International Journal of Colorectal Disease (2025) 40:47
https://doi.org/10.1007/s00384-025-04832-x

REVIEW

Efficacy and safety of laser ablation for recurrent pilonidal sinus: a systematic review and meta-analysis

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Accepted: 7 February 2025

Abstract

Background Recurrence remains a significant challenge following the surgical treatment of sacrococcygeal pilonidal sinus. Unlike patients with primary pilonidal sinus, those with recurrent cases often present with more complex sinus tracts, and scarring from previous surgeries increases the complexity of subsequent procedures. Therefore, selecting the appropriate surgical method for patients with recurrent pilonidal sinus requires greater caution. It is essential to reassess these patients to determine whether surgical techniques suitable for primary pilonidal sinus are equally effective for recurrent cases. Laser ablation, an innovative and minimally invasive technique, has emerged as a promising option for managing pilonidal sinus. This procedure uses a circular laser at the tip of a catheter to deliver energy, effectively destroying and ablating the sinus tract while promoting its closure. Previous studies have demonstrated the safety and efficacy of laser ablation in treating primary pilonidal sinus. The objective of this systematic review and meta-analysis is to assess the efficacy and safety of laser ablation in the management of recurrent pilonidal sinus.

Methods This study was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. A comprehensive literature search was carried out using PubMed, Embase, Cochrane Library, Web of Science, and ClinicalTrials.gov. Additionally, the references of all retrieved studies were screened to identify further eligible data. The search included studies published up to June 11, 2024. The primary outcome measure was the healing rate after laser ablation, which served as the metric for evaluating the efficacy of this technique in treating recurrent pilonidal sinus. Secondary outcome measures included the incidence of severe postoperative complications, which were assessed to determine the safety profile of laser ablation. According to the Clavien-Dindo classification of postoperative complications, we define severe complications as those classified as grade IIIb or higher.

Result A total of seven studies were included in this meta-analysis. With the exception of one study published in 2018, the remaining six were published within the past 3 years. Two studies originated from Middle Eastern countries, while the other five were from European countries. In total, 137 patients with recurrent pilonidal sinus were included, of whom 112 achieved healing following laser ablation treatment. The pooled healing rate across these studies was 81.9% (95% CI, 65.4–94.6%; $I^2 = 69.12\%$; $p < 0.01$). A subgroup analysis based on follow-up duration was also performed. The pooled healing rate for studies with a follow-up period of 12 months or less was 87.2% (95% CI, 63.2–100%; $I^2 = 78.57\%$; $p < 0.01$), while for studies with a follow-up duration exceeding 12 months, the pooled healing rate was 74.5% (95% CI, 51.5–92.7%; $I^2 = 47.48\%$; $p = 0.15$). In addition, five studies performed pit picking before laser ablation, while two studies did not. We conducted a subgroup analysis based on whether pit picking was performed before laser ablation. The results of the subgroup analysis indicated that the difference in efficacy between combined pit picking and laser ablation alone was not statistically significant (random effects model, $p = 0.75$). This suggests that both treatment methods may have similar effectiveness in the management of recurrent pilonidal sinus disease.

Conclusions This meta-analysis demonstrates that laser ablation is an effective and safe method for the treatment of recurrent sacrococcygeal pilonidal sinus in the short term. However, the findings indicate a trend toward a lower healing rate with extended follow-up periods. To better assess the long-term efficacy of laser ablation in managing recurrent pilonidal sinus, high-quality randomized controlled trials with extended follow-up durations are necessary.

Keywords Recurrent pilonidal sinus · Laser ablation · Healing rate · Severe postoperative complications · Meta-analysis

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Published online: 19 February 2025

