ORIGINAL RESEARCH
Endourology

Doi: 10.4274/jus.galenos.2026.2026-1-7
J Urol Surg

Impact of Lithotripsy Technology on Mini-PCNL Outcomes: A Comparative Study of Holmium and Thulium Laser

Ersin Gökmen[1], Türker Altuntaş[2], Abdul Vahap Bakır[2], Kaan Derici[2], Günal Özgür[1], Tarık Emre Şener[2]

[1]*Marmara University, Pendik Training and Research Hospital, Department of Urology, İstanbul, Türkiye*
[2]*Marmara University School of Medicine, Department of Urology, İstanbul, Türkiye*

What's known on the subject? and What does the study add?

Mini-percutaneous nephrolithotomy (PCNL) is a well-established minimally invasive technique for the management of renal stones. Holmium:YAG laser is the traditional and most widely used lithotripsy energy source in mini-PCNL. Thulium fiber laser has recently emerged as an alternative, with potential advantages in stone dusting efficiency and radiation reduction, but clinical data in mini-PCNL are limited. This study provides a comparison of holmium:YAG and thulium fiber laser in mini-PCNL performed by a single surgeon, reducing procedural variability. According to our results both laser systems demonstrate comparable safety, efficacy, and stone-free rates. Thulium fiber laser is associated with reduced radiation exposure in patients with smaller stone burdens, supporting its role as a reliable modern alternative to holmium:YAG in mini-PCNL.

Abstract

Objective: To evaluate outcomes of mini-percutaneous nephrolithotomy (PCNL) performed with holmium:YAG (Ho:YAG) versus thulium fiber laser (TFL).

Materials and Methods: This retrospective study included adult patients who underwent mini-PCNL with either Ho:YAG or TFL between January 2024-2025. Demographic features, stone characteristics, operative parameters, and postoperative outcomes were analysed. All surgeries were performed by a single surgeon using the modified supine position. Residual fragments were assessed on postoperative day 1, and stones ≥4 mm were considered significant. Patients were divided into two groups based on the laser system, and outcomes were compared across clinical, perioperative, and postoperative variables.

Results: Eighty-six patients underwent mini-PCNL (44 Ho:YAG, 42 TFL). Of the 86 patients included in the study, 64 (74.4%) were male and 22 (25.6%) were female. The median age was 52.5 years (range: 27-76). Baseline and operative parameters were comparable between groups. Stone-free rates were similar (81.4% vs. 88.1%). The thulium group showed lower radiation exposure in stones <3 cm ($p=0.028$) but a slightly higher postoperative creatinine change ($p=0.033$). Both lasers demonstrated equivalent efficacy and safety.

Conclusion: Ho:YAG and TFL demonstrate comparable safety and efficacy in mini-PCNL. TFL may offer a technical advantage by reducing radiation exposure, particularly in patients with smaller stone burdens, while overall outcomes remain similar. These results support TFL as a reliable, modern alternative to Ho:YAG, with both lasers providing safe and effective energy options for mini-PCNL.

Keywords: Basic science, endourology, functional urology

Introduction

The prevalence rates for urinary stones vary from 1% to 20% (1). The aetiology of urolithiasis is multifactorial; metabolic abnormalities, low fluid intake, dietary habits, urinary obstruction, and infections all play a critical role in stone formation. For large or complex renal stones, or those refractory to extracorporeal modalities, surgical intervention is often required (2).

Correspondence: Türker Altuntaş MD, FEBU, Marmara University School of Medicine, Department of Urology, İstanbul, Türkiye
E-mail: turkeraltuntas@hotmail.com **ORCID-ID:** orcid.org/0000-0001-9387-250X
Received: 14.01.2026 **Accepted:** 20.04.2026 **Epub:** 12.08.2026

Cite this article as: Gökmen E, Altuntaş T, Bakır AV, Derici K, Özgür G, Şener TE. Impact of lithotripsy technology on mini-PCNL outcomes: a comparative study of holmium and thulium laser. J Urol Surg. [Epub Ahead of Print]

Currently, indications for active treatment of renal stones are primarily guided by stone size, stone location, and anatomical or stone-related characteristics that influence the effectiveness of stone fragmentation or extraction. According to the European Association of Urology (EAU) guidelines, percutaneous nephrolithotomy (PCNL) is recommended as the first-line treatment for stones larger than 2 cm. For stones measuring 10-20 mm, PCNL, ureteroscopy (URS), and shock wave lithotripsy (SWL) share a similar level of recommendation, whereas for stones smaller than 10 mm, SWL and URS are preferred treatment options, with PCNL reserved for selected circumstances (2).

