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REVIEW

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Expanding urolithiasis treatment: comparison of super pulsed thulium laser and holmium:YAG laser for ureteral stone management

Qinghua Gan[1†], Jun Li[1†], Gaoqiang Zhai[1], Bangfeng Liu[1], Yan Qin[1], Shuting Tan[1], Wei Wang[1*] and Qinsong Zeng[1,2*]

Abstract

Objectives The purpose of this review is to compare the effectiveness of SuperPulsed thulium fiber laser (SP TFL) and holmium:yttrium–aluminum–garnet (Ho:YAG) laser in lithotripsy, with the aim of evaluating the differences between the two in key indicators, such as lithotripsy efficiency and safety, and providing reference for clinical selection of better lithotripsy methods.

Methods By searching multiple authoritative medical databases (PubMed, Embase, and Web of Science databases) and including the results of relevant clinical studies and laboratory studies, the indexes involving SP TFL and Ho:YAG lasers in the included literature were analyzed.

Results We found a total of 24 relevant pieces of literature. The laser parameters, such as ablation efficiency, ablation speed, operative time, dust quality, retropulsion, visibility, temperature safety, and stone-free rate, were compared between laboratory studies and clinical outcomes. Preclinical studies have shown that SP TFL has a higher rate of stone ablation, a weaker retropulsion and a lower risk of fiber breakage. The results of clinical studies showed that the two methods were comparable in the ablation rate, laser time and operative time, stone-free rate and complication. SP TFL offered better endoscopic view quality and less retropulsion.

Conclusions While the Ho:YAG laser remains the primary choice for endoscopic laser lithotripsy, the emergence of SP TFL offers a promising new option for the minimally invasive treatment of urinary calculi. Parameter range, retropulsion effect, laser fiber adaptability, and overall system performance demand comprehensive attention. SP TFL has a relatively short clinical application history, and further research is necessary to fully explore its long-term advantages, clinical significance, and possible limitations.

Keywords Superpulse thulium laser, Holmium:yttrium–aluminum–garnet, Ureteral stones, Lithotripsy

†Qinghua Gan and Jun Li are Co-first authors.

*Correspondence:
Wei Wang
wangwei_gxmu@163.com
Qinsong Zeng
zengqs3@mail.sysu.edu.cn
Full list of author information is available at the end of the article

Introduction

The management of ureteroscopic lithotripsy has evolved significantly with advancements in laser technology. For over two decades, the holmium:yttrium–aluminum–garnet (Ho:YAG) laser has been the gold standard for endoscopic lithotripsy, offering high stone removal rates, minimal tissue damage, and low complication rates [1–3]. Despite its proven efficacy, the Ho:YAG laser has limitations, including a maximum frequency of 100 Hz, a multi-mode spatial beam profile that restricts use with fibers smaller than 200 µm, and stone retropulsion during fragmentation [4]. These limitations pose significant challenges, particularly during the management of lower pole calculi or complex cases necessitating maximal endoscopic deflection.

In response to these limitations, thulium fiber laser (TFL) has emerged as a promising alternative. Operating at a wavelength of 1940 nm, TFL aligns with the peak of water absorption and achieves a fourfold higher absorption coefficient. Therefore, when operating at comparable pulse energy parameters, the TFL exhibits dual advantages: a reduced energy threshold required for ablation initiation and significantly increased ablation efficiency. In vitro studies have shown that compared with the Ho:YAG laser, the stone ablation rate of TFL was increased by four times [4–6]. In addition, TFL produces a high-quality beam that can be transmitted through smaller fibers (as narrow as 50 µm vs. Ho:YAG's 200 µm minimum), offering a better deflection range, improving accessibility, reducing impact on the operating channel, and ensuring adequate irrigation flow [6, 7]. The laser's electronic modulation capability offers unprecedented parameter flexibility, including pulse frequencies up to 2,200 Hz (44 × higher than Ho:YAG's 50 Hz limit), ultra-low pulse energies (0.005 J vs. 0.2 J minimum), and power outputs reaching 55 W (compared to Ho:YAG's typical 30 W maximum) [8, 9]. These features enhance surgical precision by improving perfusion, providing a clearer field of view, and allowing greater deflection angles for flexible scopes [5, 10]. The advantages of TFL make it a promising alternative for lithotripsy. Studies suggest TFL outperforms Ho:YAG lasers in operating time, complication rates, and stone-free rates (SFR) [3, 11–14].

The recent development of super-pulsed thulium fiber laser (SP TFL) technology represents a further advancement, combining high-frequency operation with ultra-short pulses to achieve more efficient fragmentation with minimal heat generation [15]. Preliminary evidence indicates that SP TFL achieves faster fragmentation and improved stone clearance compared to Ho:YAG lasers, without requiring higher energy inputs [10]. However, despite its promising advantages, SP-TFL was not approved for clinical use until 2017 by the Russian Ministry of Health, followed by FDA approval in 2019 and CE certification in 2020; this technology remains relatively uncommon in most urology departments around the world [9].

Due to its various advantageous characteristics, it may challenge Ho:YAG as the preferred laser for treatment; it could even represent a turning point in endourological procedures. However, given the novelty of SP TFL technology, it remains unclear whether TFL is superior to Ho:YAG in the treatment of patients with urolithiasis. The lack of robust comparative studies creates a critical knowledge gap regarding the optimal laser technology for endoscopic lithotripsy. A thorough evaluation of this issue holds significant clinical relevance. This review systematically evaluates the efficacy, safety, and clinical outcomes of SP-TFL vs. Ho:YAG laser lithotripsy, aiming to provide evidence-based insights to optimize urolithiasis management and improve patient care.

Materials and methods

This review was based on the recommendations of the Cochrane Collaboration for Systematic Reviews and reported in accordance with the PRISMA statement [16].

Eligibility criteria

According to PICOS [17], the inclusion criteria are listed as follows:

Population:

In-vitro and preclinical studies: Synthetic stone models, ex vivo tissue models and animal models.

Clinical studies: Patients (adults/children) with urinary tract calculi (renal/ureteral stones) undergoing endoscopic lithotripsy procedures.

Interventions: SP TFL lithotripsy.

Comparator: Ho:YAG lithotripsy.

Outcomes:

In-vitro and preclinical studies: Ablation rate, fragmentation, retropulsion, temperature and image distortion.

Clinical studies: Ablation speed and ablation efficiency, laser time and operative time, stone-free rate (SFR), retropulsion, visibility, and complication.

Exclusion criteria: Studies lacking direct comparisons between SP TFL and Ho:YAG. Case reports, editorials, letters, comments, conference abstracts. Nonrelevant studies after review of titles and abstracts.

