurgical control

Volume 9 Issue 3 - 2025

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Received: August 01, 2025 | **Published:** August 14, 2025

Introduction

Pearly penile papules (PPP) are benign, angiofibromatous lesions that commonly present as dome-shaped or filiform papules arranged circumferentially around the corona or sulcus of the glans penis. They are considered a normal anatomical variant and are not associated with infection, malignancy, or systemic disease.[1,2] The prevalence of PPPs ranges from 14% to 48% among post-pubertal males, with a higher incidence in uncircumcised men.[3] In a prospective study of over 2,600 men, a prevalence of 17.18% was observed, with most lesions located at the coronal margin and some extending to the frenulum or shaft.[4] Histologically, PPPs are classified as angiofibromas, composed of fibrovascular stromal cores lined by stratified squamous epithelium without cytologic atypia.[5] Immunohistochemical analysis confirms the absence of proliferation markers such as Ki-67, helping distinguish PPPs from condylomata acuminata and other genital dermatoses.[6] Despite their benign character, PPPs often elicit significant psychological distress in affected individuals. Misinterpretation as signs of sexually transmitted infections can lead to anxiety, avoidance of intimacy, and social withdrawal.[7,8] This has been described in the context of venerophobia, particularly among younger patients.[9] While reassurance remains the primary management approach, increasing numbers of patients seek elective removal due to persistent cosmetic concern or emotional discomfort.[4,10] Several treatment modalities have been employed for the cosmetic removal of PPPs, including cryotherapy, electrosurgery, and curettage. However, these methods carry a higher risk of dyspigmentation, scarring, and prolonged recovery.[11] In contrast, laser therapies, particularly ablative modalities such as CO_2 and Er:YAG lasers, have gained clinical favor due to their precision, minimal tissue disruption, and favorable cosmetic profiles[12,13] (Figure 1). Newer fractional laser systems further reduce downtime and may offer enhanced patient tolerability.[14] Given the growing demand for minimally invasive aesthetic interventions, a comprehensive evaluation of laser-based treatments for PPPs is warranted. This review explores the clinical application, safety considerations, and procedural characteristics of laser therapy for PPPs within the context of patient-centered cosmetic dermatology.

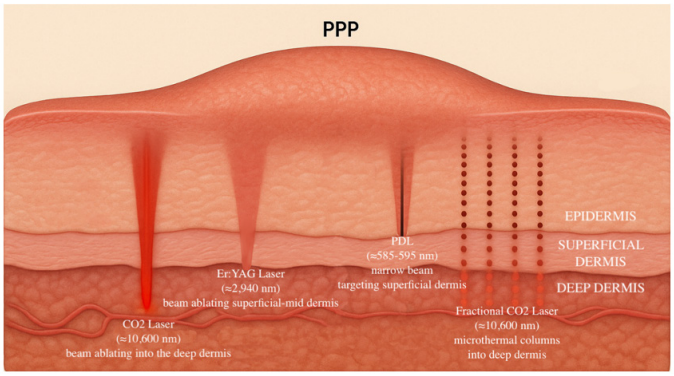

Figure 1 Comparative cross-sectional illustration of laser modalities for Pearly Penile Papule (PPP) removal.

Legend: A realistic, full-width cross-section of a PPP lesion spanning the epidermis and dermis. Four laser beams are superimposed to demonstrate relative penetration depths and tissue interactions: CO_2 Laser (≈10,600 nm): Solid red beam extending into the deep dermis, producing broad thermal coagulation and ablation. Er:YAG Laser (≈2,940 nm): Semi-opaque pink beam ablating to the superficial-mid–mid dermal layer with minimal collateral heat. Pulsed Dye Laser (PDL) (≈585–595 nm): Narrow orange beam targeting

superficial dermal vasculature via selective photothermolysis. Fractional CO_2 Laser (≈10,600 nm): Dotted orange columns creating microthermal zones in the deep dermis, preserving surrounding tissue for rapid healing. Abbreviations: PPP, Pearly Penile Papules; CO_2, Carbon Dioxide; Er:YAG, Erbium-doped Yttrium Aluminum Garnet; PDL, Pulsed Dye Laser; nm, Nanometers.