The development of miniaturized instruments has led to the emergence of mini-PCNL, typically employing a tract size ≤24 Fr. This approach provides reduced blood loss, shorter hospital stay, and lower complication rates while maintaining high stone clearance efficacy (3).

Laser lithotripsy has revolutionized endourological stone management. The Holmium:YAG (Ho:YAG) laser has long been considered the standard energy source due to its versatility, reliability, and tissue safety (4). However, limitations such as stone retropulsion, inefficient energy transfer, and prolonged lasing times have led to the development of more efficient alternatives. The thulium fiber laser (TFL), a newer technology operating at 1940 nm compared with the 2100 nm Ho:YAG laser, offers lower pulse energy, higher frequencies, minimal retropulsion, and greater ablation efficiency (5). Early evidence indicates that TFL may enable shorter lasing times, smoother dusting, and reduced radiation exposure (6,7).

Despite its increasing use, comparative data between Ho:YAG and TFL in mini-PCNL are still limited. In this study, we aimed to present our experience comparing the outcomes of mini-PCNL cases performed in our clinic using both laser types.

Materials and Methods

This retrospective study was performed at our tertiary care referral centre. Ethical approval was obtained from the Marmara University Faculty of Medicine, Drug and Non-Medical Device Research Ethics Committee (approval number: 09.2025.25-0732, date: 05.09.2025). The study was conducted in accordance with the declaration of Helsinki and designed and reported in line with the STROBE guidelines for observational studies.

Patients who underwent mini-PCNL using either Ho:YAG or TFL at our institution between January 2024 and January 2025 were included in the study and initially reviewed. Patients over 18 years of age who underwent mini-PCNL and had complete preoperative and postoperative clinical data were included. Our exclusion criteria were as follows: patients with incomplete data, abnormal renal anatomy, pregnancy, concomitant surgical interventions, bilateral renal stones, multiple stones, or prior stone surgery.

Demographic parameters (age, sex, body mass index), comorbidities (Charlson Comorbidity Index), and stone characteristics (size, location, and Hounsfield units) were recorded. Intraoperative variables, including operative duration, lasing time, total laser energy delivered, fluoroscopy time (recorded in seconds), and radiation exposure parameters, including dose-area product (DAP, expressed in $Gy.cm^2$), were obtained directly from the fluoroscopy unit and used as standardized indicators of radiation exposure. Postoperative outcomes comprised haemoglobin drop, change in serum creatinine, transfusion requirement, length of hospital stay, and complications graded according to the Clavien-Dindo system (8). Serum creatinine levels were measured at the postoperative 1 month follow-up, whereas other laboratory parameters were assessed on postoperative day 1.

All procedures were performed under general anaesthesia in the Galdakao-modified supine Valdivia position (9). The procedures were performed by a single experienced endourologist. Percutaneous access to the renal collecting system was obtained under fluoroscopic guidance. The tract was dilated using 16/20 Fr Amplatz dilators. Stone fragmentation was performed using Ho:YAG and TFL devices, including the 60-W Quanta CyberHo system and the Fiber Dust® Thulium Fiber Laser (Quanta System). Laser settings were adjusted intraoperatively according to stone hardness, as different compositions require distinct energy profiles for optimal fragmentation. Collectively, these tailored laser settings ensured efficient and controlled fragmentation across varying stone types.

Residual stone status was assessed on postoperative day 1 by abdominal X-ray. Patients with a suspicious opacity on the abdominal radiograph or who were symptomatic underwent non-contrast computed tomography in accordance with EAU guidelines. Stones ≥4 mm were considered residual stones (2).

In this study, patients were stratified into two groups based on the laser type used during mini-PCNL (Ho:YAG or TFL). The primary objective was to compare perioperative performance and postoperative outcomes between the two laser modalities, including operative parameters, complication rates, length of hospital stay, and stone-free rates, while ensuring comparable baseline demographics and stone-related characteristics between the groups.

Statistical Analysis

Statistical analyses were carried out using IBM SPSS 25.0. Because the data were not normally distributed (Kolmogorov-Smirnov test), non-parametric tests were applied. Numerical data were presented as median and interquartile range, and categorical data as counts and percentages. Categorical data were analyzed using the chi-square test or Fisher's exact test, as appropriate; group comparisons were performed with the Mann-Whitney U test. A p-value <0.05 was considered statistically significant.