Information sources and search strategy

For systematic review of currently available evidence on the Ho:YAG vs. SP TFL lithotripsy, a bibliographic search on PubMed, Embase, and Web of Science databases was conducted in September 2024. The systematic search strategy incorporated the following keywords, tailored to each database: "Super-Pulsed Thulium fiber laser", "SP TFL", "thulium", "TEL", "holmium:yttrium–aluminum-garnet", "Holmium:YAG", "Ho:YAG", "kidney stone", "urinary calculus", "renal stone", "lithotripsy", "urolithiasis". The following search strategy was used in each database: (("Super-Pulsed Thulium fiber laser" OR "SP TFL" OR "thulium fiber laser" OR "TFL") AND ("holmium:yttrium–aluminum-garnet" OR "holmium:YAG" OR "Ho:YAG") AND ("urolithiasis" OR "kidney stone" OR "ureteral stone" OR "urinary calculus" OR "renal stone" OR "lithotripsy")). A language restriction to English was applied, and studies published up to September 30, 2024, were included. Only original articles were considered eligible. Articles with irrelevant titles were eliminated in the first stage of the study selection process. In the second stage, abstracts and full texts of articles were examined to include those that satisfied the inclusion criteria. Use endnote X9 to arrange and assess headings and summaries, as well as to detect duplicate entries. Two evaluators (QG and JL) independently performed the search and cross-checked results to ensure accuracy. In instances where disagreements arose, a third evaluator (QZ) was consulted to achieve consensus, ensuring a balanced and unbiased selection process. A PRISMA 2020-compliant flow diagram has been included in Fig. 1, outlining the study identification, screening, eligibility assessment, and inclusion process.

Given the substantial heterogeneity among included studies—including variations in experimental designs, population characteristics, and outcome measures, a formal meta-analysis was not performed. Instead, a narrative review with qualitative synthesis was conducted. The methodological quality of the included studies was evaluated using the ROBINS-II for randomized controlled trials (RCTs) and the Modified Newcastle–Ottawa Scale (NOS) for observational studies [18, 19].

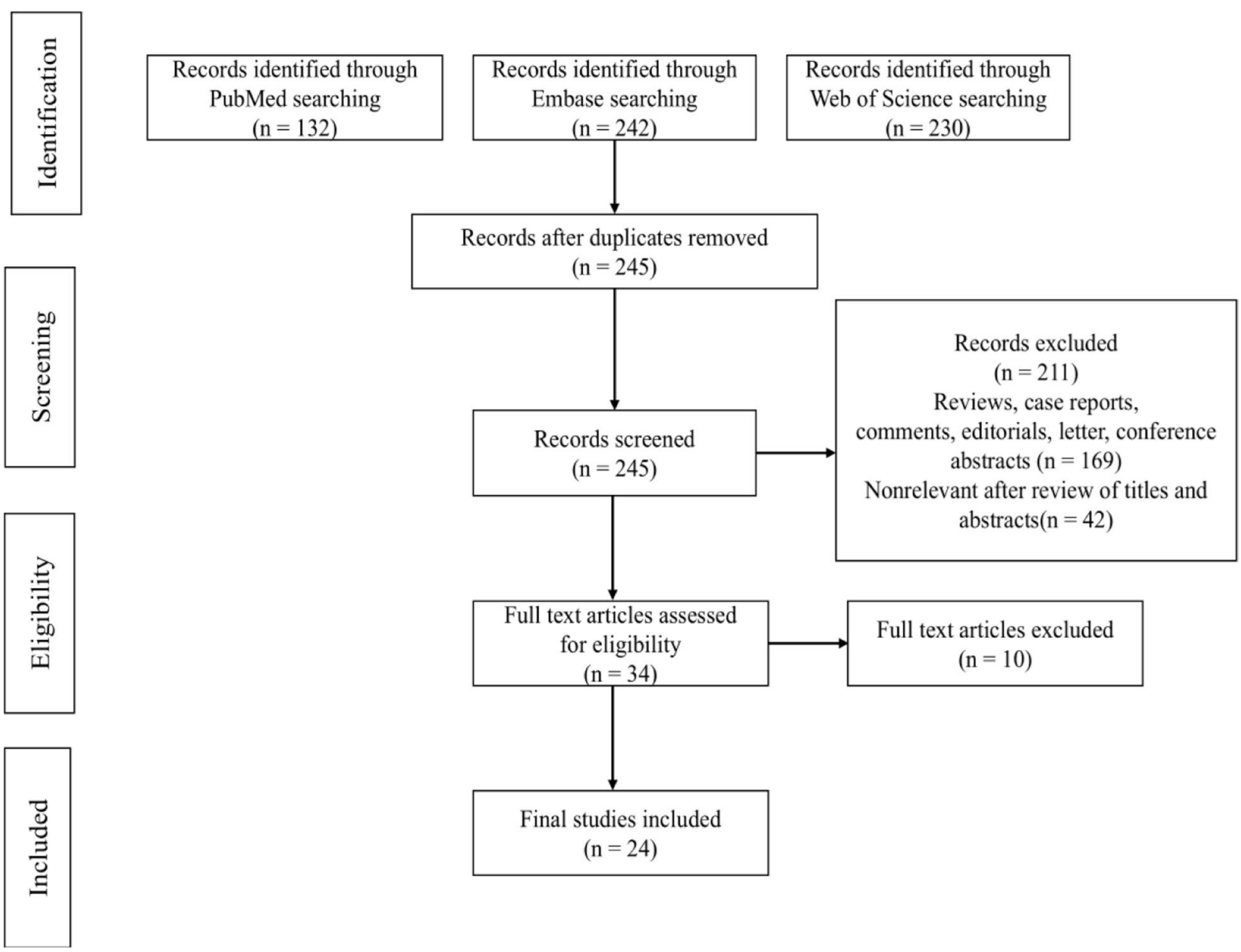

Fig. 1 Screening process of research

*In-vitro and preclinical studies (*Table 1*)*

Ablation rate

In vitro studies by Chew BH et al. found that the rate of the Ho:YAG laser to ablate a stone into fragments < 1 mm, when using both fragmentation and dusting settings, was lower than that of the SP TFL. The study highlighted that while both lasers are effective for stone fragmentation, SP TFL demonstrated superior efficiency in both fragmentation and dusting settings, achieving finer stone dust with a higher ablation rate [15]. Panthier et al. demonstrated that SP TFL achieves significantly higher ablation rates in dusting and fragmentation modes. For hard stones, SP TFL exhibits fourfold and twofold greater ablation rates in dusting(61.1 ± 7.88 vs. 16.26 ± 1.17 mm^3/min) and fragmentation modes(66.96 ± 11.39 vs. 31.74 ± 4.60 mm^3/min), respectively, while for soft stones, these rates are threefold (62.88 ± 9.25 vs. 22.99 ± 1.23 mm^3/min) and twofold (66.57 ± 10.8 vs. 38.6 ± 5.34 mm^3/min) higher than Ho:YAG under matched settings, highlighting the enhanced performance of SP TFL in both settings [20]. This enhanced performance is further validated in a porcine kidney model, where SP TFL produced shorter ablation times (9 min vs. 27 min, $P < 0.001$), lower energy expenditure (8 vs. 26 kJ, $P < 0.001$), and higher stone clearance (73% vs. 45%, $P = 0.001$) [21]. Similarly, several other studies also found that the ablation rate of SP TFL was higher than that of Ho:YAG laser under the same laser energy and repetition rate settings [22–26]. The superior stone ablation efficiency of SP TFL compared to Ho:YAG lasers can be attributed to its wavelength of 1940 nm, which is closer to the water absorption peak. This results in four- to fivefold greater water absorption compared to Ho:YAG lasers [27]. The higher water absorption reduces the tissue ablation threshold, as the water contained in the pores near the stone surface is essential for efficiently absorbing the laser energy [28]. Consequently, this enables the use of equivalent pulse energy for more effective stone ablation, making SP TFL a more efficient option for laser lithotripsy.

