To cite this version :

Mattieu HADDAD, Esteban EMILIANI, Yann ROUCHAUSSE, Frédéric COSTE, Laurent BERTHE, Steeve DOIZI, Salvatore BUTTICÈ, Bhaskar Kumar SOMANI, Olivier P. TRAXER - Impact of laser fiber tip cleavage on power output for ureteroscopy and stone treatment - World Journal of Urology - Vol. Volume 35, Issue 11, p.Pages 1765-1770 - 2017

Impact of laser fiber tip cleavage on power output for ureteroscopy and stone treatment

M. Haddad[1,2,3] · E. Emiliani[2,4] · Y. Rouchausse[3] · F. Coste[3] · L. Berthe[3] · S. Doizi[1,2] · S. Buttice[2,5] · B. Somani[1,2] · O. Traxer[1,2]

Abstract

Purpose Holmium:YAG laser is the most used laser for urolithiasis. Generally, we use metallic scissors to cut the fiber tip to restore its effectiveness. Many cleaving methods have been described to avoid fiber damage and to restore its greatest power to the fiber. There is a lack of information regarding which cleaving method should be used and its effect on the fiber. In order to compare these effects, we studied different cleavage methods in terms of power output and its effects on the fiber.

Methods New single-use 272-µm fibers were used with a holmium:YAG laser lithotripter. Five kinds of fiber tips were compared: a new intact fiber, cleaved with ceramic scissors, cleaved with metallic scissors, first cleaved then stripped and first stripped then cleaved. The fibers were used against synthetic stones (BegoStone®) similar to calcium oxalate monohydrate, with fragmentation (SP, 5 Hz, 1.5 J) and dusting (LP, 15 Hz, 0.5 J) settings. We measured power output at 0, 1, 5, 10 and 15 min.

Results For fragmentation parameters, there was a statistical difference between the 5 groups at 0 and 1 min of laser use ($p < 0.05$) and none for time period over 1 min ($p = 0.077$–0.658). For dusting parameters, there was a statistical difference between the 5 groups at 0 min of laser use ($p < 0.05$) and none for time period over 0 min ($p = 0.064$–1).

Conclusion Cleaving the fiber tip may restore its effectiveness to the fiber, but only for a limited time, although it may preserve the scopes from damage.

Keywords Cleavage tool · Ureteroscopy · Laser · Stone · Endourology · Fiber

Introduction

Holmium:YAG laser is the most used laser for urolithiasis treatment as it can efficiently fragment any type of stone regardless of the composition [1, 2]. During continuous stone lithotripsy the fiber tip may deteriorate due to the “burn-back” effect, which is a result of the thermal and mechanical effect produced when firing the laser against the stone [3].

Several factors have been shown to increase the “burn-back effect” including high energy and short-length pulse settings, treating hard stones or the use of small (<275µm) laser fibers [4, 5]. Many cleaving methods have been described to avoid fiber damage and to restore its effectiveness. This is achieved by cutting the fiber tip systematically, and many cleaving instruments, such as metallic

---

Electronic supplementary material The online version of this article (doi:10.1007/s00345-017-2053-1) contains supplementary material, which is available to authorized users.

✉ O. Traxer
olivier.traxer@aphp.fr

[1] Department of Urology, Tenon Hospital, Assistance-Publique Hôpitaux de Paris, 4 rue de la Chine, 75020 Paris, France

[2] Sorbonne Universités, UPMC Univ Paris 06, AP-HP, GRC n°20, Groupe de Recherche Clinique sur la Lithiase Urinaire, Hôpital Tenon, 4 rue de la Chine, 75020 Paris, France

[3] Process and Engineering in Mechanics and Materials Laboratory (PIMM), UMR CNRS/ENSAM 8006, Paris, France

[4] Department of Urology, Fundacion Puigvert, Universitat Autonoma de Barcelona, Barcelona, Spain

[5] Department of Human Pathology, Section of Urology, University of Messina, Via Consolare Valeria 1, 98125 Messina, Italy

surgical scissors, scalpel, ceramic scissors and/or strippers have been used [5, 6]. The aim of this study was to compare different methods of cleavage in order to improve the efficiency of the laser fibers in endourology.

