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TOPIC PAPER

A historical comparison of thulium fiber laser systems for stone lithotripsy: navigating toward safe and effective parameters

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Abstract

Introduction and objectives Medical device companies have introduced new TFL machines, including Soltive (Olympus, Japan), Fiber Dust (Quanta System, Italy), and TFLDrive (Coloplast, France). The primary objective of this study is to compare our initial clinical experiences with TFL using those devices. Through this historical comparison of Thulium Fiber Laser systems for stone lithotripsy, we aim to advance our understanding and approach toward achieving safe and effective TFL parameters.

Materials and methods The data for this comparative analysis were extracted from three distinct prospective series that were previously published, outlining our initial clinical experience with the Soltive (Olympus, Japan), FiberDust laser (Quanta System, Italy), and TFLDrive laser (Coloplast, France). Parameters such as stone size, stone density, laser-on time (LOT), and laser settings were meticulously recorded. Additionally, we assessed critical variables such as ablation speed (expressed in mm^3/s) and $Joules/mm^3$ for each lithotripsy procedure.

Results A total of 149 patients were enrolled in this study. Among them, 120 patients were subjected to analysis concerning renal stones. Statistically significant differences were observed in the median (IQR) stone volume: 650 (127–6027) mm^3 for TFLDrive, 1800 (682.8–2760) mm^3 for Soltive, and 1125 (294–4000) mm^3 for FiberDust (p: 0.007); while there were no differences regarding stone density among the groups. Significant variations were identified in median (IQR) pulse energy, frequency, and total power. The Soltive group exhibited lower energy levels (0.3 J vs. 0.6 J, p: 0.002) but significantly higher pulse frequency (100 Hz vs. 17.5 Hz, p: 0.003) and total power (24 W vs. 11W, p: 0.001) compared to the other groups. Laser-on time showed no substantial differences across all three groups. Additionally, a statistically significant difference was observed in median J/mm3, with the TFLDrive group using higher values (24 J/mm3, p: 0.001), while the Soltive group demonstrated a higher median ablation speed of 1.16 mm3/s (p: 0.001). The overall complication rate remained low for all groups, with comparable stone-free rates.

Conclusion By reducing pulsed frequency, we improved laser efficiency, but smaller volumes lead to decreased efficiency due to increased retropulsion and fragment movement. Further studies are needed to identify and establish the appropriate laser settings for this new technology.

Keywords TFL · Laser lithotripsy · Renal stones · RIRS · f-URS · Dusting

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Introduction

The evolution of laser technology in urology has spanned several decades, beginning in the 90 s [1]. A novel addition to this field is the thulium fiber laser (TFL), introduced as a promising alternative to the established gold standard for urinary stone lithotripsy: the Holmium: YAG (Ho:YAG) laser. The Ho:YAG laser set its position as the definitive choice for urinary stone lithotripsy, supported by over two decades of clinical application [2]. During this period, the efficacy and safety of the Ho:YAG laser were demonstrated across various types of stones [3]. However, the pursuit of a safer and more efficient option sparked the emergence of the TFL [4].

Recent years have witnessed numerous research groups exploring the efficacy of TFL, establishing its superiority in in-vitro performance compared to the Ho:YAG laser [5–7]. This superiority includes more efficient lithotripsy in dusting modes, stone ablation speeds increased by 1.5 to 4 times, and improved resistance against stone retropulsion [5]. Similar findings are reported in in-vivo studies, particularly following a randomized trial published in 2022 [8].

Our study aims to assess the effectiveness, safety, and optimal laser parameters of TFL in the context of laser lithotripsy during retrograde intrarenal surgery (RIRS). We compare our initial clinical experiences with TFL using three different systems: Soltive (Olympus, Japan), Fiber Dust (Quanta System, Italy), and TFLDrive (Coloplast, France) [9–11]. The focus of our investigation lies in evaluating their efficacy and performance for the treatment of renal stones. Through this historical comparison of Thulium Fiber Laser systems for stone lithotripsy, we aim to advance our understanding and approach toward achieving safe and effective TFL parameters.

Materials and methods

Study population

This study aimed to compare our initial experiences with various types of lasers used for urinary stone dusting. To achieve this objective, we drew upon data from three distinct prospective series, previously published [8–10]. The patient assignment to the three laser groups was not randomized; rather, it was based on the temporal inclusion of patients in the studies: the first series was published in 2021 using Soltive laser (Olympus, Japan) [8], the second in 2022 by FiberDust laser (Quanta, Italy) [9], and the third in 2023 by TFLDrive laser (Coloplast, France) [10]. Each of these series encompassed 50 patients afflicted with ureteral and renal stones. Only patients with renal stones were included in the analysis.