Methods

A comprehensive literature review was conducted using the databases PubMed and Google Scholar. The search was performed using relevant keywords including "pearly penile papules," "laser therapy," "CO_2 laser," "Er:YAG laser," "pulsed dye laser," "fractional laser," and "minimally invasive cosmetic procedures." Articles published between January 2010 and June 2025 were included to capture the most recent advancements and clinical practices. Studies selected for this review encompassed randomized controlled trials (RCTs), observational studies, case series, and individual case reports focused on the efficacy, safety, patient satisfaction, cosmetic outcomes, and complications associated with laser-based treatment of pearly penile papules (PPP). Exclusion criteria included non-laser treatment studies, non-English language publications, editorials, commentaries, and studies lacking detailed treatment parameters or outcome data. Study selection involved initial title and abstract screening followed by full-text review to confirm eligibility. A standardized extraction form was used to gather data on laser type, energy parameters, treatment settings, clinical outcomes, complications, follow-up duration, and patient-reported satisfaction. Collected data were systematically organized to synthesize key findings and evaluate comparative effectiveness across laser modalities.

Results

Recent advancements in laser technologies have led to the rise in various treatment options for those living with PPPs (Table 1). The following section will highlight such laser therapies as well as their potential for further dermatologic applications.

Laser technologies used for PPP removal

CO_2 lasers

The carbon dioxide (CO_2) laser operates at a wavelength of 10,600 nm, a spectrum strongly absorbed by intracellular and extracellular water.[15] Its mechanism of action involves rapid heating and vaporization of water within tissue, resulting in precise ablation of targeted lesions such as PPP. CO_2 lasers effectively excise lesions through vaporization, accompanied by coagulation of adjacent dermal tissue, which aids hemostasis and minimizes bleeding during procedures.[16] Standard clinical protocols for CO_2 laser treatment of PPPs typically utilize spot sizes between 0.2 to 1 mm with fluence settings ranging from 4-8 J/cm², often delivered via pulsed or ultra-pulsed modes. These controlled pulses allow precise thermal confinement, reducing collateral tissue damage and improving cosmetic outcomes.[14,17] Sessions usually involve topical or local anesthesia to manage patient discomfort effectively. Numerous studies affirm CO_2 lasers as highly effective in the complete removal of PPP. A survey study reported clearance rates exceeding 90% following single-session treatments, with patient satisfaction similarly high due to immediate cosmetic improvements.[18] This shows that CO_2 laser treatment for PPP achieves high clearance rates. Additionally, CO_2 lasers demonstrate favorable long-term outcomes, with low recurrence rates due to deep ablation capabilities.[19] Adverse effects associated with CO_2 laser procedures predominantly include temporary erythema, swelling, and mild discomfort post-procedure.[14] Most patients healed within a week without scarring or pigmentation issues. Less frequently reported but more significant complications involve transient hyperpigmentation or hypopigmentation, particularly among darker skin phototypes.[20] It is the most reported adverse effect among those with darker skin tones due to hypermelanosis secondary to dermal inflammation. Rare occurrences of scarring are noted, primarily associated with overly aggressive treatment parameters or inadequate postoperative care.[11,14] There was no incidence of permanent scarring.

Er:YAG lasers

The Erbium-doped Yttrium Aluminum Garnet (Er:YAG) laser emits at a wavelength of 2940 nm, possessing an exceptionally high affinity for water, markedly greater than that of the CO_2 laser.[21] Its wavelength aligns with a strong absorption band for water, resulting in the highest absorption among lasers in the near- and mid-infrared spectrum. This absorption profile leads to efficient and superficial tissue ablation with minimal residual thermal damage, facilitating rapid wound healing and reduced downtime.[18] It functions by stimulating re-epithelialization and collagen production. Er:YAG lasers are characterized by precise ablation depth control, allowing selective removal of superficial skin lesions such as PPP with minimal thermal collateral injury.[12,14,19] The diminished thermal diffusion relative to CO_2 lasers reduces the likelihood of thermal necrosis of adjacent tissue, making Er:YAG lasers ideal for sensitive anatomical sites, including penile tissue. Clinical evaluations of Er:YAG lasers consistently highlight their safety and efficacy in treating PPP, reporting high patient satisfaction rates due to reduced procedural discomfort and accelerated healing compared to other laser modalities. Baumgartner treated 45 patients using Er:YAG lasers in 1- 6 sessions (mean 2 ± 1.3), with complete lesion clearance and no reported scarring or pigmentation changes at long-term follow-up.[12] The reported clearance rates ranged from 80% to 95%, typically achieved across multiple sessions. Due to the minimal thermal injury, Er:YAG lasers pose substantially reduced risks of pigmentation alteration or scarring.[11,16] Adverse events reported are minor and predominantly transient, including mild erythema, short-term edema, and superficial crusting, resolving spontaneously within days to a week post-procedure.