Fragmentation

The in vitro experiments conducted by Chew et al. showed that the SP TFL lithotripsy produces fewer particles > 2 mm in stone fragmentation compared to Ho:YAG laser (2.10 vs. 7.20 fragments, $P < 0.001$). Most stones treated with SP TFL turn into dust < 0.5 mm [15]. A study found that the SP TFL was more effective in producing smaller stone fragments compared to the Ho:YAG laser and Ho:YAG–MOSES laser systems. The SP TFL laser typically produces stone fragments smaller than 2 mm, whereas the largest stone fragments generated by Ho:YAG and Ho:YAG–MOSES were 4 mm and 3.5 mm, respectively [29]. After SP TFL lithotripsy, 77% of the remaining fragments were ≤ 1 mm, while 17% of the remaining fragments ≤ 1 mm after Ho:YAG treatment, which was reported in the study by Jiang et al. [21]. This suggests that SP TFL may offer advantages in reducing the size of stone fragments, potentially enhancing the ease of fragment removal and improving procedural efficiency.

Retropulsion

Retropulsion is a critical factor influencing the efficiency of lithotripsy. The difference in retropulsion force may have implications for the effectiveness and safety of lithotripsy procedures, with weaker retropulsion potentially minimizing stone migration during treatment. A study by Andreeva et al. demonstrated that when the pulse energy of the Ho:YAG laser was set at 0.2 J, stone displacement began. In contrast, with the SP TFL, stone displacement was observed at a pulse energy of 1 J with a 500 W peak power setting. Notably, for equal pulse energies, the retropulsion generated by the SP TFL was weaker than that of the Ho:YAG laser [22]. Ventimiglia et al. compared the stone displacement speed of SP TFL and Ho:YAG laser under different laser modalities. Their findings revealed that the average stone displacement for Ho:YAG in short pulse and long/Moses pulse modes (21–8.6 mm) was approximately 4 times and 2 times greater than that of SP TFL (4.5–4.9 mm), respectively. The average stone speed at the first moment of retropulsion was 4 and 1.8 times lower for the regular pulse mode of SP TFL (28 mm/s) than for Ho:YAG in short pulse and long/Moses pulse modes (141–47 mm/s), respectively. Retropulsion for SP TFL was lower than for Ho:YAG in different modes [23].

Temperature

In vitro and isolated studies

Andreeva V et al. monitored water temperature using four IT-23 thermocouples placed at the inlet, outlet, and two diagonally opposed locations adjacent to the stone at the base of the experimental tube. Irrigation flow was maintained at 24 mL/min (< 1 W) or 40 mL/min (≥ 16 W). No significant temperature differences were observed between SP-TFL and Ho:YAG lasers at equivalent power settings (8W: 4.9 ± 0.1 ℃; 16W: 9.8 ± 0.1 ℃; 40 W: 14.6 ± 0.1 ℃) [22]. Taratkin M et al. employed T-type thermocouples to precisely monitor temperature variations during laser irradiation. The study was conducted in a thermally insulated test tube containing 37 ℃ warm water and an irrigated setup with flow rates set at 0, 10, and 35 mL/min, with a constant irradiation duration of 60 s. The results revealed that SP TFL induced a water temperature increase of 15.4 °C, compared to 14.9 °C for the Ho:YAG laser. The temperature rise of between the two lasers was similar. In addition,

Table 1 Comparison between in vitro and preclinical studies

Study	Laser setting	Major conclusion
Ablation rate		
Andreeva et al. [22], 2020	Laser settings were chosen according to the manufacturer's recommendations and the clinical literature	At equivalent settings, SP TFL ablation rates were higher in both dusting mode (threefold for COM stones and 2.5-fold for UA stones) and fragmentation mode (twofold for UA stones)
Ventimiglia et al. [23], 2020	Equivalent settings were used for both lasers: energies:0.2, 0.5, 0.8, 1.0, 1.5 and 2 J, and frequency = 80, 35, 20, 15, and 8 Hz, respectively	SP TFL induced significantly higher ablation
Panthier et al. [20], 2021	The TFL: "fine dusting" (FD: 0.15 J/100 Hz); "dusting" (D: 0.5 J/30 Hz); "fragmentation" (Fr: 1 J/15 Hz); Ho:YAG laser: "dusting" (D: 0.5 J/30 Hz); "fragmentation" (Fr: 1 J/15 Hz)	At equal settings and CDF, SP TFL ablation rates are at least twofold higher than those with the Ho:YAG
Sierra et al. [25], 2022	Stone dusting: 0.5 J/10 Hz, 0.5 J/20 Hz, 0.7 J/10 Hz, 0.7 J/20 Hz, 1 J/12 Hz, 1 J/20 Hz for both lasers	The overall ablation rate was 27% greater with the SP TFL than with the Ho:YAG laser
Sierra et al. [26], 2022	3 J/5 Hz (1.5W), 0.3 J/20 Hz (6W), 1.2 J/5 Hz (6W) and 1.2 J/20 Hz (24W) for both lasers	High-power setting (24W) was associated with higher delivered energy and higher ablation rates in both lasers ($P < 0.001$). Regardless of the settings, higher ablation rate was observed with SP TFL than with the Ho:YAG laser
Jiang et al. [21], 2023	SP TFL: 0.2 J, 80 Hz Ho:YAG laser: 0.4 J, 40 Hz	SP TFL ablated stones faster, with less energy expenditure, and a higher stone clearance rate
Chew et al. [15], 2023	SP TFL: short pulse 0.6 J/30 Hz,0.1 J/200 Hz 120 W Ho:YAG laser: short pulse 0.8 J/10 Hz, long pulse:0.3 J/70 Hz, moses mode: 0.3 J/70 Hz	The dusting and fragmenting efficiency of SP TFL is superior to that of the 120 W Ho:YAG laser
Kutchukian et al. [24], 2023	SP TFL: "fine dusting" (FD: 0.15 J/100 Hz), "dusting" (D: 0.5 J/30 Hz) and "fragmentation" (Fr: 1 J/15–30 Hz) Ho:YAG:"dusting" (D: 0,5 J/20 Hz) and "fragmentation" (Fr:1 J/15 Hz)	SP TFL presented higher ablation rates than the Ho:YAG
Fragmentation		
Jiang P et al. [29], 2022	Dusting settings: SP TFL:0.2 J × 80 Hz; Ho: YAG:0.4 J × 40 Hz; Ho:YAG-MOSES: 0.2 J × 80 Hz	SP TFL typically produced fragments < 2 mm, while the Ho:YAG and Ho:YAG–MOSES generated larger maximum fragment sizes of 4 mm and 3.5 mm, respectively
Chew BH et al. [15], 2023	SP TFL: short pulse 0.6 J/30 Hz,0.1 J/200 Hz. 120 W Ho:YAG laser: short pulse 0.8 J/10 Hz, long pulse:0.3 J/70 Hz, Moses mode: 0.3 J/70 Hz	SP TFL lithotripsy produces fewer particles > 2 mm in stone fragmentation compared to the Ho:YAG laser. Most stones treated with SP TFL turn into dust < 0.5 mm
Jiang P et al. [21], 2023	SP TFL: 0.2 J, 80 Hz. Ho:YAG laser: 0.4 J, 40 Hz	After SP TFL lithotripsy, 77% of residual fragments were ≤ 1 mm, compared to 17% with the Ho:YAG
Retropulsion		
Andreeva et al. [22], 2020	Laser settings were chosen according to the manufacturer's recommendations and the clinical literature	SP TFL laser generated significantly lower retropulsion effects at equal pulse energies
Ventimiglia et al. [23], 2020	Equivalent settings were used for both lasers: energies:0.2, 0.5, 0.8, 1.0, 1.5 and 2 J, and frequency = 80, 35, 20, 15, and 8 Hz, respectively	SP TFL results in lower retropulsion and movement speed of the stone compared to the Ho:YAG laser
Temperature		
Andreeva et al. [22], 2020	Laser settings were chosen according to the manufacturer's recommendations and the clinical literature	No substantial difference in the maximum temperature rise of water in the vicinity of the illuminated volume was observed between the two laser systems
Taratkin et al. [30], 2020	Equivalent settings were used for both lasers: 0.2 J, 40 Hz	SP TFL and Ho:YAG lasers are not different in terms of volume-averaged temperature increase when the same settings are used in both lasers