Results

A total of 86 patients who underwent mini-PCNL were included in the study. Forty-four patients were treated with the Ho:YAG laser (Group 1) and forty-two patients were treated with the TFL (Group 2). Of the 86 patients included in the study, 64 (74.4%) were male and 22 (25.6%) were female. The median age was 52.5 years (range: 27-76).

The median age of the patients was similar between the two groups (53 vs. 51 years, p=0.477). The male-to-female ratio did not differ significantly (77.3% vs. 71.4%, p=0.535). Similarly, no statistically significant differences were observed between the groups regarding body mass index, Charlson Comorbidity Index, or stone diameter. The majority of stones were located in the renal pelvis (59.1% in Group 1 and 61.9% in Group 2), with similar distributions across other calyceal locations. The mean stone density, was comparable between groups. Laser time, total laser energy used, radiation exposure, and operation time showed no statistically significant differences between the two groups. The median operation time was 120 minutes in both groups. Postoperative outcomes, including decreases in haemoglobin levels, hospital stays, transfusion requirements, and intensive care unit admissions, were also similar. However, there was a statistically significant difference in the change of serum creatinine levels [ΔCreatinine=0.005 (-0.08-0.08) vs. 0.06 (0.01-1.6), p=0.033], indicating a slightly higher postoperative creatinine rise in the thulium group. The overall stone-free rate was 81.4% in the holmium group and 88.1% in the thulium group (p=0.391). Postoperative complications, classified according to the Clavien-Dindo system, were distributed similarly between the groups, and most were minor (Grade I-II) (Table 1).

Table 1. Comparison of holmium and thulium laser for all patients

	Group 1 (n=44)	Group 2 (n=42)	p-value
Age (years), median (IQR)	53 (45.5-65.5)	51 (39.5-63)	0.477
Sex (male/female), n (%)	34/10 (77.3/22.7)	30/12 (71.4/28.6)	0.535
BMI (kg/m^2), median (IQR)	25.91 (24.42-28.3)	27.53 (25.99-30.4)	0.137
CCI, median (IQR)	0 (0-1)	0 (0-2)	0.564
Stone diameter (mm), median (IQR)	23.5 (17.25-28)	20.5 (16-30)	0.525
Stone location, n (%)			
Renal pelvis	26 (59.1)	26 (61.9)	0.572
Upper pole	1 (2.3)	3 (7.1)	
Middle pole	6 (13.6)	3 (7.1)	
Lower pole	11 (25)	10 (23.9)	
Stone density (Hounsfield unit), median (IQR)	1268 (960-1420)	1232.5 (959.75-1470)	0.651
Lasing time (sec), median (IQR)	1810 (1237-2980)	1647.5 (1023.75-2951)	0.554
Lasing energy (Joule), median (IQR)	45.73 (20.06-89.1)	47.36 (16.33-74.96)	0.881
Radiation time (sec), median (IQR)	75 (46.5-120)	72 (30.75-104)	0.435
Fluoroscopy energy (mGy), median (IQR)	21.01 (10-69.2)	23.48 (8-49.62)	0.659
Fluoroscopy energy (DAP), median (IQR)	6 (2.64-12.51)	2.89 (1.26-6.02)	0.077
Operation time (min), median (IQR)	120 (100-180)	120 (94.25-150)	0.324
Exit strategy (DJ/Nephrostomy), n (%)	41/3 (93.2/6.8)	38/4 (90.5/9.5)	0.474
ΔHaemoglobin, median (IQR)	0.8 (0.3-1.5)	0.5 (0-1.6)	0.582
ΔCreatinine, median (IQR)	0.005 (-0.08-0.08)	0.06 (0.01-1.6)	0.033
Stone free rate, n (%)	35 (81.4)	37 (88.1)	0.391
Blood Transfusion, n (%)	3 (6.8)	3 (7.1)	0.953
Intensive care unit necessary, n (%)	2 (4.5)	1 (2.4)	0.518
Clavien-Dindo classification, n (%)			
Grade 1	1 (2.3)	1 (2.4)	0.431
Grade 2	3 (6.8)	6 (14.3)	
Grade 3	1 (2.3)	4 (9.5)	
Grade 4	2 (4.5)	1 (2.4)	
Hospital stay (day), median (IQR)	2 (1-3)	2 (1.75-7.25)	0.4

Bold values indicate statistically significant results
BMI: Body mass index, CCI: Charlson Comorbidity Index, DAP: Dose-area product, DJ: Double-J stent, IQR: Interquartile range, mGy: Milligray, min: Minute, mm: Milimeter, sec: Second