A CT scan was available for stone volume calculation, utilizing an ellipsoid formula (4/3 × π × radius length × radius width × radius depth). For cases missing CT scan, stone volume was determined from an abdominal X-ray before lithotripsy, using antero-posterior and lateral images with the same formula. Stone density was ascertained using Hounsfield units (HU), derived from an average of multiple points within the region of interest. All patients underwent general anaesthesia. RIRS was carried out using a flexible digital reusable ureteroscope, the Flex—Xc (Karl Storz, Germany), with a consistent 0.9% saline irrigation pressure (40 cm H2O) at ambient temperature, facilitated by a manual pump (Traxerflow Dual Port, Rocamed, Monaco). An experienced endourologist (OT) performed all interventions.

Operative settings

We prospectively gathered data on laser parameters employed during the procedures from patients' medical records and the original publications. This included parameters like stone size, stone density, laser-on time (LOT), and laser settings, all meticulously documented. The initial laser settings were not standardized across all lasers and evolved over the course of the three distinct prospective series based on stone ablation and efficiency results. Crucial variables such as ablation speed (expressed in mm^3/s), and Joules/mm^3 for each lithotripsy procedure were assessed. The study also documented the overall success rate of stone fragmentation by stone free rate and post-procedural complications according to Clavien-Dindo classification.

Statistical analysis

Descriptive statistics were employed to summarize the demographic and clinical characteristics of the study cohort. Continuous variables were presented as medians with interquartile ranges, while categorical variables were expressed as percentages. Statistical analysis was conducted to compare differences between the three laser groups in terms of laser parameters, efficiency, ablation speed, and clinical outcomes. Appropriate statistical tests, including ANOVA and the Bonferroni test, were utilized for data analysis. The findings were analysed using SPSS version 25.0 (SPSS, Chicago, IL, USA).

Results

A total of 149 patients were included in this study. Among these, 120 patients exclusively presented with renal stones and were included in the analysis. Out of these, 41, 40, and

39 patients underwent treatment using the Soltive, FiberDust, and TFLDrive devices, respectively. Demographic details of the study population and a summary of stone characteristics are provided in Table 1. No statistically significant differences were observed in terms of sex, age, and BMI across the three groups. However, a statistically significant difference was identified in the median (IQR) stone volume: 1800 (682.8–2760) mm^3 for Soltive, 1125 (294–4000) mm^3 for FiberDust and 650 (127–6027) mm^3 for TFLDrive (*p* value: 0.007). Further analysis indicated that these differences were attributed to smaller stone sizes in the TFLDrive series. Notably, 50% of the series presented single stones, except for the FiberDust group where up to 62.5% of renal stones were single. Stone density demonstrated no significant variations among the groups.

TFL outcomes are comprehensively outlined in Table 2. Considerable variations were observed in median (IQR) pulse energy, frequency, and total power. Specifically, the Soltive group exhibited lower energy levels (0.3 J, *p* value: 0.002), yet significantly higher pulse frequency (100 Hz, *p* value: 0.003), and total power (24 W, *p* value: 0.001) compared to the other groups. Short pulse were employed in all cases, except for 9 instances within the Soltive series where medium and long pulse durations were used in 7 and 2 cases, respectively. The median LOT demonstrated negligible differences across all three groups, with an average of 23 min. Furthermore, a statistically significant distinction was observed in the median (IQR) energy requirement for ablating 1 mm3 of stone volume. The TFLDrive group used higher values (24 J/mm3, *p* value: 0.001), while the Soltive group exhibited a higher median ablation speed of 1.16 mm3/s (*p* value < 0.001) (Table 2).

Significantly, the overall complication rate, evaluated using the Clavien-Dindo Classification, remained similar and consistently low across all groups, with only Clavien grades I and II observed (Table 3). Successful dusting was achieved in all cases, with comparable stone-free rates assessed at 8 weeks through either no-contrast CT scan control or ultrasonography plus X-ray evaluation.