Table 1 (continued)

Study	Laser setting	Major conclusion
Molina et al. [31], 2021	Dusting settings: SP TFL:0.1 J, 200 Hz, SP; Ho:YAG:0.3 J, 70 Hz, LP. Fragmenting :0.8 J, 8 Hz, SP for both lasers	Median ureteral intra-luminal temperature rise during dusting settings was equivalent for both lasers, while it was higher in the SP TFL during fragmentation. However, neither reached the threshold for thermal injury based on the duration of exposure
Sierra et al. [25], 2022	Stone dusting: 0.5 J/10 Hz, 0.5 J/20 Hz, 0.7 J/10 Hz, 0.7 J/20 Hz, 1 J/12 Hz, 1 J/20 Hz for both lasers	The temperature changes caused by the two lasers during treatment were similar, and no differences were found after anatomic pathology evaluation 3 weeks later
Belle et al. [32], 2022,	Four different power settings for both lasers: 0.6 J/6 Hz, 1 J/10 Hz, 2 J/10 Hz, and 0.6 J/50 Hz	Under standardized irrigation (35 mL/min) with 60-s laser activation across four power settings (3.6, 10, 20, and 30 W), SP TFL consistently generated significantly higher average ureteral fluid temperatures than the Ho:YAG laser at all power levels. While maximum temperatures remained below the critical 43 °C threshold for both lasers at 3.6,10 and 20 W, the SP TFL exceeded 43 °C at 30 W
Jiang et al. [21], 2023	SP TFL: 0.2 J, 80 Hz. Ho:YAG laser: 0.4 J, 40 Hz	The temperature during the use of SP TFL and Ho: YAG laser to ablate kidney stones in pig kidney models was below 44 °c for both.
Laser fiber fracture		
Uzan et al. [35], 2021	Three laser settings were common to both lasers: 0.5 J × 12 Hz, 0.8 J × 8 Hz, 2 J × 3 Hz	SP TFL has a lower fracture risk than the Ho:YAG laser
Image distortion		
Miller CS et al.[36], 2023	Ho:YAG: Short-Pulse; Ho:YAG Moses: Distance and Contact; SP TFL: Short-Pulse. Laser settings were common to both lasers: energy of 1.0 or 0.5 J and its corresponding Hz for total power of 10, 20, 30, and 40 W	The Ho:YAG laser induces image interference at greater distances than the SP TFL

no statistically significant differences in temperature changes were observed between the two laser systems across the different irrigation flow rates [30].

In an ex vivo porcine kidney and ureter model, Molina WR et al. performed lithotripsy using both SP TFL and Ho:YAG lasers, with 5-s laser activation repeated 15 times for both dusting (SP TFL—0.1 J, 200 Hz, Short Pulse; Ho:YAG—0.3 J, 70 Hz, Long Pulse) and fragmentation settings (0.8 J, 8 Hz, Short Pulse for both). SPTFL generated higher temperatures in fragmentation mode (33.3 °C vs. 30.0 °C, $P=0.004$), while Ho:YAG showed a trend toward higher temperatures in dusting mode (40.6 °C vs. 35.8 °C, $P=0.064$). All temperatures remained below the 43 °C safety threshold, with no histological damage observed [31]. In a three-dimensional printed kidney–ureter model, Belle JD et al. demonstrated that under standardized irrigation (35 mL/min) with 60-s laser activation across four power settings (3.6, 10, 20, and 30 W), SP TFL consistently generated significantly higher average ureteral fluid temperatures than the Ho:YAG laser at all power levels ($P<0.001$). While maximum temperatures remained below the critical 43 °C threshold for both lasers at 3.6,10 and 20 W, the SP TFL exceeded 43 °C at 30 W [32].

In vivo studies

In a porcine kidney model, Jiang P et al. conducted flexible ureteroscopic lithotripsy through a 14F ureteral access sheath, with both SP TFL (0.2 J, 80 Hz) and Ho:YAG laser (0.4 J, 40 Hz) operating in dusting mode. Continuous temperature monitoring using K-type thermocouples positioned in the intra-renal and renal pelvis revealed comparable thermal profiles between the two laser modalities during the procedure, with maximum recorded temperatures consistently remaining below 44 °C in both groups [21]. In another study, the researchers compared the effects of the two lasers on urothelium using three pig models. Each pig was treated with TFL on the left urinary tract and Ho:YAG laser on the right, and a total of 23 tests were performed. The temperature changes caused by the two lasers during treatment were similar, and no difference was found after anatomic pathology evaluation 3 weeks later. In the third pig, Bellini tubes were visible in both kidneys due to the intentional reduction of perfusion during temperature testing [25].

Previous studies have set the threshold for tissue damage at 43 ℃ [33, 34]. SP TFL's higher thermal efficiency may elevate temperatures at high-power settings [32]. Clinicians should prioritize intermittent activation and adequate irrigation to keep temperatures below 43 °C and reduce the risk of tissue damage. In most preclinical models, both lasers maintained a safety threshold (<43 °C). Future human trials under different surgical conditions are needed to verify the safety of both lasers.

Laser fiber fracture

Uzan et al. compared laser fiber fracture risks between 30W Ho:YAG and 50W SP TFL under varying fiber diameters, settings, and bending radii. SP TFL exhibited no fiber fractures across all conditions, demonstrating superior safety. In contrast, Ho:YAG showed significantly higher fracture rates, particularly with short pulses and high-energy settings [35]. Fiber fracture in Ho:YAG laser may affect the efficiency of surgery and increase costs. Intraoperative fiber replacement necessitated by fractures prolongs operative time. There is an increased risk of Ho:YAG laser rupture in anatomically challenging situations, such as renal pelvis stones that require active bending of fibers. In contrast, the fracture resistance of the SP TFL may have an advantage over the Ho:YAG laser in the treatment of renal pelvis stones.

