Lasers

Dornier Thulio® dusting ablation efficiency during in vitro lithotripsy of all urinary stone composition types

Urinary stone disease has become increasingly prevalent worldwide. For over three decades, the laser has been established as the mainstay for endourological surgery and lithotripsy. The introduction of novel pulsed thulium:yttrium–aluminum–garnet (p-Tm:YAG) laser technology for clinical use indicates promising results in terms of ablation efficiency. However, existing studies are predominantly based on non-human stone models or stones with unknown composition.

The following two in vitro studies aim to assess ablation efficiency and the resulting particle sizes of the p-Tm:YAG laser (Dornier Thulio®) when used with the seven most common human urinary stone types.

Study 1: Pulsed thulium:YAG laser – ready to dust all urinary stone composition types? Results from a PEARLS analysis[1]

Objective

The study aims to evaluate whether stone dust can be obtained from all prevailing stone composition types using the novel pulsed thulium:YAG (p-Tm:YAG) laser, including analysis of stone particle size after lithotripsy.

Research Method

Human urinary stones of 7 different compositions were subjected to in vitro lithotripsy using a p-Tm:YAG laser with 270 µm silica core fibers (Dornier Thulio®, Dornier MedTech GmbH ®, Wessling, Germany). A cumulative energy of 1000 J was applied to each stone using one of three laser settings: 0.1 J × 100 Hz, 0.4 J × 25 Hz, and 2.0 J × 5 Hz (average power 10 W). Stones were selected to match a volume of approximately 100 to 200 mm^3, were extracted without laser lithotripsy, and had a > 90% degree of purity based on infrared spectroscopy.

To simulate in vivo settings, all stones were submerged in saline for 24 hours before experiments. After lithotripsy, larger remnant fragments were separated from stone dust by evacuating spontaneously floating stone dust, which is done over a 5 mm hole located 1 cm above the bottom of a 60 ml plastic container. There was also constant irrigation over the flexible ureteroscope (40 cmH2O, empty working channel).

Subsequently, fragments and dust samples were then passed through laboratory sieves with mesh size openings of 500 µm, 250 µm, 125 µm, and 63 µm. This is to evaluate stone particle count according to a semiquantitative analysis relying on a previous definition of stone dust (i.e., stone particles ≤ 250 µm).

Research Findings

The p-Tm:YAG laser generated stone dust through lithotripsy down to the smallest mesh size of 63 µm for all seven stone composition types. Notably, regardless of the three laser settings, all dust samples from the seven stone types exhibited a high particle count within the size range consistent with the definition of stone dust, i.e., ≤ 250 µm. A few isolated dust samples displayed a low count of particles > 250 µm. Small stone particles ≤ 250 µm resulting from p-Tm:YAG lithotripsy were found to spontaneously evacuate upon irrigation in the present experimental setup, as prior proved possible with Ho:YAG[2] and TFL[3] studies.

The authors emphasized that the results of this study[1] may be applicable to other p-Tm:YAG lasers operating at a similar wavelength with comparable peak powers and pulse durations. However, p-Tm:YAG lasers from different manufacturers may exhibit variations in their properties and, therefore, require separate evaluations. On the contrary, these findings are not applicable to the Thulium Fiber Laser (TFL), which is a distinct laser technology.

Conclusion

The novel p-Tm: YAG laser (Dornier Thulio®) is capable of dusting all seven common human urinary stone compositions, yielding dust particles of ≤ 250 µm, aligning with the established definition of stone dust. These findings are pivotal for the wider adoption of p-Tm:YAG laser in clinical practice.

Study 2: Pulsed Thulium:YAG laser – What is the lithotripsy ablation efficiency for stone dust from human urinary stones? Results from an in vitro PEARLS study[4]

Objective

The study aims to evaluate the ablation efficiency of p-Tm:YAG laser for stone dust produced from human urinary stones with known compositions.

Research Method

Calcium oxalate monohydrate (COM) and uric acid (UA) stones were obtained from a stone biobank at Tenon Hospital, Paris. These stones were subjected to in vitro lithotripsy using a p-Tm:YAG laser generator with 270 µm silica core fibers (Dornier Thulio®, Dornier MedTech GmbH, Germany). A cumulative energy of 200 J was applied at three different laser settings: 0.1 J × 100 Hz, 0.4 J × 25 Hz, and 2.0 J × 5 Hz (averaging 10W).

To simulate in vivo settings, all stones were immersed in saline for 24 hours before experimentation. Ablated stone dust mass was calculated from the weight difference between pre-lithotripsy stone and post-lithotripsy fragments > 250 µm. The estimated ablated volume was calculated using prior known stone densities (COM: 2.04 mg/mm^3, UA: 1.55 mg/mm^3). The primary outcome was ablation mass efficiency, defined as ablated stone dust mass (i.e., particles ≤ 250 µm) per unit of laser energy (mg/J). The secondary outcome was estimated ablation volume efficiency in terms of ablated volume per unit of energy (mm^3/J).

Research Findings

For each laser setting, the mean ablation mass efficiency was 0.04, 0.06, 0.07 mg/J (COM) and 0.04, 0.05, 0.06 mg/J (UA), respectively, translating to 0.021, 0.029, 0.034 mm^3/J (COM) and 0.026, 0.030, 0.039 mm^3/J (UA). The mean energy consumption was 26, 18, 17 J/mg (COM) and 32, 23, 17 J/mg (UA), and this translated to 53, 37, 34 J/mm^3 (COM) and 50, 36, 26 J/mm^3 (UA). No statistically significant differences were observed for laser settings or stone types (all $p > 0.05$).

The energy consumption was 26.3–53.2 J/mm^3, translating to a laser efficiency of 0.021–0.039 mm^3/J. These measurements fall within a broad range of energy consumption outcomes reported for Ho:YAG and TFL lasers, spanning from 2.0 to 43.5 J/mm^3 in vitro and 2.7 to 47.8 J/mm^3 in vivo.[5] However, direct comparisons of results between these studies seem hazardous, unless standardized lasering conditions and outcome measurement methods are applied. These standards should encompass factors such as stone composition types, volume, density, laser settings, and total energy. Hence, further in vivo studies are warranted to compare ablation efficiency among these three lasers on human urinary stones under the same conditions.

The optimal settings for ablating human urinary stones with the p-Tm:YAG laser is currently unknown. It is interesting to note that there is a non-significant trend indicating better ablation efficiency in the following order: first, with higher pulse energy (2.0 J × 5 Hz), second, with lower pulse energy (0.4 J × 25 Hz) and third, with the lowest pulse energy setting (0.1 J × 100 Hz), which exhibits the poorest ablation efficiency. This trend aligns with prior in vitro studies on evaluation versions of the p-Tm:YAG laser using BegoStone plates, which also found similar findings of increased ablation efficiency when single-pulse energy was increased.[6,7]

COM is generally considered the "harder" stone to ablate compared to UA. Astonishingly, no significant differences in ablation efficiency were found between these two stone types in this study. This is analogous to a recent study[8] where the high-power Ho:YAG MOSES technology was found to ablate stones equally well, independent of stone density or composition type. This desirable attribute requires further evaluation as its potential clinical implications affect the choice of laser and preoperative planning.

Conclusion

The p-Tm:YAG laser (Dornier Thulio®) demonstrates good ablation efficiency for both COM and UA stones, with no statistically significant differences. This showcases that the p-Tm:YAG is able to efficiently dust stones regardless of stone compositions or laser settings. Future research should focus on comparing the p-Tm:YAG laser with other laser technologies and additional urinary stone types.

References

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