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SYMPOSIUM PAPER

Ureteric guidewire damage by Holmium:YAG laser: preliminary results

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Abstract Typically, guidewires are regularly used to provide access or act as a guide during laser lithotripsy. This may result in the tip of the fibre being in close proximity to the guidewire during the firing period and consequently, this could result in accidental damage to the guidewires during the procedure. To replicate this scenario, an experimental model was designed enabling accurate and reproducible positioning of the laser fibre relative to the guidewire. The guidewire was exposed to the laser energy for a range of typical settings used in the clinic. The results demonstrate that the guidewire is susceptible to laser energy damage, especially in close proximity to the fibre.

Keywords Ho:YAG · Lithotripsy · Guidewire · Stone management

Introduction

In endourologic stone management, the Ho:YAG laser is considered the gold standard lithotripter due to its high efficacy and versatility [1]. Energy from a Ho:YAG laser is absorbed significantly by water and results in less tissue penetration compared to energy from a Nd:YAG laser [2]. With a Ho:YAG laser (0.5 J at 10 Hz) it takes 2 s for the beam to perforate the ureter at a distance of 0.5 mm [3].

Typically, laser lithotripsy uses pulse energies of 0.8–1.5 J/pulse and pulse rates of 5–12 Hz [4]. However, depending on the hardness of the stones, a maximum pulse energy of 2.0 J at 10 Hz is sometimes used in clinical practice by the authors. The total energy consumed for stone destruction ranges from 0.12 kJ for a small 5-mm stone to 6.7 kJ for a large 17-mm stone, with an average of 1.5 kJ necessary for all stones [4].

During endoscopic stone treatment, guidewires are routinely used to provide access or act as a safety guidewire over which stents can later be passed. Often the laser is deployed in the immediate vicinity of intra-ureteric wires and baskets [1]. In some cases, the laser is fired directly onto those devices, i.e., for encrusted wire stents or entrapped baskets. Damage to the guidewires or stone removal baskets due to the close proximity of the laser fibre may disrupt, prolong or complicate the endoscopic procedure and require an additional procedure to rectify the problem [5, 6].

The aim of the work was to investigate the damage produced on a 0.038 in. HiWire nitinol guidewire from a Ho:YAG laser at typical energy settings as used in clinical practice.

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Materials and methods

HiWire™ wire guide

The HiWire™ guide has a diameter of 0.038 in. (0.97 mm) and a length of 1.5 m. It consists of a nitinol core, hydrophilic coating and a 30-mm tapered tip. For all experiments, a "HiWire™ Nitinol core wire guide" (HW-038150, Cook Urological, Indiana/USA) was used.

The experimental model

In our model, a Ho:YAG laser (VersaPulse, Coherent Inc., USA) with 250-µs pulses was used. A Perspex® tank (0.45 × 0.45 × 0.16 m) was constructed and filled with 0.9% saline solution and maintained at a physiological 37°C using a thermoregulator (TE-10D, Techne Inc., Burlington, USA). The guidewire was held between two spring loaded retaining blocks (shown as A in Fig. 1) with a self-aligning channel. The 365-µm laser fibre (SureFlex™ LLF365, IQinc, Innova Quartz, Phoenix, USA) was held in a spring loaded retaining block (shown as B in Fig. 1) enabling fine adjustment. Using an eye glass (10× magnification), the fibre was accurately positioned so that it was centrally touching the guide. A thumb screw (shown as C in Fig. 1) provided movement of 1 mm per rotation which enabled the fibre to be positioned with precision control and perpendicular movement relative to the guidewire.