In the subgroup analysis of patients with stones <3 cm (Table 2), 35 patients were in the holmium group and 31 were in the thulium group. Demographic characteristics such as age, sex, BMI, and comorbidities were comparable. The median stone size was 20 mm in both groups, and the distribution of stone locations did not differ significantly (p=0.238). Intraoperative parameters, including laser time, total laser energy, radiation time, and operation duration, were similar. However, the thulium group exhibited a significantly lower fluoroscopy DAP [1.48 (1.07-4.82) vs. 6 (1.71-13.84) Gy.cm^2, p=0.028], indicating reduced radiation exposure. Postoperative changes in serum creatinine were again significantly higher in the thulium group (p=0.02). The median hospital stay was 2 days in both groups, and the stone-free rates were 76.5% and 83.9% for holmium and thulium, respectively (p=0.456). The complication profile was similar, with most events classified as Clavien-Dindo Grade II, and no Grade V complications were recorded.

Among patients with stones >3 cm (Table 3), 9 were in the holmium group and 11 were in the thulium group. Both groups had similar demographic and preoperative characteristics. The median stone diameter and density did not differ significantly. Intraoperative outcomes, including laser and radiation parameters as well as operation time, were comparable. The median operative duration was 140 minutes in Group 1 and 150 minutes in Group 2 (p=0.818). All patients in both groups achieved complete stone clearance (100% stone-free rate). Postoperative haemoglobin drops, creatinine changes, and length of hospital stay were similar in the two groups. No statistically significant differences were found in complication rates, and no major adverse events or mortality were observed.

Table 2. Comparison of holmium and thulium laser for >3 cm stones

	Group 1 (n=35)	Group 2 (n=31)	p-value
Age (years), median (IQR)	51 (42-62)	48.5 (39.5-63)	0.67
Sex (male/female), n (%)	27/8 (77.1/22.9)	24/7 (77.4/22.6)	0.979
BMI (kg/m^2), median (IQR)	25.71 (24.1-28.56)	27.17 (25.25-29.18)	0.28
CCI, median (IQR)	0 (0-1)	0 (0-1)	0.768
Stone diameter (mm), median (IQR)	20 (15-25)	20 (15-23)	0.138
Stone location, n (%)			
Renal pelvis	22 (62.9)	18 (58.1)	0.238
Upper pole	0	3 (9.7)	
Middle pole	3 (8.6)	1 (3.2)	
Lower pole	10 (28.6)	9 (29)	
Stone density (Hounsfield unit), median (IQR)	1234 (955.25-1405)	1242 (1014-1488)	0.4
Lasing time (sec), median (IQR)	1780 (1170-3011)	1647.5 (1023.75-2559.5)	0.887
Lasing energy (Joule), median (IQR)	30.64 (19.25-75.16)	37.67 (14.7-55.25)	0.719
Radiation time (sec), median (IQR)	75 (46.5-119.5)	65.5 (26.25-97.5)	0.332
Fluoroscopy energy (mGy), median (IQR)	28.52 (10-75.6)	20 (7.9-49.33)	0.53
Fluoroscopy energy (DAP), median (IQR)	6 (1.71-13.84)	1.48 (1.07-4.82)	**0.028**
Operation time (min), median (IQR)	120 (100-180)	110 (90-130)	0.292
Exit strategy (DJ/nephrostomy), n (%)	32/3 (91.4/8.6)	29/2 (93.5/6.5)	0.558
ΔHaemoglobin, median (IQR)	0.9 (0.3-1.42)	0.45 (0.2-1.37)	0.142
ΔCreatinine, median (IQR)	0 (-0.08-0.08)	0.07 (0-0.18)	**0.02**
Stone free rate, n (%)	26 (76.5)	26 (83.9)	0.456
Blood transfusion, n (%)	3 (8.6)	2 (6.5)	0.558
Intensive care unit necessary, n (%)	2 (5.7)	0	0.277
Clavien-Dindo classification, n (%)			
Grade 1	1 (2.9)	1 (3.2)	0.133
Grade 2	3 (8.6)	6 (19.4)	
Grade 3	0	3 (9.7)	
Grade 4	2 (5.7)	0	
Hospital stay (day) median (IQR)	2 (1-3)	2 (1-8)	0.335

Bold values indicate statistically significant results
BMI: Body mass index, CCI: Charlson Comorbidity Index, DAP: Dose-area product, DJ: Double-J stent, IQR: Interquartile range, mGy: Milligray, min: Minute, mm: Milimeter, sec: Second