Introduction

Sacrococcygeal pilonidal sinus is an infectious condition occurring in the sacrococcygeal region, characterized by sinus tracts or abscesses caused by embedded hairs or debris [1], with an incidence rate of 26 per 100,000 individuals [2]. Surgery remains the primary treatment modality, and various surgical techniques are available. However, recurrence is a major challenge in the surgical management of pilonidal sinus, with reported rates as high as 60.4% within 24 months postoperatively. Currently, there is no consensus on the optimal surgical approach [2]. Excisional surgeries, including primary closure and secondary healing, are the most commonly used techniques but are associated with high recurrence rates [3]. Flap-based surgeries, such as the Limberg flap and Karydakis flap, have been shown to reduce postoperative recurrence rates, yet these procedures require extensive tissue excision from the buttocks, often resulting in prolonged recovery times [4] and complications such as superficial skin disruption, surgical site infections, hematomas, and seromas [5]. This has led to the development of minimally invasive techniques for pilonidal sinus treatment. The advantages of minimally invasive surgery include reduced postoperative pain, shorter wound healing times, and the possibility of repeat procedures, as demonstrated in earlier studies [6].

In recent years, laser ablation has garnered significant attention as a treatment option. The principle behind laser ablation involves the emission of energy from a circular laser at the tip of a catheter, which ablates and destroys the sinus tract, thereby promoting the formation of new granulation tissue and closure of the sinus [4]. In 2011, Wilhelm first introduced the use of a 1470-nm laser for the ablation of anal fistulas [7]. In 2016, Dessily [8] pioneered the application of this technique for treating sacrococcygeal pilonidal sinus, achieving remarkable outcomes. Subsequent studies [6, 9, 10] have further confirmed the safety and efficacy of laser ablation in pilonidal sinus treatment. However, most of these studies have included mixed cohorts of both primary and recurrent cases, and none has specifically evaluated the effectiveness of laser ablation in treating recurrent pilonidal sinus. This systematic review and meta-analysis aim to address this gap by assessing the efficacy and safety of this novel surgical technique in patients with recurrent pilonidal sinus.

Materials and methods

Search strategy

This study was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. A comprehensive literature search was performed across PubMed, Embase, Cochrane Library, Web of Science, and ClinicalTrials.gov. The search terms included "Pilonidal Sinus[Mesh]," "Sinus, Pilonidal," "pilonidal disease," "Laser Therapy[Mesh]," "Laser Ablation," "Laser Photoablation of Tissue," "Laser Tissue Ablation," "SiLaC," "SILAT," "Recurrence[Mesh]," "recur*," "relaps*," "remission*," "treatment outcome," and "treatment failure." This systematic review was also registered with PROSPERO (CRD42024573915).

Inclusion and exclusion criteria

Since there are currently no case–control studies on laser ablation treatment for recurrent pilonidal sinus, we analyzed the clinical efficacy of laser ablation treatment for recurrent pilonidal sinus in a single-arm analysis. Therefore, the meta-analysis was conducted on single-arm studies of laser ablation treatment. The inclusion criteria using the PICOS statement are as follows:

- P (Population): Patients with recurrent pilonidal sinus.
- I (Intervention): A group of patients who received laser ablation treatment, including laser ablation, laser photoablation, SiLaC, or SILAT.
- O (Outcome): Studies that report the following outcomes: healing rate, recurrence rate, and postoperative complications.
- S (Study design): Randomized or non-randomized clinical trials, observational studies (cohort or case–control), and case series with full-text reports (including preprints).

The exclusion criteria were as follows:

1. Studies that do not include laser ablation treatment.
2. Unpublished studies or abstracts.
3. Studies focusing on treatments not related to laser ablation for pilonidal sinus.
4. Studies that do not include patients with recurrent pilonidal sinus.

Data extraction

Data were extracted independently by two researchers (JL and XL) from each study. The following data were extracted from the studies:

First author name, publication year, country, study design, median follow-up, number of patients with recurrent pilonidal sinus, number of patients healed, number of recurrences/non-healed cases, and incidence of severe postoperative complications.
Laser ablation details, including laser device, wavelength, power, and laser energy.
Healing was defined as the closure of cutaneous orifices and an absence of discharge or abscess [11].

Any conflicts and discrepancies were resolved through discussion with JW.

Outcomes

The primary outcome of this study is the healing rate of recurrent pilonidal sinus following laser ablation. The secondary outcome is the incidence of severe postoperative complications related to laser ablation.