Image distortion

Studies by Miller CS concluded that increased total power during flexible ureteroscopy causes image distortion to occur at greater distances from the tip of the ureteroscope. When comparing laser setups, the Ho:YAG laser produces image interference at greater distances than the SP TFL [36]. Image distortion in laser lithotripsy poses a significant clinical concern [37]. In laser lithotripsy, any visual distortion can compromise visibility and surgical precision, potentially prolonging operative time, increasing technical difficulty and the risk of accidental tissue damage [38]. Ultimately, this may adversely impact SFR and overall treatment efficacy.

Clinical studies (Table 2)

Ablation speed and ablation efficiency

A prospective randomized clinical trial by Taratkin M et al. compared the clinical efficacy of SP TFL with Ho:YAG in retrograde intrarenal surgery (RIRS). The study found that SP TFL required less total energy for stone ablation than Ho:YAG (8.4 vs. 15.2 kJ, $P=0.021$). Ablation speeds were similar between SP TFL (median 0.8 mm^3/s) and Ho:YAG (0.6 mm^3/s). However, the median ablation efficiency of SP TFL was lower than that of Ho:YAG laser (24.5 vs. 31.8 kJ/cm^3, $P=0.046$) [39].

For percutaneous nephrolithotomy (PCNL), Patil et al. reported comparable fragmentation speeds between SP TFL and Ho:YAG with MOSES technology (5.22 mm^3/s vs. 4.64 mm^3/s, $P=0.23$), with no significant difference in total energy consumption (SP TFL: 16.30 ± 15.04 vs. Ho:YAG: 21.88 ± 23.32 kJ, $P=0.09$). Both lasers exhibited similar efficacy in stone fragmentation and dusting across various stone densities [40]. Vergamini et al. 's study

Table 2 Clinical studies

Study	Patients (SP TFL vs. Ho:YAG laser)	Laser setting		Primary outcome	Secondary outcome	Major conclusion
		SP TFL	Ho: YAG laser			
Martov et al. [10], 2021	87:87	400 μm and 365 μm laser fibers, 1 J, 10 Hz	400 μm and 365 μm laser fibers, 1 J, 10 Hz	The ability to effectively treat the stone	The total operation and lasering times, the degree of retropulsion and endoscopic view deterioration	The SP TFL technology is associated with considerably lower fragmentation and surgery times in comparison with the Ho: YAG technology
Ulvik et al. [3], 2022	60:60	60W, 200 μm laser fibers, Equal initial settings in both groups: 0.4 J/6 Hz (Max setting: ureter 0.4 J at 6 Hz; and renal 0.8 J at 20 Hz)	30 W, 200 μm laser Laser setup is the same as SP TFL	SFR	Operative time, intraoperative complications, and rates of postendoscopic ureteral stenting	The SP TFL is superior to the Ho:YAG in clearing kidney stones and reducing operative complications
Mahajan et al. [11], 2022	59:66	60 W, 400 μm 1–1.5 J/6–15 Hz	35W, 550 μm Ho:YAG: 0.8–1.2 J/10–15 Hz	SFR	Stone disintegration time, operative time, hospital stay, intra-and postoperative complications	SP TFL has shorter stone disintegration time, operative time and higher SFR than the Ho:YAG
Patil et al. [40], 2022	51:51	60W, 400 μm laser fibers, 0.1–1 J,100–250 Hz	120W with MOSES technology, 365 μm laser fibers, 0.3–1.2 J, 20–80 Hz	SFR	Stone fragmentation rate, lasing time, operative time, total energy, stone fragment distribution, and perioperative complications	HPH-M and SP TFL showed similar SFR. Within constraints of the laser fiber size and energy settings, both modalities were equivalent in terms of fragmentation efficiency and proportion of dusting across stone densities
Geavlete et al. [45], 2022	59:187	High power Ho: YAG 120W with MOSES, 270 μm laser fibers. 0.15–0.5 J/30–100 Hz	60 W, 150 μm laser fibers. 0.4 J/80 Hz	SFR	Operative time and perioperative events	SP TFL has a higher SFR compared to the Ho:YAG
Ryan et al. [42], 2022	51:51	-	-	Operative time	Cost saving	SP TFL has a significantly shorter operative time and decreased cost when compared to the standard the Ho:YAG
Jaeger et al. [43], 2022	32: 93	0.2–3.5 J, 3–25 Hz	0.2–3.5 J, 3–25 Hz	SFR	Operative times and complication	The SP TFL laser had a higher SFR than the low-power Ho:YAG laser without compromising operative time and safety

Table 2 (continued)

Study	Patients (SP TFL vs. Ho:YAG laser)	Laser setting		Primary outcome	Secondary outcome	Major conclusion
		SP TFL	Ho: YAG laser			
Delbar et al. [44], 2023	100:76	–	–	SFR	Complication rates and results regarding the cumulative stone size	SP TFL and Ho:YAG lithotripsy are comparable in terms of the SFR and safety for the treatment of UUT lithiasis. According to this study, for a cumulative stone size of 1–2 cm, TFL is more effective than the Ho:YAG
Candela et al. [47], 2023	97:29	Dusting (0.2 J × 200 Hz) fragmentation (1.2 J × 50 Hz)	Dusting (0.4 J × 40 Hz) popdusting/fragmentation (1.2 J × 20 Hz)	Intra-and postoperative complications	Operative time, SFR and reintervention rate	Both laser technologies are safe and effective and showed similar SFR. SP TFL showed less operative time and lower re-intervention rate compared to the Ho:YAG laser
Taratkin et al. [39], 2023	32:28	200 µm laser, fragmentation (1.5 J*20 Hz), dusting (0.5* 30 Hz), popcorning (0.15 J*100 Hz) fibers, surgeons could adapt the regimen to their own needs if necessary	Laser fibers and laser setup is the same as SP TFL	Laser on time, ablation speed, ablation efcacy, energy consumption	Radiation exposure time, operation time, complication rates, blood loss, duration of catheterization and SFR	SP TFL laser is a safe and effective procedure. SP TFL can decrease the laser on time and total energy for stone ablation in RIRS compared to the Ho:YAG. The SFR and complication rates are comparable for both lasers
Haas et al. [46], 2023	52:52	60W, 200 µm laser fibers. Equal initial settings in both groups: fragmentation 0.8 J/8 Hz and dusting 0.3 J/ 80 Hz	120W with MOSES, 200 µm laser fibers. Laser setup is the same as SP TFL	Laser-on time	SFR, complications	The two lasers showed no significant clinical advantage of one technology over the other in ureteroscope time, SFR, or complications
Vergamini et al. [41], 2024	49:51	60W, 1.0 J and 20 Hz, short pulse. surgeons could adapt the regimen to their own needs if necessary	120W with MOSES technology, 1.5 J and 30 Hz, with MOSES distance mode. surgeons could adapt the regimen to their own needs if necessary	SFR	Residual stone volume, ablation efficiency and speed. We hospital stay, intra-operative bleeding, changes in GFR	The Ho:YAG laser with MOSES technology and SP TFL are excellent choices for laser lithotripsy, with similar SFRs and comparable, low complication rates. The Ho:YAG laser showed a shorter operating time and greater intra-operative laser efficiency

found no significant difference in ablation speed between SP TFL and Ho:YAG with MOSES technology (3.2 vs. 4.8 mm^3/s, $P>0.05$). However, SP TFL showed lower ablation efficiency (5.2 kJ/cm^3) compared to the Ho:YAG (5.2 vs. 10.3 kJ/cm^3, $P<0.001$), and higher energy consumption (31.9 kJ vs. 11.8 kJ, $P<0.001$) [41].