Table 3. Comparison of holmium and thulium laser for <3 cm stones			
	Group 1 (n=9)	**Group 2 (n=11)**	**p-value**
Age (years), median (IQR)	59 (50.5-69.5)	53 (39-66)	0.268
Sex (male/female), n (%)	7/2 (77.8/22.2)	6/5 (54.5/45.5)	0.272
BMI (kg/m^2), median (IQR)	26.88 (24.41-29.86)	27.68 (26.54-35.26)	0.427
CCI, median (IQR)	0 (0-1)	2 (0-2)	0.189
Stone diameter (mm), median (IQR)	35 (31-40)	32 (31-35)	0.376
Stone location, n (%)			
Renal pelvis	4 (44.4)	8 (72.7)	0.502
Upper pole	1 (11.1)	0	
Middle pole	3 (33.3)	2 (18.2)	
Lower pole	1 (11.1)	1 (9.1)	
Stone density (Hounsfield unit), median (IQR)	1300 (971.5-1584.5)	1216 (935-1440)	0.47
Lasing time (sec), median (IQR)	2156.5 (1741-2675.5)	1683.5 (934.25-2951)	0.438
Lasing energy (Joule), median (IQR)	81.25 (54.7-122.21)	95.5 (57.5-147)	0.657
Radiation time (sec), median (IQR)	123.5 (37.5-164.5)	93 (58.75-110.75)	0.83
Fluoroscopy energy (mGy), median (IQR)	20.5 (9.75-37.75)	39.01 (9.5-54.25)	0.451
Fluoroscopy energy (DAP), median (IQR)	5.8 (4.2-21.25)	7.38 (2.88-10.25)	0.667
Operation time (min), median (IQR)	140 (120-190)	150 (120-176)	0.818
Exit strategy (DJ/nephrostomy), n (%)	9/0 (100/0)	9/2 (81.8/18.2)	0.289
∆Haemoglobin, median (IQR)	0.4 (0-2.45)	1.5 (0.3-2.4)	0.403
∆Creatinine, median (IQR)	0.01 (-0.065-0.085)	0.02 (-0.16-0.11)	0.76
Stone Free rate, n (%)	9 (100)	11 (100)	-
Blood transfusion, n (%)	0	1 (9.1)	0.55
Intensive care unit necessary, n (%)	0	1 (9.1)	0.55
Clavien-Dindo classification, n (%)			
Grade 1	0	0	0.648
Grade 2	0	0	
Grade 3	1 (11.1)	1 (9.1)	
Grade 4	0	1 (9.1)	
Hospital stay (day), median (IQR)	2 (2-3)	2 (2-5)	0.901
BMI: Body mass index, CCI: Charlson Comorbidity Index, DAP: Dose-area product, DJ: Double-J stent, IQR: Interquartile range, mGy: Milligray, min: Minute, mm: Milimeter, sec: Second			

Overall, both Ho:YAG and TFL lithotripsy demonstrated comparable efficacy and safety in mini-PCNL procedures. The TFL was associated with a slightly lower radiation exposure in smaller stones and a marginally higher postoperative creatinine increase, but without a clinically significant difference in outcomes.

Discussion

In the present study, we compared the efficacy and safety of the Ho:YAG and TFL systems in patients undergoing mini-PCNL. Both modalities demonstrated comparable operative durations, laser times, haemoglobin decreases, lengths of hospital stay, and complication rates. The stone-free rate did not differ significantly between the groups. However, a statistically significant yet clinically minor postoperative increase in serum creatinine was observed in the TFL group. Although the absolute change was small and clinically insignificant, several mechanisms may explain this finding. We believe that differences in irrigation dynamics and intrarenal pressure during lithotripsy may play a role. TFL is typically used with higher frequencies and longer lasing durations, which may require sustained irrigation and potentially lead to transient increases in intrarenal pressure. Elevated intrarenal pressure has been associated with temporary impairment in renal function due to pyelovenous and pyelolymphatic backflow. In addition, the higher ablation efficiency and finer dusting characteristics of TFL may increase particulate load within the collecting system, potentially causing transient tubular stress or micro-level obstruction.

Therefore, the observed difference in our cohort is more likely to reflect procedural and perioperative factors rather than a direct detrimental effect of the TFL itself. Future studies incorporating real-time intrarenal pressure monitoring and standardized laser settings would be valuable to better elucidate this association.