Table 1 Demographics of study population and stone characteristics

	Renal stones (Olympus) January 2021	Renal stones (Quanta) July 2022	Renal Stones (Coloplast) July 2023	*p*
Total patients (*n*)	41	40	39	0,4
Male adult, *n* (%)	23 (56.1%)	24 (60%)	21 (53.8%)	0,4
Female adult, *n* (%)	18 (43.9%)	16 (40%)	18 (46.1%)	0,28
Age (Median (IQR), years)	55 (44–61.5)	56 (5–065)	49 (15–81)	0,31
BMI (Median (IQR), kg/m2)	25.6 (22–28.7)	25.5 (22–28.4)	24.5 (18–51)	0,77
Stone volume (Median (IQR), mm^3)	1800 (682.8–2760)	1125 (294–4000)	650 (127–6027)	0,007*
Stone density (Median (IQR), HU)	1200 (750–1300)	950 (725–1125)	1000 (376–2000)	0,184
Number of stones				
1, *n* (%)	21 (51%)	25 (62.5%)	20 (51,28%)	0,03*
1 +, *n* (%)	20 (49%)	15 (37.5%)	19 (48,7%)	

BMI Body Mass Index, *HU* Hounsfield Units

Table 2 TFL study outcomes and peri-operatory results

	Renal stones (Olympus)	Renal stones (Quanta)	Renal Stones (Coloplast)	*p*
Pulse energy (Median (IQR), J)	0.3 (0.2–0.6)	0.6 (0.5 – 0.9)	0.6 (0.4–1.2)	0,002*
Pulse frequency (Median (IQR), Hz)	100 (50–180)	15 (10–20)	20 (10–30)	0,003*
Power (Median (IQR), W)	24 (20–32)	10 (7.75–15)	12 (6–20)	0,001*
Short pulse, *n* (%)	32 (78%)	40 (100%)	39 (100%)	
Laser on time (Median (IQR), min)	23 (14.2–38.7)	26.38 (17–57.1)	20 (4.03–100)	0,622
J/mm3 (median (IQR, J/mm3)	18.6 (9.5–26.1)	14.3 (7.8–24.7)	23.7 (3.92–72.70)	0,001*
Ablation speed (Median (IQR), mm3/s)	1.16 (0.8–2.1)	0.7 (0.4–1.2)	0.51 (0.19–2.17)	0,001*
SFR	20	30	31	0,067

SFR Stone Free Rate

Table 3 Clavien Dindo Classification > 30 days

Complications (Clavien-Dindo)	Renal stones (Olympus)	Renal stones (Quanta)	Renal stones (Coloplast)
Grade 1, *n* (%)	39 (95%)	37 (92.5%)	35 (90%)
Grade 2, *n* (%)	2 (5%)	3 (7.5%)	4 (10%)
Grade > 2, *n* (%)	0 (0%)	0 (0%)	0 (0%)

Discussion

Numerous preclinical and clinical investigations have demonstrated the TFL's precision, safety, and efficacy in the domain of laser lithotripsy, thus positioning it as a contender to the Ho:YAG laser technology [5–8]. Nonetheless, owing to its novelty, the attainment of optimal and safe laser settings is a subject of concern. The influence of the learning curve inherent to this emerging technology on the selection of optimal settings should be taken into consideration, particularly given the temporal gap among the analysed studies. During the initial introduction of TFL, in the absence of clinical evidence, key opinion leaders advocated maximizing pulse frequency for faster dusting [12]. Consequently, the Soltive series focused primarily on high-frequency settings. Increasing pulse frequency did not reduce surgical time, but rather resulted in a decrease in effectiveness, accompanied by energy loss into the surrounding tissue, which presents a danger due to both direct and indirect thermal lesions [6, 13, 14]. The achievement of efficient stone ablation while mitigating tissue damage requires fine-tuning of laser parameters such as pulse energy and pulse frequency.

TFL employs selective photothermolysis to realize precise and controlled tissue ablation in urinary stone treatment [15]. This targeted absorption generates heat and mechanical effects that result in stone fragmentation. Heightening power yields increased heat generation and elevated temperatures, causing indirect tissue damage [14]. Additionally, elevated pulse rate settings precipitate direct thermal damage via unintentional thermal lasering lesions [6]. These findings prompted the modification of our settings in subsequent series, involving a reduction in both frequency and total power.

Furthermore, the choice of the appropriate pulse modality for laser lithotripsy depends on the inherent features of the laser pulse, the peak power and pulse modulation [16]. During the early stages of our study, when we had limited knowledge about the TFL specific features, we occasionally opted for medium and long pulse settings. This decision was partly driven by extrapolations from the established Ho:YAG laser applications [17]. However, as our experience with the Soltive laser deepened, we discovered that the extension of pulse length inadvertently diminished the critical peak power required for effective stone fragmentation. This unintended consequence often resulted in carbonization rather than the desired fragmentation effect [18]. Hence, our initial use of medium and long pulses with the Soltive laser reflected a reliance on analogies from Ho:YAG lasers, but over time, we recognized the need to adapt and refine our approach based on the Soltive laser's unique attributes.