Materials and methods

New single-use 272-μm fibers (Rocamed®) were used with the MH01-ROCA FTS30W (Rocamed®) lithotripter. Five different kinds of fiber tips were compared: a new fiber (stripped and cleaved by the manufacturer), fiber tip cleaved with ceramic scissors, fiber tip cleaved with metallic scissors, fiber tip first cleaved with ceramic scissors then stripped and fiber tip first stripped then cut with ceramic scissors.

The fibers were fired against a synthetic hard stone BegoStone-Plus (Bego USA, Lincoln, RI, USA) for 15 min. These synthetic stones have the acoustic impedance of calcium oxalate monohydrate-type stones [7, 8]. A robotic arm Staübli-RX90 (Staübli International©, Zurich, Switzerland) was programmed to move the fiber in a straight axis along the stone while firing the laser, with a constant distance of 1 mm between them, at a constant velocity of 1 mm/s.

As described in the literature, two different laser settings were established: fragmentation (1.5 J, 5 Hz and short-pulse) and dusting (0.5 J, 15 Hz and long-pulse) settings [9, 10]. All theoretical powers were set at 7.5 W. We measured power output at 0, 1, 5, 10 and 15 min of lithotripsy with a Molectron EPM1000 wattmeter (Coherent Inc.). Every experiment for each parameter and each kind of fiber tip were repeated three times. Additionally, the fiber tips were analyzed with an optical microscope (Zeiss® AxioCam Imager 2) before and after 1 min of use to look for any damage at the fiber tip. Also, light beam emitted through the fibers were evaluated. Fibers were placed at 1 cm above a black surface to observe the shape of the beam. To achieve consistency, the same operator conducted all these experiments.

Statistical analysis was performed using Kruskal–Wallis test on BioStaTGV (France) only for the power output, with a significant level set at $p < 0.05$. No statistical analysis was performed for fiber tip and light emission.

Results

Power output

At T0 min, all these fibers had less than 7.5 W (Table 1). Table 1 and Fig. 1a summarise the mean power achieved for different fiber tips using the fragmentation parameters. There was a statistical difference between these 5 groups at 0 min (right after cleaving the fiber, $p = 0.042$) and after 1 min of laser use ($p = 0.042$), reducing the power output between -0.04 W (for metallic scissors cut

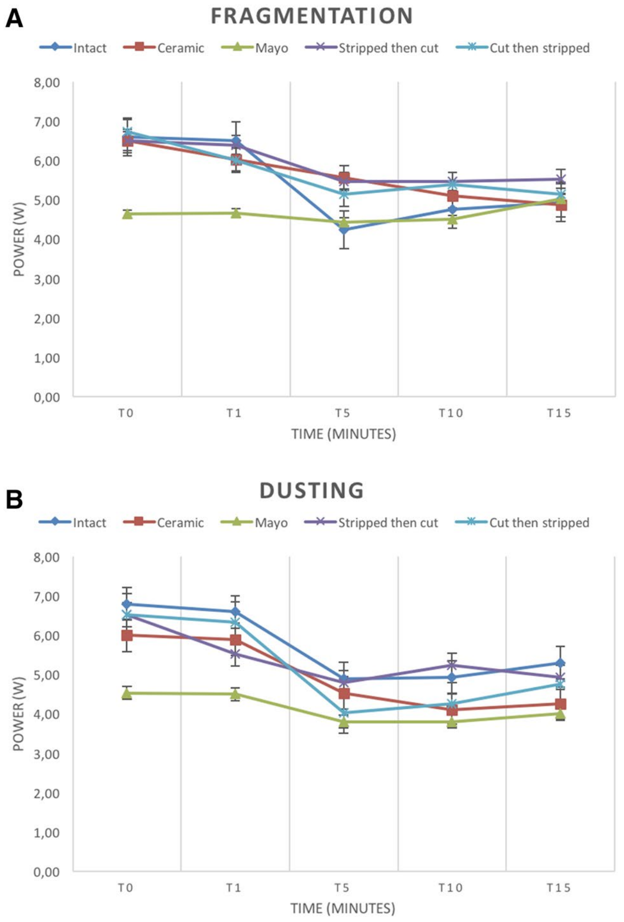


Fig. 1 Mean power of different fiber tips using fragmentation (**a**) and dusting (**b**) parameters