While these studies report various outcomes regarding ablation speed, energy consumption, and efficiency, there are notable discrepancies, primarily due to differences in laser parameters, surgical modalities and patient demographics. Future studies should aim for more homogeneous study designs, with standardized protocols and consistent reporting formats, to better elucidate the comparative effectiveness of SP TFL and Ho:YAG lasers in different clinical contexts.

Laser time and operative time

The SP TFL demonstrates advantages over the Ho:YAG laser in reducing operative and laser times across different lithotripsy procedures. Martov et al. observed that SP TFL was associated with shorter operative (24.7 ± 0.7 vs. 32.4 ± 0.7 min, $P<0.05$) and laser times (8.4 ± 0.4 vs. 15.9 ± 0.5 min, $P<0.05$) compared to Ho:YAG in ureterolithotripsy [10]. Similarly, Ulvik et al. reported a 14% shorter total operative time for SP TFL in ureterorenoscopic lithotripsy (49 vs. 57 min, $P=0.008$), despite comparable laser times between the two lasers [3]. Ryan et al. further corroborated these findings, noting a 21% reduction in operative time with SP TFL (49.8 ± 29.1 vs. 62.8 ± 26.3 min, $P=0.021$) [42]. Jaeger CD et al. found a longer laser time for SP TFL in pediatric ureteroscopy (11 vs. 2 min, $P<0.05$), but no significant difference in total operative time (78 vs. 84 min, $P>0.05$) [43]. In a comparative analysis of laser lithotripsy, SP TFL exhibited superior efficiency for 1–2 cm calculi, with operative times reduced by 18% compared to Ho:YAG (56.6 vs. 65.6 min, $P=0.04$). However, this benefit did not extend to < 1 cm or > 2 cm stones [44].

For RIRS, Taratkin M et al. reported shorter laser times with SP TFL (9.2 vs. 14.1 min, $P<0.05$); however, the reduction in operative time was not statistically significant (74.4 vs. 90.0 min, $P=0.054$) [39]. While three studies found no difference in operative time between the two groups for RIRS [45–47].

Comparative studies reported inconsistent operative time for SP TFL in mini-PCNL. Mahajan AD et al. found that SP TFL was superior to the Ho:YAG laser in terms of laser time (11.19 vs. 20.45 min, $P<0.01$) and operative time (55 vs. 68 min, $P=0.01$) [11]. Patil et al. observed no difference in laser time but reported shorter operative times with SP TFL (23.68 vs. 41.86 min, $P<0.05$) [40]. On the contrary, Vergamini et al. observed prolonged operative (91 vs. 67 min, $P<0.05$) and laser times (17 vs. 7 min, $P<0.05$) compared to Ho:YAG with MOSES in mini-PCNL [41]. Most studies support the advantages of SP TFL in shortening operative time. However, there is heterogeneity in the results, which may be related to differences in surgical procedures, surgical parameters, and patient populations. The current data are difficult to directly compare due to differences in surgical procedures and patient choices, and more standardized studies are needed.

SFR

Existing research indicated that the SFR of SP TFL was comparable to or even higher than that of the Ho:YAG laser. A prospective randomized clinical trial reported higher SFR for SP TFL compared to Ho:YAG (92% vs. 67%, $P=0.001$) 3 months post-ureterorenoscopic lithotripsy, with a notable advantage for renal stones (86% vs. 49%, $P=0.001$) [3]. Martov AG et al. found no stone residue in the SP TFL group and 5 patients with stone residue in the Ho:YAG laser group through non-contrast CT evaluation 1 month after ureteroscopy lithotripsy (0 vs. 6%) [10]. Jaeger CD et al. identified SFR as the absence of any stone fragments on the first imaging examination within 90 days after pediatric ureteroscopy. They observed that the SP TFL group had a higher SFR (70% vs. 59%, $P<0.05$) [43]. Geavlete B et al. evaluated the SFR following RIRS via secondary ureteroscopy, revealing that 96.61% of patients in the SP TFL group achieved a stone-free status, compared to 86.63% in the Ho:YAG laser group [45]. Delbarre et al. found similar overall SFRs between the lasers; however, for stones measuring 1–2 cm, SP TFL achieved a higher SFR (81.6% vs. 62.5%, $P=0.04$) [44]. Conversely, Haas CR et al., Taratkin et al., and Candela et al. reported no significant difference in SFR between SP TFL and Ho:YAG laser after RIRS [39, 46, 47].

For mini-PCNL, Mahajan AD et al. observed no statistical difference in SFR between SP TFL and Ho:YAG laser (94.9% vs. 90.9%, $P=0.498$) [11]. Patil et al. found that the proportion of dusting (< 1 mm fragments) and SFR at 48 hours were similar between HPH-M and SP TFL [40]. Vergamini LB et al. also did not observe a difference in the SFR between the two groups, whether the SFR was defined as no fragments, no fragments > 2 mm, or no fragments > 4 mm ($P=0.52$, 0.64 and 1.00, respectively) [41].

Retropulsion and visibility

The research results of Martov AG et al. showed that almost all (96%) cases in the SP TFL group experienced no observe retropulsion, while 31% of cases in the Ho:YAG laser group experienced retropulsion ($P < 0.05$). In 51% of cases in the Ho:YAG laser group and 4% of cases in the SP TFL group, mild retropulsion was observed ($P < 0.05$). Additionally, 0.18% of cases in the Ho:YAG laser group showed severe stone retropulsion, while no severe stone retropulsion was observed in the SP TFL group. SP TFL provided better endoscopic view quality, with 87% of patients in the SP TFL group having a clear endoscopic field, more than those in Ho:YAG laser group (87% vs. 64%, $P < 0.05$). The proportion of mild blurred visual field and severe blurred visual field in SP TFL group was lower than that in Ho:YAG laser group(12% vs. 30% and 1% vs. 6%, $P < 0.05$, respectively) [10].

Complication

In Ulvik et al.'s study, the proportion of intraoperative bleeding in the SP TFL group was lower than that in the Ho:YAG group (5% vs. 22%, $P = 0.014$) [3]. Martov AG et al. reported similar proportions of Clavien–Dindo I and II complications in the SP TFL group and the Ho:YAG laser group (10% vs. 13% and 1% vs. 5%, respectively) [10]. In Jaeger CD et al.'s retrospective study, no difference was found in the incidence of complications between SP TFL and Ho:YAG laser (25% vs. 22%, $P > 0.05$) [43]. Similarly, several studies have reported no difference in complication rates between the two groups [11, 39–41, 46, 47].