In the subgroup analysis of stones <3 cm, the TFL group exhibited significantly lower fluoroscopy DAP, suggesting that TFL may reduce radiation exposure during procedures for smaller stones. In the subgroup of patients with stones <3 cm, stone-free rates were higher in the TFL group, although the difference was not statistically significant. Several factors may explain this finding. First, the relatively small sample size in this subgroup limits the statistical power to detect modest differences between the two laser modalities. Second, while TFL has been shown in previous studies to provide superior dusting and reduced retropulsion, these technical advantages may be more pronounced during ureteroscopic procedures than during PCNL, in which active fragment extraction plays a major role. This may explain why, despite its theoretical advantages, TFL did not translate into a significantly higher stone-free rate in our cohort. Finally, variability in stone composition and hardness, which was not systematically analysed in our study, may also have influenced fragmentation efficiency and final clearance rates. These findings are consistent with existing literature suggesting comparable clinical success rates between Ho:YAG and TFL despite differences in laser physics and fragmentation characteristics. In light of these results, we believe that both laser platforms can be safely and effectively used in mini-PCNL for small and large stone burdens, with broadly similar surgical outcomes and postoperative complication profiles.

A review of the existing literature identified several studies that, as in our work compare different lithotripsy modalities with respect to efficacy and complication rates in mini-PCNL and other endourological procedures. Shubham et al. (10) conducted a large comparative mini-PCNL study in which patients were treated with Ho:YAG, TFL, or a pneumatic lithotripter, and reported comparable stone-free and complication rates between all three groups, with a tendency toward shorter operative time in the TFL arm. Similar to our findings, they showed that both Ho:YAG and TFL are safe and effective options in a mini-PCNL setting. In contrast to our findings, TFL in their cohort was associated with a more pronounced reduction in operative time. This discrepancy may be related to differences in sample size and study design. Shubham et al. (10) analysed a larger population and included a third treatment arm (pneumatic lithotripsy), which may have increased the power to detect modest differences in efficiency. Furthermore, their results may reflect centres with greater experience in optimizing TFL settings, where reduced retropulsion, higher ablation rates, and thinner fibres could facilitate faster stone clearance. In our series, the absence of a significant difference in operative time between lasers may, in part, be explained by the relatively limited sample size, heterogeneity in stone characteristics, and potential variability in surgeon experience with TFL.

In a prospective randomized trial specifically designed to compare TFL and Ho:YAG in the mini-PCNL setting, Mahajan and Mahajan (11) reported that TFL achieved significantly shorter stone disintegration times while maintaining similar overall operative times, stone-free rates, and complication profiles compared with Ho:YAG. In line with our results, their study supports the view that both lasers are clinically equivalent in terms of safety and success, but that TFL may offer technical advantages with respect to stone fragmentation. Unlike our retrospective design, their randomized methodology and larger sample size allowed a more detailed analysis of laser-efficiency endpoints, such as pure disintegration time. The lack of a measurable operative-time advantage for TFL in our cohort, despite similar technological properties, may therefore be attributable to non-laser factors that contribute substantially to total procedure duration in mini-PCNL (e.g., access creation, tract dilation) and could overshadow modest differences in lithotripsy speed.

From a broader endourological perspective, several ureteroscopic series have also compared TFL with Ho:YAG. Ulvik et al. (12) and subsequent prospective studies have shown that TFL can achieve higher or at least non-inferior stone-free rates, shorter laser activation times, and comparable or lower complication rates during ureteroscopic treatment of ureteral and renal stones. These URS data, consistent with our findings in mini-PCNL, suggest that TFL does not compromise safety and may improve lithotripsy efficiency. In contrast to some of these studies, we did not demonstrate a clear superiority of TFL in terms of stone-free rates, which may again be attributable to differences in stone burden, access route, and the relative contribution of non-lithotripsy steps to total operative time in mini-PCNL. Nevertheless, the comparable stone-free and complication rates observed in our study reinforce the concept that, in terms of clinical outcomes, both Ho:YAG and TFL are appropriate energy sources in contemporary endourological practice.

Our finding of a significantly lower DAP in the TFL group for stones <3 cm is noteworthy, as it aligns with the growing emphasis on radiation reduction strategies in stone surgery. Prior work has demonstrated that modifications such as pulsed fluoroscopy, ultrasound-guided access, and protocol optimization can substantially decrease radiation exposure during URS and PCNL (13). Some ureteroscopic series have suggested that more efficient lithotripsy techniques, including TFL-based protocols, may indirectly shorten fluoroscopy time and reduce dose (5,13). In our cohort, the lower DAP observed for small stones treated with TFL may similarly reflect faster fragmentation, a reduced need for repeated fluoroscopic checks, or greater operator confidence in endoscopic rather than fluoroscopic guidance. Although we did not record surgeon radiation exposure or fluoroscopy time separately, the reduction in DAP is relevant to the "as low as reasonably achievable" principle and suggests that TFL could contribute to radiation-sparing mini-PCNL strategies, particularly in patients with limited stone burden.