Table 1 Mean power of different fiber tips using fragmentation parameter

Fiber tip	t0	t1	t5	t10	t15
Intact	6.60 (±0.26)	6.50 (±0.46)	4.23 (±0.26)	4.77 (±0.81)	4.93 (±0.70)
Ceramic	6.50 (±0.47)	6.03 (±0.47)	5.57 (±0.31)	5.10 (±0.21)	4.87 (±0.42)
Metallic	4.63 (±1.35)	4.67 (±1.30)	4.43 (±0.99)	4.50 (±0.25)	5.03 (±0.81)
Stripped then cut	6.50 (±0.55)	6.40 (±0.56)	5.47 (±0.70)	5.47 (±1.01)	5.53 (±1.17)
Cut then stripped	6.73 (±0.32)	6.00 (±0.52)	5.13 (±0.52)	5.40 (±0.56)	5.13 (±0.47)

fiber) and 0.73 W (for cut-then-stripped fiber) after 1 min of laser use set at fragmentation parameters.

On pairwise comparison at 0 min, metallic scissor-cleaved fibers were inferior to intact fibers, ceramic-cleaved fibers, stripped-then-cut fibers and cut-then-stripped fibers (4.53 vs. 6.60—$p = 0.034$, 4.53 vs. 6.50—$p = 0.046$, 4.53 vs. 6.50—$p = 0.046$ and 4.53 vs. 6.73—$p = 0.043$, respectively). Also, cut-then-stripped fibers were superior to intact fibers and stripped-then-cut fibers (6.73 vs. 6.60—$p = 0.034$ and 6.73 vs. 6.50—$p = 0.046$, respectively).

On pairwise comparison at 1 min of laser use with fragmentation parameters, metallic scissor-cleaved fibers were inferior to intact fibers, ceramic-cleaved fibers, stripped-then-cut fibers and cut-then-stripped fibers (4.67 vs. 6.50—$p = 0.037$, 4.67 vs. 6.03—$p = 0.049$, 4.67 vs. 6.40—$p = 0.049$ and 4.67 vs. 6.00—$p = 0.049$, respectively).

After more than 1 min of laser use with fragmentation parameters, there were no statistical differences between these 5 groups at 5, 10 and 15 min of laser use ($p > 0.05$).

Table 2 and Fig. 1b summarise the mean power achieved for different fiber tips using the dusting parameters. There was a statistical difference between these 5 groups at 0 min (right after cleaving the fiber, $p = 0.022$) reducing the power output between 0.03 W (for metallic scissor-cut fiber) and 1.00 W (for stripped-then-cut fiber) after 1 min of laser using the dusting parameters.

On a pairwise comparison at 0 min, metallic scissor-cleaved fibers were inferior to the intact fibers, ceramic-cleaved fibers, stripped-then-cut fibers and cut-then-stripped fibers (4.53 vs. 6.60—$p = 0.049$, 4.53 vs. 5.90—$p = 0.049$, 4.53 vs. 5.53—$p = 0.049$ and 4.53 vs. 6.33—$p = 0.046$, respectively). However, there were no statistical differences between these 5 groups at 1, 5, 10 and 15 min of laser use with dusting parameters ($p > 0.05$).

Fiber tips and light emission (Fig. 2)

The light emitted by the fibers was systematically scattered when the fiber tip was cut (Fig. 2c). None of the cleavage methods succeeded in achieving a narrow beam as the one seen with the intact fiber before its use. Fibers cut with ceramic scissors seem to have the narrowest beam, followed by those cut with metallic scissors. Cut and stripped fibers had the most scattered beam.

While cutting the fiber tip, ceramic scissors was able to achieve a clean cut while metallic scissors fissured the glass (Fig. 2). After 1 min of use, the fiber tips that were still coated had less damage than stripped fibers. Less than 0.5 mm of the fiber coating on non-stripped fibers was systematically burnt by the laser. With all laser fibers, emitted light after 1 min of laser use was systematically more scattered than previously.