Pulsed Dye lasers

Pulsed dye lasers (PDL) emit yellow light at a wavelength of 595 nm, which is specifically absorbed by oxyhemoglobin within blood vessels, making them well-established for vascular lesions.[22] The rationale for PDL use in PPP stems from histopathologic similarities between PPP and angiofibromas, both of which feature prominent vascular networks beneath the epidermis.[7] By selectively targeting the vasculature of these benign papules, PDL offers a non-ablative approach with theoretically reduced risk of scarring and pigmentary alteration compared to traditional ablative techniques. Despite the theoretical advantages, PDL has been infrequently studied in the context of PPP. The existing literature primarily consists of small case series and reports, with no randomized controlled trials to date.[3,22] In a pivotal case series by Sapra et al.,[7] four patients underwent PDL treatment using a Mini V Pulse-Dye (595 nm) device with settings of 5 mm spot size, 0.5 ms pulse duration, and fluence ranging from 6–10 J/cm². Patients received one to three sessions under topical anesthesia.[7] Similarly, Forbat & Al-Niaimi corroborate these findings, noting significant reduction or complete clearance of lesions in all reported cases.[22] PDL treatment has demonstrated favorable cosmetic outcomes with minimal side effects. In Sapra et al.,[7] three of four patients experienced complete clearance of PPP, while the remaining patient achieved a substantial reduction after a single session and expressed satisfaction with the result. Discomfort was minimal, with only mild, transient bruising or purpura and no reported

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scarring, infections, or pigmentary changes. Post-procedure care was simple, requiring only topical antibiotics and no special dressings.[7] Comparative literature supports these findings, highlighting the nonablative, safe, and well-tolerated profile of PDL across multiple benign dermatologic indications.[16,22] However, the overall evidence base remains limited to small series, emphasizing the need for further prospective and comparative studies to establish optimal protocols and long-term efficacy. While pulsed dye laser therapy is not yet widely adopted for PPP, available studies suggest it is an effective and cosmetically superior alternative to ablative modalities, particularly for patients concerned about downtime, scarring, or pigmentary changes. Ongoing investigation is warranted to confirm these early results and clarify the precise role of PDL in the management of PPP.

Fractional and Non-ablative lasers

Recent advances in laser technology have introduced both fractional and non-ablative laser systems as promising alternatives to fully ablative treatments for PPP. Fractional lasers, such as the fractional CO_2 and fractional 1550-nm erbium devices, deliver energy in a grid-like pattern, creating microscopic treatment zones (MTZs) that spare surrounding tissue and stimulate rapid re-epithelialization.[14,16] Non-ablative lasers, including pulsed dye lasers (PDL) and certain erbium devices, target underlying vascular or dermal components without vaporizing the entire lesion, thus minimizing disruption to the epidermis.[3,22] Fractional CO_2 lasers have shown consistently high clearance rates, with most studies reporting >90% resolution after 1–3 sessions, minimal complications, and strong cosmetic results.[13,14,18,23] Fractional erbium devices and non-ablative 1550-nm erbium lasers have also demonstrated complete or near-complete clearance, with one series noting all 45 patients achieved full resolution after an average of two sessions.[16] While ablative modalities such as full-field CO_2 or Er:YAG lasers are highly effective, they carry greater risks of discomfort, pigmentary alteration, and downtime. Comparative data suggest that fractional and non-ablative lasers match or exceed ablative techniques in both efficacy and safety, especially for patients with darker skin types or heightened cosmetic concerns.[3,11] A key advantage of fractional and non-ablative approaches is markedly reduced downtime and improved patient tolerance. Most patients experience only transient erythema and mild swelling, with re-epithelialization typically complete within 3–7 days.[14,23] The pain profile is generally mild to moderate and easily managed with topical anesthetics or cool air. In reported case series, no significant scarring, pigment changes, or long-term complications have been observed, even in Fitzpatrick type IV–V skin.[14,18] These characteristics make fractional and non-ablative lasers particularly suitable for PPP patients who prioritize rapid recovery and minimal risk of visible sequelae.