Statistical analysis

Meta-analyses of primary healing rates across the studies were performed using the meta package in R software version 4.2.0 (R Foundation for Statistical Computing, Vienna, Austria). The data were pooled and presented as weighted mean rates with corresponding 95% confidence intervals (CIs). Interstudy heterogeneity was assessed using the Q test and the inconsistency index (I^2). A random effects model was applied to determine the pooled healing rate for laser ablation in recurrent pilonidal sinus disease. Forest plots were generated to illustrate the variability in the efficacy of laser ablation for recurrent pilonidal sinus across the included studies ($p < 0.01$).

Results

Search results

A total of 249 relevant articles were retrieved from the five databases. After removing duplicates and screening abstracts and titles, seven studies met the inclusion criteria and were ultimately included in this meta-analysis. The detailed literature selection process is illustrated in Fig. 1.

Characteristics of the included studies

A total of seven studies [10–16] were included in this meta-analysis. With the exception of one study [10] published in 2018, the remaining six studies [11–16] were published within the past 3 years. Two studies [14, 15] were conducted in Middle Eastern countries, while the other five [10–13, 16] originated from European countries. In total, 137 patients with recurrent pilonidal sinus were included, 112 of whom achieved healing following laser ablation treatment. The basic characteristics of these studies are summarized in Table 1.

Risk of bias evaluation

As a minimum of ten studies is required to assess publication bias using a funnel plot or similar tests [17], it was not feasible to evaluate publication bias due to the small number of included studies ($n = 7$). The methodological quality of the studies was assessed by two authors (JL and XL) using the National Institute for Health and Clinical Excellence (NICE) checklist for quality assessment of case series. Discrepancies in interpretation were resolved through discussion with a third author (JW). The quality of the studies was categorized as good (score = 7–8), fair (score = 4–6), or poor (score = 0–3). The results are summarized in Table 2.

Technical aspects of laser ablation

Of the seven included studies, three studies [10, 13, 15] used biolitec (Biomedical Technology, Germany) laser equipment, while one study [14] used equipment manufactured by Wuhan Gigaa Optronics Technology Co., Ltd. (Wuhan, China). The remaining studies [11, 12, 16] did not specify the type of laser equipment used. Six studies [10–14, 16] employed a laser wavelength of 1470 nm, with the exception of one study [15]. Five studies [11–13, 15, 16] utilized a laser power of 10 W, one study [14] used 13.5 W, and one study [10] did not specify the laser power. Regarding laser energy, Zubaidi [15] used 10 J/cm^2, Decker [13] applied 867 J, Pappas [10] used 200 ± 30 J/cm^2, and Horesh [14] used 1081 J.

Healing rates

A total of 112 patients (81.8%) with recurrent pilonidal sinus achieved healing following laser ablation treatment. The pooled healing rate across the studies was 81.9% (95% CI, 65.4–94.6%; $I^2 = 69.12\%$; $p < 0.01$) (Fig. 2). To assess the impact of follow-up duration on the healing rate, we conducted a subgroup analysis by dividing the seven studies into two groups based on whether the follow-up period exceeded 12 months. The analysis revealed that the pooled healing