Discussion

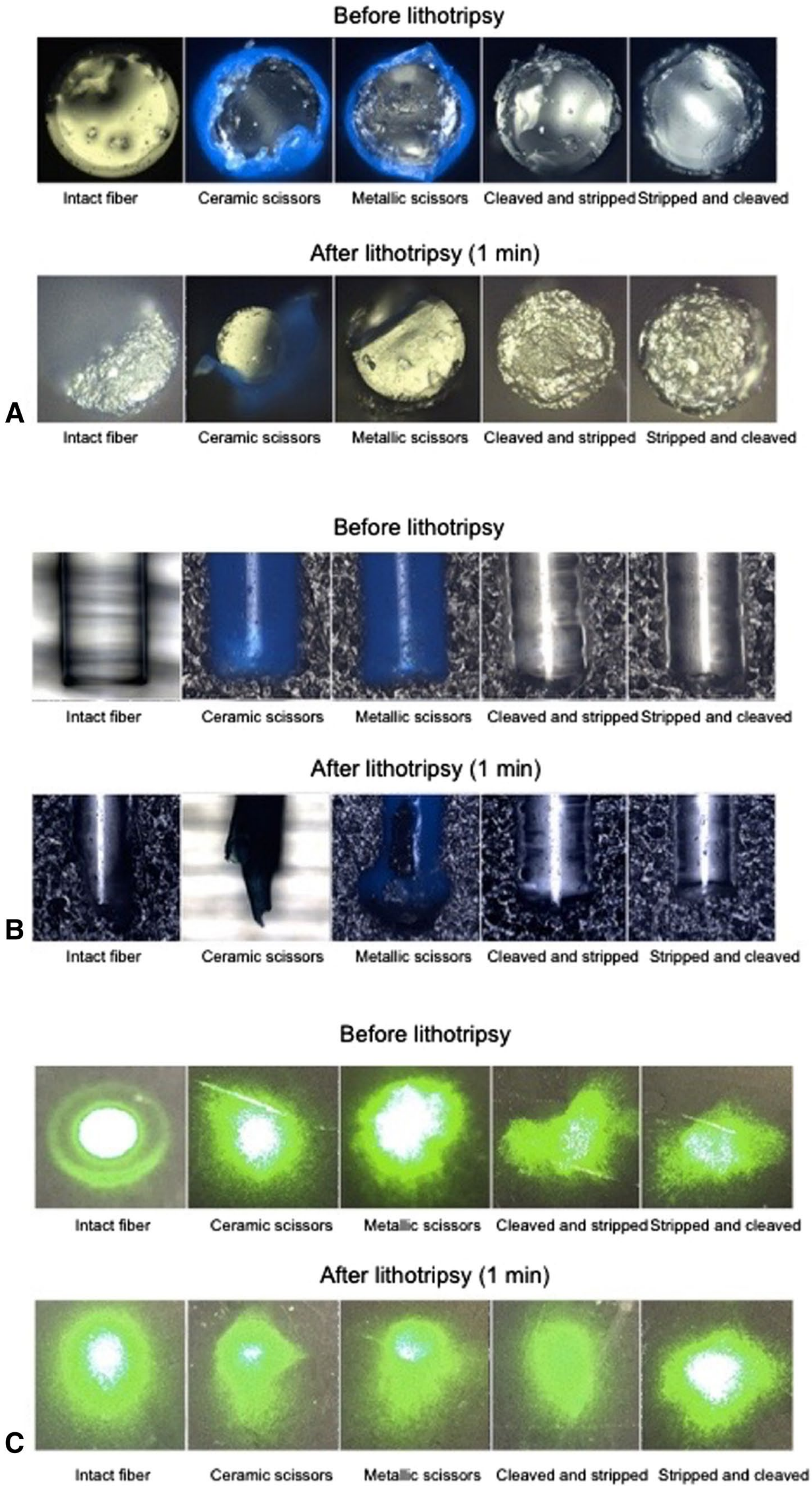
Laser fibers are made with two layers of silica (amorphous silicon dioxide, SiO_2): the core and the cladding with different refractive indices (RI). RI defines the direction of light and by how much the light bends or refracts. Energy is conducted along the fiber because of the difference between RI, making the light reflect inside the core as it travels through the fiber. The physical theory behind the propagation of light through the optic fiber is called “total internal reflection (TIR)”. TIR is defined by Snell–Descartes’ law, which states that the incident and refracted light rays’ angles are equal when the light beam reflects on an interface. It occurs when light rays in an optically dense medium tries to propagate into a less optically dense medium. Light is reflected back into the original medium if the incident ray has an angle that equals or exceeds the critical angle of TIR. This critical angle is a function of the numerical aperture. In laser fibers, these two media are the core and the cladding, and their interface acts as a reflector when the light rays’ angle equals or exceeds the critical angle of TIR.