Clinical outcomes

Past studies have consistently demonstrated high rates of complete lesion removal when minimally invasive lasers are used (Table 2). A systematic review by Maranda et al.,[16] reported that fractional photothermolysis therapies and Er:YAG, pulsed dye, and CO_2 lasers achieved complete clearance of PPP in the eight studies analyzed. These minimally invasive laser therapies precisely remove PPP without significantly damaging the skin around the treatment sites. Furthermore, these treatments are associated with minimal discomfort and complications.[16] The findings from this study suggest that these laser modalities are highly effective and well-tolerated treatments for PPP. Other case series studies further highlight the success of minimally invasive lasers in treating PPP. For instance, in a case series study, all 20 PPP cases resulted in complete clearance after being treated with a fractionated CO_2 laser, with 14 cases requiring two treatment sessions and 6 requiring one.[18] Similarly, in a four-case report involving PDL treatment, the laser intervention resulted in complete resolution of PPP in two out of four patients after one to three sessions, while the remainder experienced significant reductions to their satisfaction.[7] The high rates of complete lesion removal highlight the efficacy and advantages of utilizing minimally invasive laser approaches to treat PPP. Another case series conducted by Baumgartner reported 100% lesion clearance in 45 PPP cases previously unresponsive to other non-laser therapies, with a mean of two sessions using the ablative Er:YAG laser.[12] Collectively, these findings show the efficacy of minimally invasive lasers in treating PPP. The high clearance rates reported in these studies strongly support laser therapy as a favorable treatment modality for PPP. Healing time after PPP removal using laser therapy can vary depending on the type of laser used, as the thermal damage produced and penetration depth differ across laser treatment modalities. Overall, the healing time generally ranges from 7 to 10 days. In the Sapra et al.,[7] case reports, four patients who underwent PDL treatment for PPP experienced little bruising and minimal discomfort that was eventually resolved within 7 days. Targeting the vasculature of PPP, PDL therapies create less disruption to the skin surface, which can lead to shorter recovery times when compared to other modalities.[7]

Table 2 Comparative efficacy and risks of PPP treatments

Modality	Sessions (Typical)	Clearance rate	Side Effects/ Complications	Healing time	Notes/Comments	Source(s)
CO_2 Laser	1–3	100%	Mild erythema, swelling, rare	3–10 days	Fractional, rapid, safe for dark skin	Deda,[13] Gan,[14] Maranda[16]
Er:YAG Laser	1–6 (avg 2)	100%	Minor bleed/ discomfort, rare	<2 weeks	Effective even after failed other treatments	Maranda,[16] Aldahan[3]
PDL	1–3	75–100%	Mild bruising, minimal	<1 week	Nonablative, no scarring or pigment change	Sapra,[7] Maranda[16]
Cryotherapy	1–2	80–90%	Scarring, pigment change, pain	Variable	Less reliable, more adverse effects	Aldahan,[3] Honigman, et al.[11]
ED&C	1	100%	Scarring risk (operator-dep)	~10 days	Operator dependent, higher risk	Honigman, et al.[11]
Ho:YAG Laser	1	100% (light skin)	None in light skin	NR	Not recommended for dark skin, risk of pigment change	Honigman, et al.[11]
Reassurance	N/A	N/A	None	N/A	First-line for asymptomatic, not distressed patients	Aldahan,[3] Honigman, et al.[11]