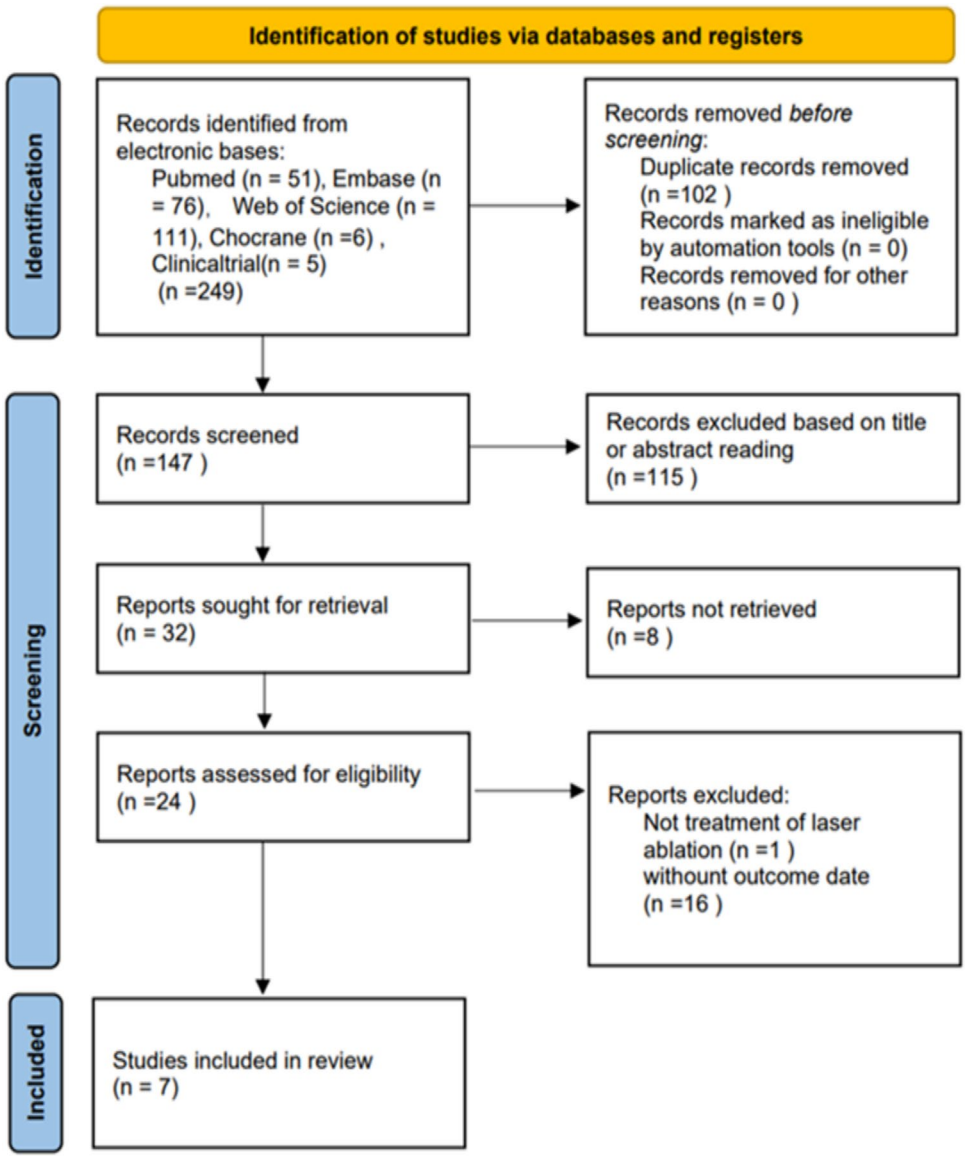

Fig. 1 Flow diagram of the meta-analysis

rate for studies with a follow-up duration of 12 months or less was 87.2% (95% CI, 63.2–100%; $I^2 = 78.57\%$; $p < 0.01$). In contrast, for studies with a follow-up period exceeding 12 months, the pooled healing rate was 74.5% (95% CI, 51.5–92.7%; $I^2 = 47.48\%$; $p = 0.15$). In addition, we conducted a subgroup analysis based on whether pit picking was performed before laser ablation. The results of the subgroup analysis showed that the pooled healing rate for studies using combination therapy with pit picking was 80.8% (95% CI, 71.6 ~ 88.8%; $I^2 = 0$; $p = 0.55$), while the pooled healing rate for studies using laser ablation alone was 88.5% (95% CI 27.1 ~ 100%; $I^2 = 89.21\%$; $p < 0.01$). The difference in efficacy between combination therapy and laser ablation alone was not statistically significant (random effects model, $p = 0.75$) (Fig. 3).

Surgical complications

Postoperative complications were classified according to the Clavien-Dindo classification system, and severe complications were defined as those classified as grade IIIb or higher. Among the 137 cases of recurrent pilonidal sinus included in this meta-analysis, no severe complications were reported. One study [10] documented three cases (3/27, 11.1%) of delayed healing and five cases (5/27, 18.5%) of mild postoperative pain.