The optimal combination of these parameters can vary based on factors such as stone composition, size, and location, patient anatomy, endoscopic vision, and surgical skills. It's important to note that there isn't a standard value for laser settings. Instead, there is a safety range that we adjusted according to stone and patient characteristics based on our experience with stone ablation. These adjustments were made to optimize the balance between efficient stone fragmentation and minimizing collateral tissue damage, recognizing that the optimal settings may vary on a case-by-case basis [19]. As evidenced by our findings, for both the FiberDust and TFLDrive series, pulse energy ranged from 0.6 J to 1.2 J, while pulsed frequency varied from 10 to 30 Hz—which clearly differ from the preceding Solitve series. While efficiency improves with the reduction of pulse frequency between the first and second series, our results revealed the most challenging outcomes in the last series, with a laser efficiency of 23.7 J/mm^3 (range: 3.92–72.70 J/mm^3) and the worst ablation speed 0.51 mm^3/s (range: 0.19–2.17). This could be attributed to the smaller stone fragments at the TFLDrive Serie, which are associated with increased retropulsion, presenting challenges in maintaining efficient stone ablation [20].

The observed variations in laser settings have profound clinical implications on patient outcomes. Incomplete stone fragmentation resulting from suboptimal settings may necessitate additional procedures, consequently extending hospital stays and affecting patient recovery. According to our results, even differences in laser settings between series, no differences were reported in terms of complications and stone free rates. However, ensuring optimal settings is not merely a technical concern; it directly impacts the patient's overall treatment success and post-procedural experience.

There are inherent limitations within our study, encompassing its retrospective nature. Additionally, the study is limited to our institution's experience and may not be fully generalizable to other healthcare settings. Comprehensive randomized controlled trials are requisite to attain more definitive conclusions. We recognize that constrained clinical data, lack of standardized protocols, and the dynamic evolution of TFL technology engender complexity in the pursuit of optimal laser settings. Furthermore, pulse width values are kept confidential by laser manufacturers and are not fixed; each laser device recalculates the pulse width according to its settings to provide the most optimal pulse width. Pulse duration can vary between devices and may impact the results.

Conclusion

The results through this comparative analysis of our initial experiences with the Soltive, FiberDust, and TFLDrive lasers show that reducing frequency can improve laser efficiency. However, when dealing with smaller volumes, there is a noticeable loss of efficiency in fragmenting tiny fragments. This phenomenon contributes to a decrease in overall efficiency and a worse ablation rate. The findings suggest that further research and studies are necessary to identify and establish the appropriate laser settings for this new technology. By understanding the optimal laser parameters, it may be possible to mitigate the challenges associated with smaller stone volumes and enhance the overall efficiency and effectiveness of the procedure.

Authors' contribution AS: manuscript writing. EV: manuscript editing. MC: data analysis, manuscript writing. CS: data management. LC: data management. OT: project development, manuscript editing.

Data availability Not applicable.

Declarations

Conflict of interest The authors declare that they have no conflict of interest.

Research involving human participants and/or animals This research does not involve research in humans or animals.

Informed consent I hereby acknowledge that all participants have been duly informed and are aware that their medical records will be subject to review for the purpose of this study.