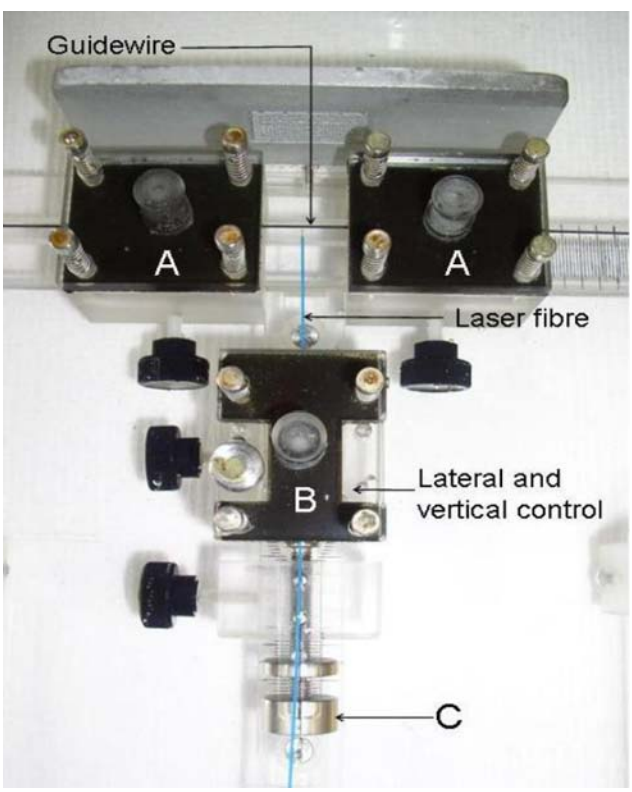


Fig. 1 Removable assembly platform with fibre and guidewire holding devices providing fine adjustment of the fibre in relation to the guidewire

Typical settings used in clinic (pulse energies of 0.5, 1.0 and 2.0 J with a pulse frequency of 10 Hz) were studied to determine the resultant damage on the guidewire. A range of cumulative energies were investigated (0.05, 0.1, 0.2, 0.3, 0.9 and 1.5 kJ) at distances of 0–5 mm between the fibre tip and guidewire.

After each measurement, the guide was moved (5–10 mm) within the holder so the next laser firing measurement was completed on a new section of the guide. The measurement was repeated three times, for each energy setting, cumulative energy and position. After each set of three measurements, the output from the fibre was checked using a Nova II meter with a L50A thermal head (OPHIR, Jerusalem, Israel). The fibre was cleaved when the measured output was ≤75% of the stated laser output and the output re-checked.

The maximum measured output from a newly cleaved fibre was typically ~85% of the stated output of the laser. By checking the output from the laser, consistent and reproducible cumulative energies were achieved. This was especially the case with the fibre positioned close to the guidewire, as the fibre tip regularly became damaged resulting in reduced output from the laser and necessitating cleaving of the fibre.

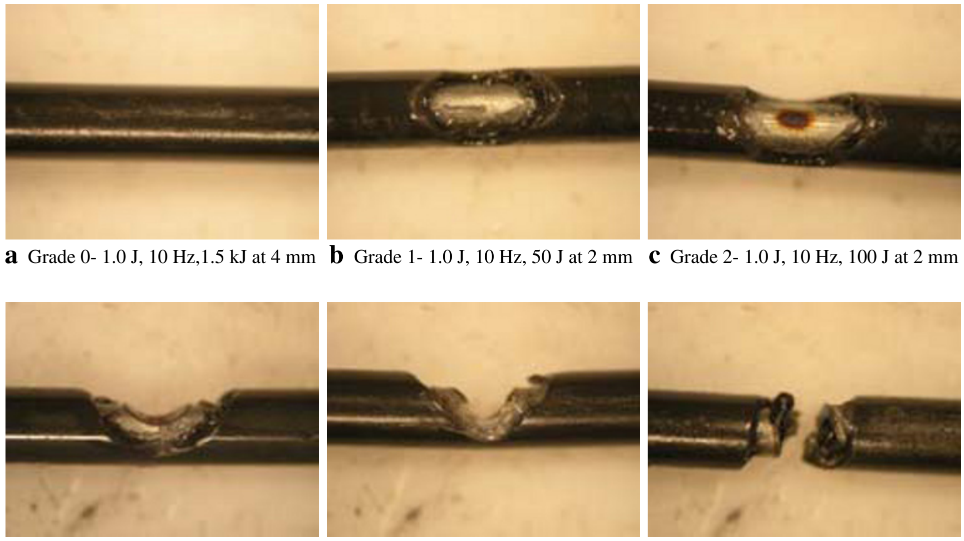
The damage to the guidewire was investigated using a microscope at 60× magnification (SZ61, Olympus, Center Valley, PA, USA), a light source (KL1500, Olympus, Center Valley, PA/USA) and the data recorded using a camera (C-5060, Olympus, Center Valley, PA, USA) mounted on the microscope.

Results

The guidewire damage was quantified as shown in Table 1. Typical results obtained for a range of laser energies used in the clinic are shown in Fig. 2a–f and Tables 2, 3, 4.