Table 1 Characteristics of the included studies

Study (year)	Country	Study design	Median follow-up	Total number of recurrent disease	Healed	Healing rate	Recurrent/non-healing case	Severe postoperative complications
Draullette 2024	France	Retrospective single center	339.2 days	18	13	0.722	5	None
Zubaidi 2022	Saudi Arabia	Retrospective single center	35.3 months	7	4	0.571	3	None
Spindler 2021	France	Retrospective single center	370.3 days	8	5	62.5	3	None
Decker 2023	Belgium	Retrospective multicenter	129 days	34	27	0.794	7	None
Pappas 2018	Greece	Prospective single center	354 days	27	27	1	0	None
Bonito 2021	Portugal	Retrospective single center	8.3 months	3	2	0.667	1	None
Horesh 2023	Israel	Retrospective single center	24.2 months	40	34	0.85	6	None

None: no severe postoperative complications were reported in the literature

Table 2 Assessment of the methodological quality of studies included in the review

Study	Multicenter study	Clearly defined objective	Reported inclusion and exclusion criteria	Clearly defined outcomes	Prospective data collection	Patients recruited consecutively	Clearly described results of the study	Stratified outcomes	Total score
Draullette 2024	0	1	1	1	0	1	1	1	6
Zubaidi 2022	0	1	1	1	0	0	1	1	5
Spindler 2021	0	1	1	1	0	1	1	1	6
Decker 2023	1	1	1	1	0	1	1	1	7
Pappas 2018	0	1	1	1	1	1	1	1	6
Bonito 2021	0	1	1	1	0	0	1	1	5
Horesh 2023	0	1	0	0	0	1	1	1	4

Yes = 1; no (not reported) = 0. Highest possible score = 8, ≤ 3 = poor quality, 4–6 = fair quality, ≥ 7 = good quality

Discussion

Recurrence remains a significant issue following the surgical treatment of sacrococcygeal pilonidal sinus, with recurrence rates reaching up to 60.4% within 24 months postoperatively, depending on the surgical technique used [2]. Unlike patients with primary pilonidal sinus, those with recurrent disease often present with extensive wounds or scarring from previous surgeries, affecting the entire buttocks and complicating subsequent procedures [18]. As a result, the surgical outcomes of primary pilonidal sinus should not be directly extrapolated to recurrent cases, highlighting the need for re-evaluating the efficacy of surgical interventions in these patients. Laser ablation, an innovative minimally invasive technique, has been shown to be safe and effective for primary pilonidal sinus [8, 9]. However, to date, no studies have specifically focused on assessing the efficacy of laser ablation in recurrent cases. Most studies have included mixed cohorts of both primary and recurrent pilonidal sinus patients. This meta-analysis demonstrates a healing rate of 81.9% (95% CI, 65.4–94.6%; $I^2 = 69.12\%$; $p < 0.01$) for laser ablation in recurrent pilonidal sinus patients, underscoring its significant efficacy in this population.

Excisional surgery and flap techniques remain the primary treatments for recurrent pilonidal sinus [19]. Iesalnieks [18] followed 33 patients with recurrent pilonidal sinus who underwent midline excision surgery, with a median follow-up of 11.4 months, reporting a recurrence rate of 58% (19/33). Cihan [20] studied 35 patients treated with the classic rhomboid flap, with a follow-up of 28.60 ± 1.70 months and a recurrence rate of 5.7% (2/35), but a high postoperative wound infection rate of 22.9% (8/35). In recent years,