The modest but statistically significant postoperative change in creatinine in the TFL group in our study warrants comment. Prior multicentre analyses of mini-PCNL have generally reported only minor and transient changes in renal function, irrespective of the energy source used (14). Our data are in line with this overall pattern, and the absolute magnitude of creatinine change remains small and clinically negligible. Although our study cannot definitively attribute this difference to the laser type, it is conceivable that subtle variations in intrarenal pressure, irrigation flow, or thermal profile between systems could contribute to transient changes in renal function. Future studies incorporating standardised intraoperative pressure monitoring, detailed documentation of laser settings, and longer-term renal follow-up would help clarify whether the observed difference is purely statistical or physiologically relevant.

Beyond laser technology itself, recent work has increasingly focused on integrating artificial intelligence (AI) and machine learning (ML) approaches into PCNL to predict stone-free status, complications, and operative time based on preoperative imaging and clinical variables (15,16). Several groups have developed ML models that outperform traditional scoring systems such as Guy's Stone Score and the S.T.O.N.E. score in predicting stone-free outcomes, whereas others have created algorithms to estimate complication risk and hospitalisation needs after PCNL (17). Although these models do not yet routinely incorporate laser type as an input variable, they illustrate an emerging paradigm in which individualised risk prediction and procedural planning may be enhanced by AI. In this context, future studies could explore whether the choice between Ho:YAG and TFL, combined with detailed stone and patient characteristics, can be integrated into predictive models to refine patient selection for mini-PCNL and optimise perioperative management.

Study Limitations

The present study has several limitations. Its retrospective design may have introduced selection bias, and the single-centre setting may limit the generalisability of our findings. The sample size, particularly for patients with stones >3 cm, was relatively small, reducing the statistical power of subgroup analyses. Furthermore, stone composition and long-term recurrence data were not evaluated, and intraoperative parameters such as intrarenal pressure and detailed laser settings were not systematically recorded. Prospective, multicentre studies with larger patient populations, standardised laser protocols, and extended functional follow-up are needed to confirm our results and better define the impact of laser type on long-term renal outcomes.

Conclusion

Both Ho:YAG and TFL demonstrate comparable safety and efficacy in mini-PCNL, with similar stone-free and complication rates. TFL may reduce radiation exposure for smaller stones, while showing a statistically significant but clinically negligible increase in postoperative creatinine. Overall, both energy sources can be safely used in mini-PCNL, and the choice of laser may be guided by institutional availability and surgeon preference.

Ethics

Ethics Committee Approval: Ethical approval was obtained from the Marmara University Faculty of Medicine, Drug and Non-Medical Device Research Ethics Committee (approval number: 09.2025.25-0732, date: 05.09.2025).

Informed Consent: Because the study was designed retrospectively no written informed consent form was obtained from the patients.

Footnotes

Authorship Contributions

Surgical and Medical Practices: E.G., Concept: E.G., G.Ö., T.E.Ş., Design: E.G., G.Ö., T.E.Ş., Data Collection or Processing: E.G., T.A., A.V.B., K.D., Analysis or Interpretation: E.G., T.A., A.V.B., K.D., Literature Search: E.G., T.A., Writing: E.G., T.A., A.V.B., K.D., G.Ö., T.E.Ş.

Conflict of Interest: No conflict of interest was declared by the authors.

Financial Disclosure: The authors declared that this study received no financial support.