Table 1 Grading of resultant damage produced by the laser

Grading	Observed damage	Functionality of guidewire
0	No observed damage	No effect on functionality
1	Damage to sheath/sheath removed from guide	Potential for sections of sheath to be left in patient
2	Charring of core	
3	Damage to core (<50%)	Increased potential for breakage during removal
4	Damage to core (>50%)	
5	Burned through guidewire	Additional procedure to remove distal section of guidewire



a Grade 0- 1.0 J, 10 Hz,1.5 kJ at 4 mm **b** Grade 1- 1.0 J, 10 Hz, 50 J at 2 mm **c** Grade 2- 1.0 J, 10 Hz, 100 J at 2 mm

d Grade 3- 1.0 J, 10 Hz, 100 J at 1mm (sideview) **e** Grade 4- 1.0 J, 10 Hz, 900 J at 1mm (sideview) **f** Grade 5- 2.0 J, 10 Hz, 50 J at 0 mm

Fig. 2 Damage of the guidewire at various laser settings and grading used to quantify the damage

Table 2 0.5 J at 10 Hz for a range for energies

Distance (mm)	Cumulative energy					
	50 J	100 J	200 J	300 J	900 J	1.5 kJ
0	3	3	4	4		
1	3	3	3	3	3	3
2	1	1	1	1	1	1
3					0	0

Table 3 1.0 J at 10 Hz for a range of energies

Distance (mm)	Cumulative energy					
	50 J	100 J	200 J	300 J	900 J	1.5 kJ
0	4	4	4	4		
1	3	3	4	4	4	4–5
2	1	2	2	2	2	3
3	1	1	1	1	1	1
4					0	0

Grades 3, 4 and 5 describe increasing amounts of damage to the nitinol core of the guidewire, which might result in sharp sections that may damage the lumen wall during extraction of the guide.

For all laser settings investigated in this work, substantial damage to the guide core was initiated with distances of 0–1 mm between the tip of the fibre and the guidewire surface. At 2 mm, pulses of 1.0 and 2.0 J resulted in damage to the guidewire core. At 3 mm, there was no observed sheath damage using 0.5-J pulses, but sheath damage was observed with 1.0 and 2.0 J pulses. Increasing the distance to 4 and 5 mm demonstrated no observable effect on the guide at pulse energies of 1.0 and 2.0 J, respectively.

Table 4 2.0 J at 10 Hz for a range of energies

Distance (mm)	Cumulative energy					
	50 J	100 J	200 J	300 J	900 J	1.5 kJ
0	5					
1	3	4	4–5	5		
2	3	3	3	3	3–4	4
3	1	1	1	1	2	1
4	1	1	1	1	1	1
5			0	0	0	0

Discussion

In contact mode, previous authors have investigated the time taken to transect the guide. Using a 365-μm fibre at 0.8 J (5 Hz), the average time to transect a standard 0.035 in. guide was 103 ± 1.5 s, and at 2.0 J (5 Hz), the time of transection was 55 ± 0.6 s [1]. Whilst other authors have investigated the damage produced by a Ho:YAG laser, by firing two pulses for a range of energies and distances [5]. In this paper, the damage created by a Ho:YAG laser to a 0.038-in. nitinol guidewire has been investigated at typical pulse energies used in clinical practice for a range of cumulative energies and distances.

The results demonstrate that the tested guidewire is susceptible to Ho:YAG laser damage even for short firing exposures. Microscopic inspection of the guidewire showed that the damage is dependent on pulse energy, cumulative energy and distance. In contact mode and at 1 mm, the core of the guidewire was damaged at pulse energies and cumulative energies used in clinical practice. Damage to the guidewire was less likely to occur as the distance between the fibre and the guidewire was increased. However, even at moderate pulse energies of 1.0 J at 2–3 mm, the laser energy resulted in damage to the sheath in relatively short firing periods (<10s). When comparing identical cumulative energies, it was observed that greater damage occurred as the energy/pulse was increased.

The work shows that laser energy can result in extensive damage to the guidewire and even in some cases breakage of the guidewire. It should be noted that all experiments were performed using the worst case scenario, i.e. the fibre and guide perpendicular to each other. In contrast, in clinical practice, i.e. during ureteroscopy, the laser is usually parallel to the guidewire. However, the work illustrates that care is necessary to avoid inadvertent contact with the guidewires even for short firing times during stone treatments. Especially during the surgeons' training phase, laser energy might result in damage to the instruments used during the procedure [3].

The advantage of our methodology was that it enabled the fibre to be accurately positioned relative to the guidewire. This was considered to be a shortcoming of previous techniques with potential measurement errors of ± 1 mm [5]. It was estimated that the uncertainties in positioning the fibre in this work, were within ± 0.1 mm.

It was considered that any damage to the central core could weaken the guidewire and result in fracture during removal, especially in tortuous ureters. It is essential to maintain adequate distances between the fibre and the guidewire to prevent or minimise any potential guidewire damage.

Studies are ongoing to test a range of various guidewires and to look at a variety of contact angles between guidewire and laser fibre, all of which may influence the above results.

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