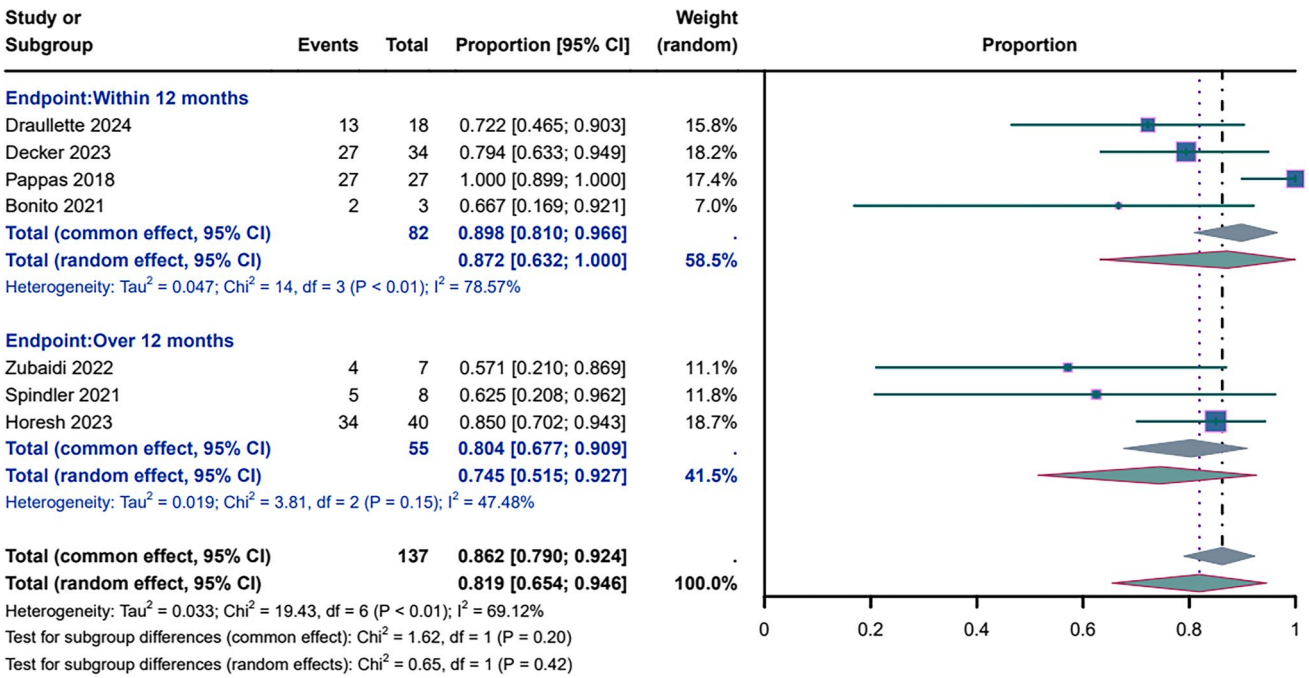

Fig. 2 The proportion meta-analysis plot (random effects) of all seven studies showed a pooled healing rate of 81.9% (95% CI 65.4–94.6%, $I.^2 = 69.12\%$, $p < 0.01$)