Abbreviations: NR = not reported

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As outlined in a case report conducted by Krakowski et al.,[23] re-epithelialization after CO_2 laser treatment occurs within 5 to 7 days.[23] Due to the amount of thermal energy created and the depth of dermal penetration, CO_2 laser therapy has a longer healing time compared to the other laser technologies, as time to re-epithelialization is longer.[11] In a case series study conducted by Deda et al.,[13] minimal swelling and erythema from pulsed CO_2 laser-treated PPP resolved within 48 hours postprocedurally, and full healing was observed within 7 to 10 days after treatment.[13] The postprocedural healing times reviewed in this work highlight the suitability of these laser approaches for patients with PPP who aim for quick recovery times and prompt cosmetic results. Based on current literature, the rates of recurrence of PPP following minimally invasive laser treatment remain low. Sustained clearance of PPP lesions during follow-up appointments is reported in several of the studies reviewed in this work. In a case report by Krakowski et al.,[23] a patient treated with full-field ablative CO_2 laser had no recurrence at the 6-month follow-up.[23] Similarly, in another study, ablative Er:YAG lasers resulted in complete lesion removal without any significant recurrence reported. Specifically, the 45 patients treated with the Er:YAG laser in this report had remained lesion-free at the 1-year follow-up.[12] These results show that the utility of laser therapy in treating PPP yields favorable outcomes and maintains a low risk of recurrence.

While pigmentary alteration, including hypopigmentation or hyperpigmentation, is a concern with the use of laser technologies, these side effects are not consistently reported in the literature reviewed. In the case series by Baumgartner,[12] among the patients who received multiple sessions with the ablative Er:YAG laser, scarring and pigmentary alteration were not reported.[12] Due to its lower penetration and thermal injury through strong absorption by water, Er:YAG lasers can mitigate the risk of scarring, making it a favorable laser therapy for PPP. In another literature review conducted by Honigman et al.,[11] one of the studies reviewed showed that treated areas with continuous wave CO_2 laser demonstrated re-epithelialization without clinical evidence of scarring at the 2-month follow-up.[11] This finding shows that the occurrence of pigmentary alteration with CO_2 laser treatment can vary even though CO_2 laser therapy has an increased risk for pigmentary alteration due to its deeper dermal penetration. Other nonablative laser modalities, such as PDL, produce similar treatment outcomes but without the risk of scarring and pigmentary alteration.[7] Minimally invasive laser use for treatment of PPP is associated with high patient satisfaction throughout the studies examined in this work. In one study, patients with PPP who underwent unsuccessful attempts with other non-laser therapies, including topical agents, cryotherapy, and podophyllin, reported high satisfaction after receiving Er:YAG laser treatment, with no adverse effects.[12] In a systematic review by Maranda et al.,[16] the cosmetic outcomes and patient satisfaction remained high across various laser modalities such as PDL, CO_2, and Er:YAG lasers. The positive cosmetic outcome and relief from psychological distress and morbidity contribute to high patient satisfaction with these treatments.[16] The key drivers of patient satisfaction following minimally invasive laser therapy are disease resolution, short recovery time, and low risk for disease recurrence and adverse effects.

Safety and complication profiles

There are subtle differences in the risks of complications among different laser technologies. Operating at 2940 nm, Er:YAG lasers have a high water coefficient, carrying precision and a low risk of scarring and delayed healing.[12] This makes Er:YAG lasers reliable and favorable treatment options for removing PPP in sensitive genital areas. Similarly, CO_2 lasers are highly effective in completely removing PPP due to the fact that these lasers penetrate deeper into the skin. However, this increased penetration also increases the risk of thermal injury and scarring. Despite this, many studies have reported little to no incidences of scarring or pigmentary changes from complete PPP removal with CO_2 lasers.[3,11] Moreover, the safety profile of fractionated CO_2 lasers is comparable to that of traditional ablative lasers, preserving sites of untreated skin and reducing the healing time. In a case series study, Rivera,[18] demonstrated that the use of fractionated CO_2 laser was able to treat PPP in all of the cases without producing adverse events. Despite the deeper fractional ablation mechanism, complications such as scarring, pain, and infection from fractionated CO_2 lasers were rare.[18] In contrast, PDL is a non-ablative laser modality that creates less disruption to the skin surface, with a lower risk of pigmentary changes and other complications. This favorable safety profile may potentially compromise efficacy, but recent studies have shown that PDL results in both significant reductions and complete resolutions of PPP.[7] Overall, this review demonstrates the high degree of safety among various laser modalities when utilized appropriately for the removal of PPP. Although the risks of complications vary among the different modalities, their efficacies are comparable, with a low incidence of adverse effects across laser types. Minimally invasive lasers for the removal of PPP are typically well-tolerated. Patients report feeling minimal pain during and after the procedure.[11] Sapra et al.,[7] also found that when using PDL for the treatment of PPP, patients experienced little to no discomfort during the procedure. While one patient in this study experienced minimal discomfort postprocedurally, this discomfort went away within a week.[7]