Covering the cladding, the fiber is coated with ethylene tetrafluoroethylene (ETFE) for protection. When the interface between the fiber core and the cladding is damaged (such as during lithotripsy, or after cleaving the fiber), fiber tip degradation is inevitable because energy leaks and burns the cladding as well as the coating through these fissures. The fissures are the consequences of physical damage during lithotripsy, either by a small stone particle that crashes against the fiber tip, or by the cavitation bubble made by every laser impulsion (burnback effect). Fissures can also be made by the cleaving tool, which breaks the fiber tip instead of cleaving it.

Table 2 Mean power of different fiber tips using dusting parameter

Fiber tip	t0	t1	t5	t10	t15
Intact	6.80 (±0.42)	6.60 (±0.20)	4.90 (±0.10)	4.93 (±0.50)	5.30 (±0.60)
Ceramic	6.00 (±0.26)	5.90 (±0.15)	4.53 (±1.07)	4.10 (±0.36)	4.27 (±0.85)
Metallic	4.53 (±0.31)	4.50 (±0.10)	3.80 (±0.35)	3.80 (±0.50)	4.00 (±0.35)
Stripped then cut	6.53 (±0.17)	5.53 (±0.17)	4.80 (±0.23)	5.23 (±0.36)	4.93 (±0.26)
Cut then stripped	6.53 (±0.31)	6.33 (±0.32)	4.03 (±0.17)	4.27 (±0.10)	4.77 (±0.12)

Fig. 2 Frontal and profile views of fiber tips and emitted light by fibers



Cleaving the laser fiber systematically has been recommended with the intention of regaining the efficiency of a fiber damaged by mechanical and thermal burn-back effects of lithotripsy [3, 11].

When performing lithotripsy, the power output decreases because the fiber tip is damaged by the burn-back effect, regardless of the cleaving method. The ideal way to keep power at its greatest level would be to cut the fiber tip every 3 min, which is potentially inefficient during surgery.

Nominal intensity (NI) is what is important when you analyze pulse-by-pulse emission. NI is the ratio between nominal power and the surface, so when the beam is scattered, NI decreases. This explains the power decrease through lithotripsy, caused by the "burn-back" effect on laser fiber.

Although some manufacturers recommend the use of ceramic scissors, it has been shown that coated fibers achieve equal stone ablation rates whether they are cut with metallic or ceramic scissors, a finding corroborated in this study too [5]. Our results also showed a lower power output in coated fibers, although coated laser fibers have shown to achieve better ablation rates than stripped fibers [5].

Vassantachart et al. [12.] reported on the power output and light dispersion after four different cleaving methods. They compared new fibers cleaved with a scalpel blade, a scribe pen cleaving tool, a diamond cleaving wheel and metallic scissors. They concluded that the new uncleaved fibers had the best power output, followed by the scribe pen cleaving tool, scalpel, diamond cleaving wheel, and metallic scissors, respectively. Light dispersion followed the same trend in these fibers. Unfortunately the authors did not evaluate the power output through time or after lithotripsy. Also the scribe pen cleaving tool and diamond cleaving wheel are tools only available for basic research in "controlled laboratory environments" but not for routine clinical use [13].

Peplinski et al. [6.] studied five different cleaving methods on two different fiber diameters (200 and 365 µm) after 15 min of laser use on calcium oxalate monohydrate stones. They concluded that the 365-µm fibers were more durable and less affected by the burn-back effect than the 200-µm fibers. Secondly, they also found that while the initial power varies between the laser fibers cut with different cleaving methods, these differences disappear after 3 min of laser use. These results go in accordance with ours suggesting that there are no benefits of cutting the fibers with any specific tool or method, as there were no differences between the power output among fibers after 1 min of use.

Analyzing the images of the fiber tips at 0 min, a difference was seen between different cleaving methods. The ceramic scissors had precise cuts respecting both layers of silica (theoretically allowing energy to reflect along the fiber until its end). Metallic scissors fissure the silica glass spreading the energy and explaining why metallic scissors had the lowest power output of all initially. These results might be pictured by examining the light emitted by the fibers. Non-stripped fibers, except for the intact fiber, emitted almost round light beams before use, but the metallic scissors emitted a more scattered beam than their ceramic counterparts. Stripped fibers, except for the intact fiber, emitted the most scattered beams in our study because of small fissures caused by the stripper. All these beams were rounder and equivalent after use, as if the energy burned the defects at the fiber tip concentrating all the power.