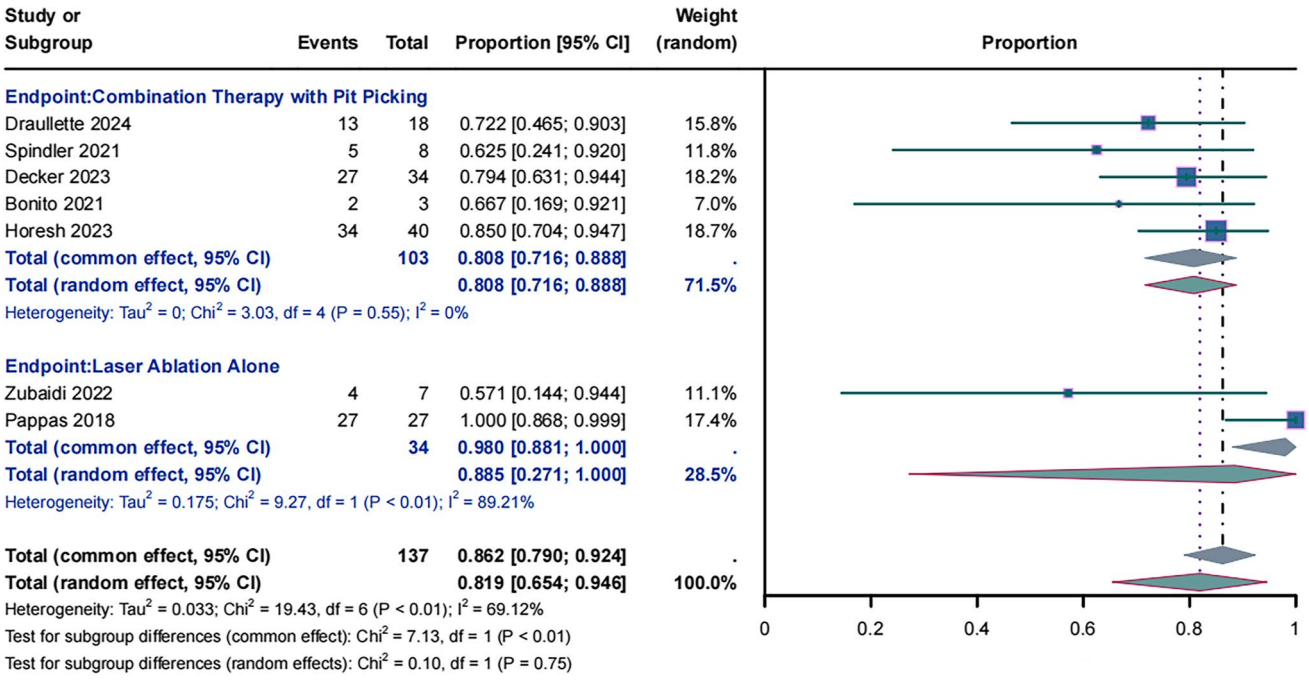

Fig. 3 The subgroup analysis results showed that there is no statistical difference in the efficacy between combination therapy with pit picking and laser ablation alone (random effects model, $p = 0.75$)

minimally invasive techniques for pilonidal sinus have gained increasing attention due to their ability to shorten wound healing times and reduce complication rates. These techniques include laser ablation, endoscopic treatment, and phenolization. Our early studies confirmed the significant efficacy of laser ablation in pilonidal sinus patients [6],

though these studies included mixed cohorts of primary and recurrent cases without specifically evaluating efficacy in recurrent cases. Endoscopic pilonidal sinus treatment (EPSiT) involves the use of a fistuloscope for visualized removal of infected tissue within the sinus tract. Meinero [3] included 122 patients with recurrent pilonidal sinus treated with EPSiT, with an average follow-up of 16 months, achieving a healing rate of 95% and no reported postoperative complications. However, the high cost and steep learning curve associated with EPSiT limit its widespread adoption [3]. Phenolization is another treatment for pilonidal sinus and is considered effective by American guidelines [21]. Pronk [22] included 57 patients treated with phenolization, reporting a success rate of 89.8% after a 12-week follow-up. While this success rate is higher than the 81.9% healing rate found for laser ablation in this meta-analysis, the short follow-up period raises concerns about delayed recurrences. Thus, the success rate of phenolization may be overstated, and we do not consider it superior to laser ablation for the treatment of recurrent pilonidal sinus. Platelet-rich plasma (PRP) promotes tissue healing through its high concentration of growth factors, and its mechanism in treating pilonidal sinus is similar to that of phenolization. Sevinc conducted a randomized controlled trial, randomly assigning patients to the PRP treatment group and the phenolization treatment group. In the PRP group, 96% of patients achieved healing after one treatment, whereas only 53% of patients in the phenolization group achieved healing. Additionally, the median healing time in the PRP group was significantly shorter (6 days), compared to 10 days in the phenolization group ($p < 0.001$). After an average follow-up of 43.1 months, the recurrence rate in the PRP group was 4%, compared to 12% in the phenolization group (95% CI, 0.024–0.251). The study results indicate that PRP combined with curettage significantly outperforms phenolization combined with curettage in terms of both healing rate and recurrence rate [23].

The treatment of recurrent pilonidal sinus is more complex than that of primary cases due to potentially intricate sinus tracts. Dessily [8] included 200 patients with primary pilonidal sinus who underwent laser ablation, reporting a healing rate of 94% with a follow-up of 2 months and a postoperative complication rate of 15%, mainly due to infections (9.5%). Another prospective observational study [9] of 60 patients with primary pilonidal sinus treated with laser ablation, with a 12-month follow-up, reported a healing rate of 92%. These healing rates for primary pilonidal sinus are higher than the 81.9% healing rate observed in this meta-analysis for recurrent pilonidal sinus.

Draullette [16] included 111 patients with pilonidal sinus treated with laser ablation, comprising 93 primary and 18 recurrent cases, with an average follow-up of 339.2 (±221.4) days. The healing rate was 79.6% for primary pilonidal sinus patients and 72.2% for recurrent cases. The healing rate for recurrent pilonidal sinus in this study is consistent with the findings of our meta-analysis and lower than that of primary pilonidal sinus within the same cohort.