Discussion

The introduction of SP TFL provides a promising advancement in the field of urinary lithotripsy. Compared to the Ho:YAG, SP TFL offers several distinct advantages, including higher efficiency, a broader range of operational parameters, reduced retropulsion, enhanced visualization, and improved safety profiles. SP TFL, utilizing advanced pulse modulation technology, produces extremely high peak power, making it a more efficient option for stone fragmentation. This review aims to evaluate the current realities of SP TFL and Ho:YAG laser, with the goal of offering readers a balanced, evidence-based perspective.

Ablation efficiency

The results of in vitro studies indicated that SP TFL had higher ablation efficiency, particularly in dusting and fragmentation modes. For hard stones, SP TFL exhibits fourfold and twofold greater ablation rates in dusting and fragmentation modes, respectively, compared to Ho:YAG, while for soft stones, these rates are threefold and twofold higher under equivalent settings [15, 20]. This superiority is further corroborated by in vivo models, where SP TFL reduced ablation time by 67% (9 vs. 27 min, $P < 0.001$) and energy consumption by 69% (8 vs. 26 kJ, $P < 0.001$), alongside superior stone clearance (73% vs. 45%, $P = 0.001$) [21]. This is attributable to its 1940 nm wavelength, which exhibits a fourfold higher water absorption coefficient than the Ho:YAG laser. This unique optical property enables a "water-explosion" mechanism: water trapped within microcrystalline gaps, pores, and cracks inside and near the surface of the stone suddenly evaporates explosively, generating extremely high pressure in localized areas. These high pressures create mechanical stress waves within the stone, further contributing to its ablation, reducing the stone ablation threshold by a factor of four [5, 28]. In vitro studies by Hardy LA et al. showed that SP TFL had higher ablation efficiency than Ho:YAG laser under the action of this mechanism [48]. However, this mechanism has not been directly proven to impact Ho:YAG laser ablation [5]. In addition, SP TFL generated less retropulsion compared to Ho:YAG, which reduced the number of times the fiber moves toward the stone. This characteristic, combined with the water-explosion mechanism, allows SP TFL to achieve a comparable ablation rate while using less total ablation energy [39].

Retropulsion

SP TFL generates less retropulsion than Ho:YAG laser due to its lower peak power and smaller cavitation bubbles, which are four times smaller than those produced by Ho:YAG laser. Ventimiglia et al. quantified this disparity, revealing that Ho:YAG in short-pulse and long/Moses-pulse modes induced fourfold and twofold greater stone displacement distances (21–8.6 mm vs. 4.5–4.9 mm for SP TFL, $P < 0.001$) and 4–1.8 times higher initial retropulsion velocities (141–47 mm/s vs. 28 mm/s for SP TFL, $P < 0.001$) [23].SP TFL generates local pressures that are ten times lower than those of the Ho:YAG laser, contributing to reduced retropulsion [49]. The smaller retropulsion reduces the need to change the position of the optical fiber to adapt to the position of the stone. This leads to shorter operative times, improved efficiency in stone fragmentation, and a lower skill threshold for inexperienced surgeons, making SP TFL a more user-friendly option for lithotripsy.

Visibility

Due to the phenomenon of "snowstorm" in Ho:YAG laser lithotripsy, the clarity of the visual field during the operation is reduced. SP TFL has a better endoscopic field of view due to the smaller retropulsion and the consequent reduction in medium turbulence, resulting in less debris and dust particles being swept up, thus reducing the "snowstorm" effect [5]. A clear field of view reduces the number of interruptions in laser operations, shortens surgical time, and also lowers the risk of kidney and ureteral injuries.

Operative time

Multiple studies have investigated the impact of SP TFL and Ho:YAG laser on operative time and laser time. In ureteroscopy, SP TFL reduced total operative time by 14–21% and laser time by up to 47% [3, 10, 42]. In mini-PCNL, SP TFL exhibited conflicting outcomes: two studies reported shorter operative and laser times [11, 40], while another observed prolonged operative and laser times [41]. Most findings suggest that SP TFL offers advantages in reducing procedural duration, due to its smaller retropulsion, clearer field of view and higher ablation efficiency [3, 10, 11, 39, 40, 42]. Shorter operative time not only reduces surgeon fatigue but also decreases the risk of infection associated with prolonged operative time. However, it is worth noting that the study by Vergamini LB et al. found that the Ho:YAG laser had a shorter operative time in mini-PCNL [41]. Vergamini LB suggested that this may be due to differences in laser energy characteristics. The SP TFL absorbs four times more energy in water than the Ho:YAG laser and produces smaller pieces of stone. In PCNL surgery, the percutaneous sheath can remove the medium-sized stone fragments from the body without the need for SP TFL to break the stone into thinner fragments. The postoperative SFR showed no difference between the two groups, regardless of whether SFR was defined as no fragments, no fragments > 2 mm, or no fragments > 4 mm [41]. Two additional studies reported that SP TFL provided shorter operative times and similar SFR, compared to the Ho:YAG laser [11, 40]. While the overall evidence supports the efficiency of SP TFL, variations in surgical techniques, laser settings, and patient characteristics contribute to the observed inconsistencies across studies. Given the heterogeneity in current data, further standardized studies with uniform surgical protocols and laser parameters are necessary to better define the comparative advantages of SP TFL and Ho:YAG laser in different clinical situations.

SFR

Existing research indicated that the SFR of SP TFL was comparable to or even higher than that of the Ho:YAG laser [10, 39–41, 43]. In ureterorenoscopic lithotripsy, a prospective randomized trial reported a significantly higher SFR for SP TFL at 3 months postoperatively (92% vs. 67%, $P = 0.001$), with pronounced efficacy for renal stones (86% vs. 49%, $P = 0.001$) [3]. Martov et al. further supported this advantage, showing no residual stones in the SP TFL group vs. 6% in the Ho:YAG group at 1 month ($P < 0.05$) [10]. Pediatric ureteroscopy data also favored SP TFL, with a 70% SFR compared to 59% for Ho:YAG ($P < 0.05$) [34]. Residual stone fragments after treatment may become the focus of stone regeneration, recurrence, urinary tract infection and ureteral obstruction [50]. This may become the reason for re-treatment, affecting the health of patients and increasing the burden on patients. Traditionally, non-obstructive stone fragments ≤ 4 mm in diameter have been described as clinically irrelevant residual fragments, but this concept has been questioned, because up to 26% of patients with residual stones develop symptoms and require intervention within 2 years of treatment [50, 51]. Studies have shown that stone fragments ≤ 2 mm were less likely to grow over time, more likely to pass spontaneously, and had lower rates of regrowth, clinical events, and reintervention [52, 53]. Therefore, stone-free status or smaller stone fragments are of great significance for the prognosis of patients. The results of the in vitro study showed that SP TFL produced a higher proportion of stone fragments < 2 mm and a larger quantity of dust [15, 21, 29]. The clinical results showed that the SFR of SP TFL was better than that of the Ho:YAG laser [10, 43]. This is related to the higher water absorption of SP TFL and the resulting micro-explosive water vapor expansion mechanism, as well as the clearly defined and precise emission of laser energy [5, 48]. With its wide-ranging and flexible parameters, the SP TFL is also capable of high-frequency dusting, pop-corning, pop-dusting, corn-dusting, and micro-dusting. SP TFL can produce smaller stone fragments, reducing the chance of residual debris after stone surgery. This could ultimately reduce repeat surgery and related clinical events for patients. Notably, there was a lack of significant SFR differences between the two in some studies, highlighting the influence of factors, such as surgical technique, stone characteristics, and follow-up time. Further large-scale, multicenter trials with standardized definitions of SFR are needed to clarify the clinical benefits of SP TFL over Ho:YAG laser across different lithotripsy modalities.

