Lasers

Advantages of p-Tm:YAG over Ho:YAG technology

Over the past few decades, Ho:YAG laser lithotripsy has been established as the gold standard for endoscopic stone treatment due to its safe, efficient, and versatile properties. In the last few years, laser powers have been increased, sophisticated pulse modulation techniques have been invented, and other laser technologies such as Thulium laser lithotripsy have undergone further improvements.

Study: Preclinical comparison of a novel pulsed solid-state Tm: YAG laser versus Ho:YAG technology

Dornier MedTech Laser GmbH (Wessling, Germany) provided an evaluation model of a novel pulsed solid-state Thulium laser (p-Tm:YAG) that should not be confused with a Thulium fiber laser (TFL). All these laser technologies offer different emission wavelengths, which result in different water absorption (see Table 1). The water absorption coefficient of the p-Tm:YAG laser is approximately twofold that of the Ho:YAG laser technology. This results in a lower penetration depth for p-Tm:YAG of about 0.3 mm than the gold standard Ho:YAG technology (~0.4 mm).

Specification	p-Tm:YAG laser	Ho:YAG laser
Wavelength (nm)	2013	2080
Absorption coefficient (1/m)	5888	3198
Penetration depth into biological tissue (mm)	~0.3	~0.4

▲ *Table 1: Comparison of wavelength and absorption coefficients between Ho:YAG laser and p-Tm:YAG laser. Due to the different wavelength-related absorption coefficients, the two laser techniques have different penetration depths.*

An ideal laser for stone treatment has a high stone ablation rate for dusting and fragmentation while having a low retropulsion effect on the stone. By adjusting the laser parameters of pulse energy and pulse frequency, different settings for stone disintegration can be achieved. A combination of low pulse energies and high pulse frequencies dusts stones to very small particles, while high pulse energies and low pulse frequencies enable the fragmentation of stones. Low stone retropulsion is also preferable because high stone retropulsion results in a reduction of the stone ablation rate, increased operative time, and decreased stone-free rates. The emitted laser light generates almost no force since the radiation pressure is negligible. Retropulsion is, therefore, mainly generated by the pressure wave created by a laser-induced gas bubble and released stone fragments.

Objective

This literature review focuses on the novel p-Tm:YAG laser and its performance in preclinical studies about retropulsion, the dusting of stones, gas bubble formation, and temperature development in in-vitro setups.

Research Findings

Author and study title	Year	Key findings and benefits
Petzold, R. et al.[1] Retropulsion force in laser lithotripsy—an in vitro study comparing a Holmium device to a novel pulsed solid-state Thulium laser	2021	The novel p-Tm:YAG laser produced **significantly lower retropulsion forces than the current Ho:YAG laser technology** at the same energy and pulse frequency settings, likely due to p-Tm:YAG's longer pulse lengths. **The p-Tm:YAG laser device offered a long pulse setting that was more advantageous for considerably reducing retropulsion forces** by 7–55% in the tested energy and frequency settings. The potential to combine frequencies up to 200 Hz with low single pulse energies e.g., 100 mJ promised highly efficient dusting with minimal retropulsion. **Significantly lesser retropulsion was detected with the fiber in contact** with the sensor.
Petzold, R. et al.[2] Gas Bubble Anatomy During Laser Lithotripsy: An Experimental In Vitro Study of a Pulsed Solid-State Tm:YAG and Ho:YAG Device	2021	No obvious differences between p-Tm:YAG and Ho:YAG was observed in pulse length-related bubble shape divergences. As for the clinical relevance of the present findings, the authors wished to emphasize the risk of high pulse energies ≥ 1.0 J inside the ureter, as the gas bubble can easily reach the surrounding urothelium, thus risking collateral damage through pressure- and temperature-related damage. **A reduced lateral gas bubble expansion in p-Tm:YAG could possibly lead to lesser collateral damage** to surrounding structures during laser lithotripsy. Furthermore, the authors recommended less frequent laser fiber cutting, as it may shorten operative times without affecting lithotripsy efficiency.
Petzold, R. et al.[3] In Vitro Dusting Performance of a New Solid State Thulium Laser Compared to Holmium Laser Lithotripsy	2021	The additional advantages of longer pulse duration, high frequencies, and low single pulse energies delivered promising results, namely highly efficient fine dusting (particle size below 125 μm). **The p-Tm:YAG laser was clearly superior to the Ho:YAG device, offering longer pulse durations at otherwise similar settings, resulting in lesser retropulsion.** A higher fiber movement speed showed a tendency toward increased ablation effectiveness in p-Tm:YAG. Considering the clinical application, the authors assumed that the new **p-Tm:YAG laser technology will allow a more convenient workflow and reduced operating time,** attributing to the increased range of power and frequency settings that can accommodate the different needs during dusting and fragmenting.
Petzold, R. et al.[4]	2021	When comparing p-Tm:YAG laser with Ho:YAG laser, the authors observed maximum deviations of less than 0.82 K in temperatures at 120 seconds with all