Although the healing rate of laser ablation in recurrent pilonidal sinus is lower than in primary cases, a healing rate exceeding 80% remains satisfactory.

Unlike excisional surgery, laser ablation does not require the removal of large amounts of tissue, which allows the procedure to be repeated in cases of incomplete closure or recurrence after the initial treatment. Dessily [8] reported a success rate of 75% (9/12) for repeat laser ablation in 12 patients with pilonidal sinus who did not achieve closure after the initial laser treatment. This result is comparable to the 78.3% success rate observed in the study by Pappas [10]. Sluckin [24] conducted consecutive repeat laser treatments in patients who did not respond to the initial treatment, with some patients even undergoing a third laser procedure. This approach raised the overall success rate from 73.6 to 97.7%. Such remarkable outcomes may be attributed to significant improvement in the condition from prior treatments, making repeat high-energy laser ablation highly effective [10].

A meta-analysis by Stauffer [25] examined the relationship between recurrence rates of pilonidal sinus after laser ablation and follow-up duration, including 125 patients with pilonidal sinus. The recurrence rates were 1.9% (95% CI, 0.0–4.7%) at 12 months postoperatively, 5.1% (95% CI, 0.4–9.8%) at 14 months, and 36.6% (95% CI, 3.8–69.4%) at 60 months, indicating a decline in the long-term efficacy of laser ablation over time. To assess this relationship in recurrent pilonidal sinus, this meta-analysis performed a subgroup analysis based on follow-up duration. The analysis revealed that the short-term healing rate of laser ablation for recurrent pilonidal sinus was 87.2% (95% CI, 63.2–100%; $I^2 = 78.57\%$; $p < 0.01$), while the long-term healing rate was 74.5% (95% CI, 51.5–92.7%; $I^2 = 47.48\%$; $p = 0.15$). These findings suggest that the long-term efficacy of laser ablation for recurrent sacrococcygeal pilonidal sinus may be lower than its short-term efficacy.

In terms of cost, laser ablation requires expensive laser equipment; however, the equipment is portable and can be shared by different specialists within the same institution. Additionally, it can be used for the treatment of other anorectal conditions, such as hemorrhoids and anal fistulas, potentially reducing overall costs. Furthermore, due to the minimally invasive nature of laser ablation, it can shorten patients' hospital stay, reduce postoperative care costs, minimize the use of pain medications, and decrease time off work, which may lead to greater long-term economic benefits [8].

The primary limitation of this study is that nearly all the included studies are retrospective, with a lack of prospective randomized controlled trials. Additionally, the studies

involved mixed cohorts of primary and recurrent pilonidal sinus patients, with insufficient postoperative complication data specific to recurrent cases. Furthermore, only seven studies were included, which restricted the ability to adequately assess publication bias. In addition, laser ablation, as a novel treatment for pilonidal sinus, was first reported by Dessily in 2017 [8], and subsequent studies have followed. However, the follow-up periods in the related clinical studies have been relatively short, with a lack of research involving longer follow-up durations. This limitation also affects the ability of this meta-analysis to evaluate the long-term efficacy of laser ablation. Future studies should consider extending the follow-up period to more comprehensively assess the long-term effectiveness of laser ablation in treating pilonidal sinus.

Conclusions

This meta-analysis demonstrates that laser ablation has a high healing rate for recurrent sacrococcygeal pilonidal sinus, with no reported severe postoperative complications. Laser ablation is an effective and safe method for the treatment of recurrent pilonidal sinus in the short term. However, its long-term efficacy seems to decline compared to its short-term outcomes as the follow-up period extends. Given the limited data currently available, future high-quality randomized controlled trials with extended follow-up periods are needed to more accurately assess the long-term efficacy of laser ablation for recurrent pilonidal sinus.

Author contribution J.Q. and X.X. wrote the main manuscript text; Z.L. was responsible for data analysis and interpretation; L.J. prepared Figs. 1–2; Z.W. and J.W. designed the study and supervised the overall project implementation. All authors reviewed and approved the final manuscript.

Data availability No datasets were generated or analysed during the current study.

Declarations

Competing interests The authors declare no competing interests.

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