References

1. U.S. Corporate News (1988) News from Candela Corporation. Laser Medi Surg News Adv 6(5):24–25
2. Gould DL (1998) Retrograde flexible ureterorenoscopic holmium-YAG laser lithotripsy: the new gold standard. Tech Urol 4(1):22–24 (**PMID: 9568772**)
3. Kronenberg P, Traxer O (2014) In vitro fragmentation efficiency of holmium:yttrium-aluminum-garnet (YAG) laser lithotripsy—a comprehensive study encompassing different frequencies, pulse energies, total power levels and laser fibre diameters. BJU Int 114(2):261–267
4. Traxer O, Keller EX (2020) Thulium fiber laser: the new player for kidney stone treatment? A comparison with Holmium:YAG laser. World J Urol 38(8):1883–1894. https://doi.org/10.1007/s00345-019-02654-5
5. Andreeva V, Vinarov A, Yaroslavsky I, Kovalenko A, Vybornov A, Rapoport L, Enikeev D, Sorokin N, Dymov A, Tsarichenko D et al (2020) Preclinical comparison of superpulse thulium fiber laser and a holmium: YAG laser for lithotripsy. World J Urol 38:497–503
6. Sierra A, Corrales M, Kolvatzis M, Panthier F, Piñero A, Traxer O (2022) Thermal Injury and Laser Efficiency with Holmium YAG and Thulium Fiber Laser-An In Vitro Study. J Endourol 36(12):1599–1606. https://doi.org/10.1089/end.2022.0216. (**PMID: 35793107**)
7. Chua ME, Bobrowski A, Ahmad I, Kim JK, Silangcruz JM, Rickard M, Lorenzo A, Lee JY (2023) Thulium fibre laser vs holmium: yttrium-aluminium-garnet laser lithotripsy for urolithiasis: meta-analysis of clinical studies. BJU Int 131(4):383–394. https://doi.org/10.1111/bju.15921. (**Epub 2022 Nov 23 PMID: 36260370**)
8. Ulvik Ø, Æsøy MS, Juliebø-Jones P, Gjengstø P, Beisland C (2022) Thulium Fibre Laser versus Holmium:YAG for Ureteroscopic Lithotripsy: Outcomes from a Prospective Randomised Clinical Trial. Eur Urol 82(1):73–79. https://doi.org/10.1016/j.eururo.2022.02.027. (**Epub 2022 Mar 14 PMID: 35300888**)
9. Corrales M, Traxer O (2021) Initial clinical experience with the new thulium fiber laser: first 50 cases. World J Urol 39(10):3945–3950. https://doi.org/10.1007/s00345-021-03616-6. (**Epub 2021 Feb 15 PMID: 33590280**)
10. Sierra A, Corrales M, Kolvatzis M, Traxer O (2022) Initial clinical experience with the thulium fiber laser from Quanta System: First 50 reported cases. World J Urol 40(10):2549–2553. https://doi.org/10.1007/s00345-022-04096-y. (**Epub 2022 Jul 21 PMID: 35861860**)
11. Catalina Solano et al. Initial experience with the Graphical User Interface for laser parameters setting of a new Thulium fiber laser source device for urinary pathologies treatment. Peer review
12. Sierra A, Corrales M, Piñero A, Traxer O (2022) Thulium fiber laser pre-settings during ureterorenoscopy: Twitter's experts' recommendations. World J Urol 40(6):1529–1535. https://doi.org/10.1007/s00345-022-03966-9. (**Epub 2022 Mar 4 PMID: 35246704**)
13. Æsøy MS, Juliebø-Jones P, Beisland C, Ulvik Ø (2022) Temperature profiles during ureteroscopy with thulium fiber laser and holmium:YAG laser: Findings from a pre-clinical study. Scand J Urol 56(4):313–319. https://doi.org/10.1080/21681805.2022.2104367. (**Epub 2022 Aug 3 PMID: 35924316**)
14. Peteinaris A, Tsaturyan A, Bravou V, Tatanis V, Faria-Costa G, Pagonis K, Faitatziadis S, Vagionis A, Liatsikos E, Kallidonis P (2023) High-power laser lithotripsy - do we treat or harm? Histological evaluation of temperature effects in an in vivo study with thulium fiber laser. Cent European J Urol 76(1):44–48
15. Taratkin M, Azilgareeva C, Cacciamani GE, Enikeev D (2022) Thulium fiber laser in urology: physics made simple. Curr Opin Urol 32(2):166–172. https://doi.org/10.1097/MOU.0000000000000967. (**PMID: 34954703**)
16. Ventimiglia E, Villa L, Doizi S, Briganti A, Proietti S, Giusti G, Montorsi F, Montanari E, Traxer O, Salonia A (2021) Laser Lithotripsy: The Importance of Peak Power and Pulse Modulation. Eur Urol Focus 7(1):22–25. https://doi.org/10.1016/j.euf.2021.01.012. (**Epub 2021 Jan 30 PMID: 33531287**)
17. Panthier F, Germain T, Gorny C, Berthe L, Doizi S, Traxer O (2021) Laser Fiber Displacement Velocity during Tm-Fiber and Ho:YAG Laser Lithotripsy: Introducing the Concept of Optimal Displacement Velocity. J Clin Med 11(1):181. https://doi.org/10.3390/jcm11010181.PMID:35011922;PMCID:PMC8745998
18. Chan KF, Pfefer TJ, Teichman JMH, Welch AJ (2001) A perspective on laser lithotripsy: the fragmentation processes. J Endourol 15:257–273. https://doi.org/10.1089/089277901750161737
19. Sierra A, Corrales M, Somani B, Traxer O (2022) Laser Efficiency and Laser Safety: Holmium YAG vs. Thulium Fiber Laser J Clin Med 12(1):149. https://doi.org/10.3390/jcm12010149.PMID:36614950;PMCID:PMC9821183

20. Ventimiglia E, Doizi S, Kovalenko A, Andreeva V, Traxer O (2020) Effect of temporal pulse shape on urinary stone phantom retropulsion rate and ablation efficiency using holmium:YAG and super-pulse thulium fibre lasers. BJU Int 126(1):159–167