Temperature Assessment of a Novel Pulsed Thulium Solid-State Laser Compared with a Holmium: Yttrium-Aluminum-Garnet Laser

settings. The highest examined laser power of 30 W resulted in a temperature increase of 6.7 K compared to the initial value. Out of the five comparisons, p-Tm:YAG showed significantly lower final temperatures in four cases and a slightly lower cumulative time above 43°C in three cases. The p-Tm:YAG laser resembled Ho:YAG laser device in the temperatures generated during in vitro application. An increase in laser power, thus, led to equivalent increases in temperature. P-Tm:YAG laser and Ho:YAG laser seemed to share a similar risk profile for patients in temperature development.

Conclusion

The four preclinical studies examined the performance of a pulsed solid-state Tm:YAG (p-Tm:YAG) laser in terms of stone retropulsion, fragmentation, dusting, gas bubbles expansion in water, and temperature development in in-vitro settings.

In terms of **retropulsion forces for stone treatments**, a significantly lower retropulsion force of the p-Tm:YAG laser was observed compared to Ho:YAG technology which was most likely related to the longer pulse lengths of the p-Tm:YAG laser. Additionally, significantly lesser retropulsion was detected when the fiber was in contact with the sensor than when the distance between the fiber and the sensor surface was 3 mm. Regarding **gas bubble formation**, no obvious differences between p-Tm:YAG laser and Ho:YAG technology were observed apart from pulse length-related bubble shape divergences. A reduced lateral gas bubble expansion in p-Tm:YAG could possibly lead to lesser collateral damage to surrounding structures during laser lithotripsy. In terms of **dusting performance**, the p-Tm:YAG device significantly outperformed the Ho:YAG device, offering longer pulse durations and thus higher ablation rates of 32% to 54% with otherwise similar settings. The study indicated that the new p-Tm:YAG laser technology will allow a more convenient workflow and reduced operating time attributable to the increased range of power and frequency settings that can accommodate different needs during dusting and fragmenting. Regarding **temperature development**, the p-Tm:YAG laser resembled Ho:YAG laser in the temperatures generated during in vitro application. The p-Tm:YAG laser and Ho:YAG laser seemed to share a similar risk profile for patients in terms of temperature development. However, intrarenal power outputs exceeding 10 W during clinical application should be compensated by ensuring enough irrigation.

Overall, the preclinical results showed that the **p-Tm:YAG technology was performing better than Ho:YAG technology**. This novel p-Tm:YAG laser offered a wide range of adjustable laser settings, longer pulse durations, and a slightly different wavelength than Ho:YAG lasers, which provided several advantages, such as better fragmentation of stones into dust, lower retropulsion of stones, lower lateral expansion of gas bubbles for lesser tissue damage, and higher absorption in water, resulting in lesser penetration of laser light into tissue.

Glossary

p-Tm:YAG: Pulsed Thulium:Yttrium-Aluminum-Garnet Laser

Ho:YAG: Holmium:Yttrium-Aluminum-Garnet Laser

TFL: Thulium Fiber Laser

References

1. Petzold, R. et al. (2021). Retropulsion force in laser lithotripsy—an in vitro study comparing a Holmium device to a novel pulsed solid-state Thulium laser. World J Urol, 39(9):3651–3656. https://doi.org/10.1007/s00345-021-03668-8
2. Petzold, R. et al. (2021). Gas Bubble Anatomy During Laser Lithotripsy: An Experimental In Vitro Study of a Pulsed Solid-State Tm:YAG and Ho:YAG Device. J Endourol, 35(7):1051-1057. https://doi.org/10.1089/end.2020.0526
3. Petzold, R. et al. (2021). In Vitro Dusting Performance of a New Solid State Thulium Laser Compared to Holmium Laser Lithotripsy. J Endourol. 35(2):221-225. https://doi.org/10.1089/end.2020.0525
4. Petzold, R. et al. (2021). Temperature Assessment of a Novel Pulsed Thulium Solid-State Laser Compared with a Holmium:Yttrium-Aluminum-Garnet Laser. J Endourol, 35(6):853-859. https://doi.org/10.1089/end.2020.0803

Manufacturer's note: The pulsed Tm:YAG (p-Tm:YAG) device is now the CE marked Dornier Thulio from Dornier MedTech.