References

1. Sorokin I, Mamoulakis C, Miyazawa K, Rodgers A, Talati J, Lotan Y. Epidemiology of stone disease across the world. World J Urol. 2017;35:1301-1320. [Crossref]
2. Türk C, Petřík A, Sarica K, Seitz C, Skolarikos A, Straub M, Knoll T. EAU Guidelines on interventional treatment for urolithiasis. Eur Urol. 2016;69:475-482. [Crossref]
3. Knoll T, Buchholz N, Wendt-Nordahl G. Extracorporeal shockwave lithotripsy vs. percutaneous nephrolithotomy vs. flexible ureterorenoscopy for lower-pole stones. Arab J Urol. 2012;10:336-341. [Crossref]
4. Candela L, Keller EX, Pietropaolo A, Esperto F, Juliebø-Jones P, Emiliani E, De Coninck V, Tailly T, Talso M, Tonyali S, Sener ET, Hameed BMZ, Tzelves L, Mykoniatis I, Tsaturyan A, Salonia A, Ventimiglia E. New technologies in

endourology and laser lithotripsy: the need for evidence in comprehensive clinical settings. J Clin Med. 2023;12:5709. [Crossref]

5. Taratkin M, Azilgareeva C, Petov V, Morozov A, Ali S, Babaevskaya D, De Coninck V, Korolev D, Akopyan G, Scoffone CM, Chinenov D, Androsov A, Fajkovic H, Lifshitz D, Traxer O, Enikeev D. Thulium fiber laser vs Ho:YAG in RIRS: a prospective randomized clinical trial assessing the efficacy of lasers and different fiber diameters (150 µm and 200 µm). World J Urol. 2023;41:3705-3711. [Crossref]

6. Chua ME, Bobrowski A, Ahmad I, Kim JK, Silangcruz JM, Rickard M, Lorenzo A, Lee JY. Thulium fibre laser vs holmium: yttrium-aluminium-garnet laser lithotripsy for urolithiasis: meta-analysis of clinical studies. BJU Int. 2023;131:383-394. [Crossref]

7. Kozubaev B, Oguz Demirdogen S, Aksakalli T, Ozkaya F, Adanur S. Comparison of thulium fiber laser and holmium:YAG laser lithotripsy in retrograde intrarenal surgery for kidney Stone treatment: a randomized prospective study. Actas Urol Esp (Engl Ed). 2025;49:501808. English, Spanish. [Crossref]

8. Dindo D, Demartines N, Clavien PA. Classification of surgical complications: a new proposal with evaluation in a cohort of 6336 patients and results of a survey. Ann Surg. 2004;240:205-213. [Crossref]

9. Ozgur G, Gokmen E, Tanidir Y, Cam K, Sener TE. Surgical success and predictive factors for residual stones following supine percutaneous nephrolithotomy in the Galdakao-modified Valdivia position. Medeni Med J. 2025;40:217-225. [Crossref]

10. Shubham N, Kumar U, Singh Y, Trivedi S, Kumar L, Srivastava A, Data S, Baliyan A, Gopal Bhardwaj M. Comparative analysis of the thulium fiber laser, holmium: YAG laser, and pneumatic lithotripter in mini-percutaneous nephrolithotomy: a tertiary care center experience. Cureus. 2025;17:e93209. [Crossref]

11. Mahajan AD, Mahajan SA. Thulium fiber laser versus holmium:yttrium aluminum garnet laser for stone lithotripsy during mini-percutaneous nephrolithotomy: a prospective randomized trial. Indian J Urol. 2022;38:42-47. [Crossref]

12. Ulvik Ø, Æsøy MS, Juliebø-Jones P, Gjengstø P, Beisland C. Thulium Fibre Laser versus Holmium:YAG for Ureteroscopic Lithotripsy: Outcomes from a Prospective Randomised Clinical Trial. Eur Urol. 2022;82:73-79. [Crossref]

13. Gan Q, Li J, Zhai G, Liu B, Qin Y, Tan S, Wang W, Zeng Q. Expanding urolithiasis treatment: comparison of super pulsed thulium laser and holmium:YAG laser for ureteral stone management. Eur J Med Res. 2025;30:379. [Crossref]

14. Jones P, Beisland C, Ulvik Ø. Current status of thulium fibre laser lithotripsy: an up-to-date review. BJU Int. 2021;128:531-538. [Crossref]

15. Zhao H, Li W, Li J, Li L, Wang H, Guo J. Predicting the stone-free status of percutaneous nephrolithotomy with the machine learning system: comparative analysis with Guy's stone score and the S.T.O.N.E score system. Front Mol Biosci. 2022;9:880291. [Crossref]

16. Zou XC, Luo CW, Yuan RM, Jin MN, Zeng T, Chao HC. Develop a radiomics-based machine learning model to predict the stone-free rate post-percutaneous nephrolithotomy. Urolithiasis. 2024;52:64. [Crossref]

17. Ali M, Nzekwue C, Moseley E, Singh S, Vinoo A, Ajzajian J. A comparative evaluation of holmium:YAG and thulium fiber lasers in urinary stone treatment. Cureus. 2025;17:e89491. [Crossref]