The literature reviewed in this work consistently found that a low pain profile is associated with laser therapies, enhancing their appeal among patients seeking a minimally invasive, effective solution for PPP. Moreover, providers can use local anesthesia to reduce potential pain at the treatment site. Krakowski et al.,[23] reported a case where CO_2 laser resurfacing treated PPP in an adolescent patient, and procedural pain was managed effectively by using only local anesthetic.[23] This also underscores the importance of considering a patient's individual pain tolerance before laser treatment. While infection is a risk of treating PPP with laser therapy, this potential risk is low, especially if proper wound care is implemented. Current studies indicate that infections from these procedures are infrequent, with many patients recovering without any systemic infections or adverse effects within 7 to 10 days.[7,13] To optimize healing and cosmetic outcomes while preventing infections, patients who have undergone minimally invasive laser treatments for PPP are advised to keep the treatment areas clean and dry. Patients are also advised to reduce irritation to the treated areas, such as avoiding sexual activity and tight-fitting undergarments.[13] Effective postprocedural care includes applying topical antibiotic cream after treatment to minimize the overgrowth of bacteria.[7] Additionally, prophylactic oral antibiotics can be taken as well, but specific studies have reported no bacterial complications associated with the absence of antibiotic use.[14] Although the risk of infections is low, preventative strategies and proper postprocedural care help ensure greater satisfaction and optimal recovery.

Psychosocial considerations

Due to PPP being benign in nature, relatively common, and physiologically asymptomatic, reassurance is the leading management practice.[4] However, there are treatment options available for patients who have cosmetic concerns or are experiencing psychosocial distress from the appearance of their PPP.[3] PPP can resemble and often be mistaken for a sexually transmitted infection, such as condyloma acuminata, genital warts caused by *human papillomavirus*.[3] Although

non-infectious, this resemblance can often negatively impact a patient's body image, as well as strain intimate relations with sexual partners due to anxiety, self-consciousness, embarrassment, or fear of transmission.[4] These deleterious effects on body image, self-esteem, and sexual confidence lead to a decrease in quality of life and psychosocial well-being, motivating patients to seek removal. When cosmetically treating benign skin lesions, there are several ethical factors that must be strategically managed and carefully considered within the context of each patient visit. First and foremost, is transparency, which allows the patient to fully understand their condition, reason for removal, risks, benefits, and cost, in order to give informed consent.[24] Additionally, throughout the treatment process, patients need to be involved in decision-making where their preferences and values are upheld, to respect autonomy and avoid unnecessary suggestions that may cause further psychosocial distress.[25] Healthcare professionals must maintain the ethical principles of beneficence and nonmaleficence by fully considering all potential complications, adverse events, and psychological impact of treatment.[26] Due to the profound emotional and psychosocial implications of PPP, careful ethical considerations must be taken prior to, during, and post-treatment to ensure patient comfort, satisfaction, and well-being.