Thermal damage

The thermal damage resulting from increased temperatures during laser lithotripsy is a recognized issue. Due to the higher water absorption rate of SP TFL, this may lead to temperature increases during stone fragmentation, potentially causing thermal damage [5]. In vitro studies suggest that both SP TFL and Ho:YAG laser are safe under typical lithotripsy conditions with appropriate irrigation [21, 22, 30, 31]. However, SP TFL demonstrated a trend of generating slightly higher temperatures in fragmentation mode and at higher power settings [31, 32], highlighting potential thermal risks at high-power settings. According to Sapareto et al., 43 °C was the threshold temperature for inducing tissue damage. At this temperature, a duration of 120 min is required to trigger thermal injury, highlighting the close correlation between cellular damage and exposure time [33]. Clinically, these findings underscore the importance of optimizing irrigation flow rates, as increased irrigation can effectively mitigate temperature elevation [54], particularly at higher power settings, as increased power can lead to significant rises in intra-ureteral temperature, elevating the risk of thermal injury to the ureter [26]. While SP TFL's higher efficiency in stone fragmentation may reduce total energy application and procedural duration, minimizing prolonged laser activation and ensuring adequate irrigation are essential to prevent thermal injury. At present, there is a lack of clinical studies on the thermal damage caused by two types of lasers. Further research should investigate potential thermal injury manifestations, such as ureteral stricture formation, especially in cases where high-power settings or prolonged activation are used. In addition, the interaction of SP TFL's higher water absorption with different irrigation strategies and laser settings requires further refinement to optimize clinical protocols.

Laser fiber fracture and image distortion

Uzan A et al. found that SP TFL did not experience fiber breakage regardless of the laser setting, fiber diameter, and bending radius. In contrast, the Ho:YAG laser demonstrated a higher risk of fiber breakage compared to SP TFL [35]. In addition, Miller CS et al. reported that increased laser power led to image distortion at a distance from the ureteroscope tip. At the same laser setup, Ho:YAG produced image interference at a greater distance than SP TFL [36]. The reduced risk of fiber breakage across various laser settings and fiber configurations suggests greater durability and operational reliability during lithotripsy procedures, potentially lowering the need for frequent fiber replacement and reducing procedural interruptions. Furthermore, the superior endoscopic visibility associated with SP TFL, particularly under high-power settings, enhances intraoperative precision and safety. These advantages may contribute to improved procedural efficiency and surgical outcomes, supporting that SP TFL may offer a safer option for lithotripsy.

Implications for clinical practice

SP TFL demonstrates excellent ablation efficiency, shortening operative time while producing finer fragments. This translates into improved surgical efficiency, reduced anesthesia exposure, a lower risk of infections associated with prolonged surgery, and enhanced operating room turnover. A comparable or superior SFR means lower residual stone volume, reducing the risk of infection, obstruction, and the need for secondary procedures. The SP TFL has a smaller retropulsion force and better visualization, which improves surgical precision and reduces the need for instrument repositioning and interruptions to restore the visual field. The breakage resistance of the SP TFL fiber means it can meet the bending requirements in anatomically challenging cases, such as renal calyx stones. In addition, SP TFL shares a similar safety profile with Ho:YAG lasers, and in vitro experiments show similar temperature variations at the same output power. Therefore, strategies used for Ho:YAG lasers, such as using cold irrigation fluids and intermittent laser firing to minimize thermal effects, are also applicable to SP TFL, helping to prevent unnecessary damage to surrounding tissues. Overall, SP TFL represents a promising advancement in laser lithotripsy, offering improvements in visualization, handling, and procedural efficiency without compromising safety or efficacy. However, inconsistencies still exist across some studies, likely due to variations in surgical technique, patient characteristics, and energy settings.

Limitation

The limitations of this review should be acknowledged. The number of studies on this new technology is limited and the number of studies on which conclusions can be drawn is small. Many studies have small sample sizes and are conducted in single centers, which may introduce selection and performance bias. Furthermore, there was significant heterogeneity in surgical techniques, laser settings and outcome definitions, making direct comparison across studies challenging. To better define the clinical advantages of SP TFL over Ho:YAG laser, future research should prioritize well-designed randomized controlled trials with larger, multicenter cohorts. In addition, studies focusing on long-term outcomes such as complication rates (e.g., ureteral strictures), cost-effectiveness, and procedural learning curves are warranted to guide more comprehensive clinical decision-making. Finally, although the parameter settings and effects of lithotripsy mode have been reported in the literature, the ideal SP TFL lithotripsy parameters have not been determined, and more high-quality clinical studies are still needed to evaluate the efficiency and safety of SP TFL lithotripsy at different parameter settings.

Conclusion

The emergence of SP TFL offers a promising new option for the minimally invasive treatment of urinary calculi. SP TFL has several advantages over the Ho:YAG laser, including enhanced lithotripsy efficiency, more versatile and comprehensive parameter settings, significantly reduced retropulsion, and a higher degree of miniaturization. These benefits contribute to more effective and controlled treatments, especially in cases, such as ureterorenoscopic lithotripsy and RIRS, where SP TFL has shown a shorter operative time and a higher stone-free rate compared to Ho:YAG laser. Clinicians need to understand the technical characteristics and settings of SP TFL under different conditions to apply the most appropriate techniques for various procedural approaches. Despite its potential, SP TFL has a relatively short clinical application history, necessitating further research to fully elucidate its long-term advantages, clinical significance, and possible limitations. Future studies should focus on in vivo evaluations, randomized clinical trials, and cost-effectiveness analyses to provide comprehensive insights into the utility of SP TFL in urological practice.

Abbreviations

SP TFL	SuperPulsed thulium fiber laser
Ho:YAG	Holmium:yttrium–aluminum–garnet
TEL	Thulium fiber laser
RIRS	Retrograde intrarenal surgery
PCNL	Percutaneous nephrolithotomy

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Author contributions
Qinghua Gan, Jun Li and Gaoqiang Zhai wrote the main manuscript, Qinghua Gan, Gaoqiang Zhai, Bangfeng Liu, Jun Li, Yan Qin, Shuting Tan collected the literature and prepared the tables. Qinghua Gan, Jun Li, Wei Wang and Qinsong Zeng modified and revised the manuscript; Wei Wang and Qinsong Zeng supervised in the design of the study and finalized the manuscript. All authors have contributed to the manuscript and approved the submitted version.

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Availability of data and materials
The data sets used or analyzed during the current study are available from the corresponding author on reasonable request. No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate
Not applicable.

Competing interests
The authors declare that they have no competing interests.

Author details
[1]Department of Urology, Guangxi Hospital Division of The First Affiliated Hospital, Sun Yat-Sen University, No.3 Fozi Ling Road, Qingxiu District, Nanning 530022, Guangxi, China. [2]Department of Urology, The First Affiliated Hospital of Sun Yat-Sen University, Guangzhou 510080, Guangdong, People's Republic of China.

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