Limitations in the literature

Despite the growing interest and favorable outcomes associated with minimally invasive laser treatment PPPs, several limitations within the existing literature constrain the generalizability and clinical standardization of these interventions. A predominant issue across many studies is the small sample size, with the majority of available evidence deriving from case reports or small case series. This limitation hampers the statistical power needed to draw definitive conclusions regarding treatment efficacy, recurrence rates, and safety profiles across diverse patient populations. Moreover, small cohorts reduce the ability to identify rare but potentially significant complications or adverse outcomes. A further limitation is the lack of standardized treatment protocols across studies. Variability in laser types, energy settings, pulse durations, and the number of treatment sessions introduces significant heterogeneity. Without consistent parameters, comparing outcomes between modalities or establishing best practices becomes challenging. Additionally, most existing studies focus on short-term results, with limited long-term follow-up. While initial lesion clearance and cosmetic outcomes are frequently documented, few studies assess long-term recurrence rates, sustained cosmetic satisfaction, or delayed complications such as pigmentary changes or textural alterations. Studies that do report long-term follow-up typically assess outcomes only up to a few months post-treatment. To date, a 2016 study by Lee et al. represents the longest follow-up duration reported in the literature for patients treated for pearly penile papules. This study followed 3 patients for 16 months following Er:YAG treatment.[27] Furthermore, the long-term psychological impact of PPP and its treatment, including effects on self-image, sexual confidence, and anxiety, also remains underexplored. Without longitudinal data, clinicians are left without a robust evidence base to inform patients about the durability of outcomes or the need for retreatment. Finally, underreporting of complications remains a significant concern. Many studies selectively highlight favorable outcomes without consistently documenting adverse events, including transient erythema, hypo- or hyperpigmentation, discomfort, or infection. This reporting bias may overstate the safety profile of laser modalities and limit clinicians' ability to weigh risks accurately when counseling patients. Comprehensive adverse event reporting is essential for a balanced understanding of the risk-benefit profile of cosmetic laser treatment for PPP.

Future directions and innovations

To address the previously mentioned limitations and further refine the management of PPPs, there are several avenues for future research and clinical innovation. Foremost among these is the development of standardized treatment guidelines for laser-based PPP removal. Establishing consensus on optimal laser parameters, procedural techniques, treatment intervals, and post-treatment care would enhance consistency, reproducibility, and overall treatment efficacy across diverse clinical settings. Additionally, large-scale, longitudinal studies are essential to assess the long-term durability of lesion clearance, cosmetic satisfaction, potential delayed complications, and the broader psychosocial outcomes associated with PPP treatment. Incorporating validated patient-reported outcome measures with a focus on body image, anxiety, sexual confidence, and quality of life would provide valuable insight into the full spectrum of treatment benefits and risks. Technological innovations in laser safety and targeting represent another promising advancement in the treatment of PPP. The integration of real-time thermal feedback systems, robotic-assisted handpieces, and AI-guided energy delivery could minimize collateral tissue injury while enhancing procedural precision. These advancements may be particularly beneficial in delicate anatomical areas such as the glans penis, where both cosmetic and functional preservation are critical.

Conclusion

The studies for minimally invasive procedures with laser therapy for pearly penile papules provide important insight into treating this benign cosmetic dermatologic condition. While these lesions are asymptomatic, they can be mistaken for sexually transmitted infections and cause distress and anxiety in patients, so it is imperative to communicate all treatment options with patients to prioritize their satisfaction. Several promising treatment candidates have shown favorable outcomes and improvements in cosmetic appearance. Previous studies show that ablative CO_2 lasers are successful in the complete removal of PPPs with just one treatment session and a minor risk of adverse events, such as pigment changes and scarring. Fractional CO_2 lasers provide an alternative to traditional ablative lasers by reducing the risk of scarring and infection even further while preserving surrounding skin. The non-ablative PDL laser modality offers a high safety profile with less disruption to the surrounding skin but may require more treatment sessions to achieve desired results. The highly efficient Er:YAG laser offers superficial tissue ablation and precise control with rare temporary side effects. Future research comparing these effective laser modalities should focus on increasing sample sizes and promoting long-term follow-up post-treatment. Clinicians are encouraged to foster open communication with their patients on their goals, mental wellbeing, and advice for postprocedural care to optimize recovery.

Acknowledgments

None.

Conflict of interests

The authors declare there is no conflict of interest.

Funding

None.

Citation: Parga AD, Oladinni D, Vu TN, et al. An evaluation of minimally invasive laser approaches for cosmetic removal of pearly penile papules. *J Dermat Cosmetol.* 2025;9(3):91–96. DOI: 10.15406/jdc.2025.09.00298

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Citation: Parga AD, Oladinni D, Vu TN, et al. An evaluation of minimally invasive laser approaches for cosmetic removal of pearly penile papules. *J Dermat Cosmetol.* 2025;9(3):91–96. DOI: 10.15406/jdc.2025.09.00298