This study suffers from a few limitations. First of all, we used only one brand of laser fiber (Rocamed®) for the purposes of experimental consistency. But, it has been shown that all fibers are not manufactured the same way, and thus vary in their properties in terms of fiber durability [14, 15]. Hence, more similar studies with a wider range of fiber size and brands might be necessary. Similarly, more number of experiments might also help increase the power of this study, which was not done due to cost constraints with the expense associated with laser fibers and conducting these experiments. We chose to use only new single-use fiber in order to have better results regarding the effects of cleaving. Finally, fiber tip and light emission were described without statistical analysis. In future, this data should be recorded as categorical data to perform statistical analysis.

Conclusion

Different cleaving and stripping methods did not show any significant differences in power output after 1 min of lithotripsy. Thus, we suggest cutting the fiber with metallic scissors as it is widely available and is most cost-effective.

Acknowledgements Mattieu Haddad is supported by the AFU scholarship from the French Association of Urology. Esteban Emiliani is supported by the EUSP scholarship program from the European Association of Urology.

Author contributions Protocol/project development was by M. Haddad and O. Traxer. Data collection or management was by M. Haddad Y. Rouchausse, F. Coste and L. Berthe. Data analysis was done by M. Haddad and S. Buttice. Manuscript writing/editing was by M. Haddad, E. Emiliani, S. Doizi and B. Somani.

Compliance with ethical standards

Conflict of interest Prof. O. Traxer is a consultant for Olympus, Rocamed, Coloplast and Boston Scientific. The rest of the authors declare that they do not have conflicts of interest.

Funding None.

References

1. Kronenberg P, Traxer O (2014) Update on lasers in urology 2014: current assessment on holmium:yttrium-aluminum-garnet (Ho:YAG) laser lithotripter settings and laser fibers. World J Urol 33(4):463–469
2. Vicente Rodríguez J, Fernández González I, Hernández Fernández C, Santos García-Vaquero I, Rosales Bordes A (2006) Lasers in urology. Actas Urol Esp 30(9):879–895
3. Mues AC, Teichman JMH, Knudsen BE (2009) Quantification of holmium:yttrium aluminum garnet optical tip degradation. J Endourol Endourol Soc 23(9):1425–1428
4. Khemees TA, Shore DM, Antiporda M, Teichman JMH, Knudsen BE (2013) Evaluation of a new 240-μm single-use holmium:YAG optical fiber for flexible ureteroscopy. J Endourol 27(4):475–479
5. Kronenberg P, Traxer O (2015) Are we all doing it wrong? Influence of stripping and cleaving methods of laser fibers on laser lithotripsy performance. J Urol 193(3):1030–1035
6. Peplinski B, Faaborg D, Miao E, Alsyouf M, Myklak K, Kelln W et al (2016) The effect of laser fiber cleave technique and lithotripsy time on power output. J Endourol 30(6):678–684
7. Esch E, Simmons WN, Sankin G, Cocks HF, Preminger GM, Zhong P (2010) A simple method for fabricating artificial kidney stones of different physical properties. Urol Res 38(4):315–319
8. Yunbo Liu PZ (2002) BegoStone—a new stone phantom for shock wave lithotripsy research (L). J Acoust Soc Am 112(4):1265–1268
9. Sea J, Jonat LM, Chew BH, Qiu J, Wang B, Hoopman J et al (2012) Optimal power settings for Holmium:YAG lithotripsy. J Urol 187(3):914–919
10. 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
11. Giusti G, Proietti S, Villa L, Cloutier J, Rosso M, Gadda GM et al (2016) Current standard technique for modern flexible ureteroscopy: tips and tricks. Eur Urol 70(1):188–194
12. Vassantachart JM, Lightfoot M, Yeo A, Maldonado J, Li R, Alsyouf M et al (2015) Laser fiber cleaving techniques: effects on tip morphology and power output. J Endourol Endourol Soc 29(1):84–89
13. From Cook Medical"Fiber cleaving tool" brochure. Visited on July 2016 [Internet]. Available from: https://www.cookmedical.com/data/IFU_PDF/T_FCT_REV2.PDF
14. Mues AC, Teichman JMH, Knudsen BE (2009) Evaluation of 24 Holmium:YAG laser optical fibers for flexible ureteroscopy. J Urol 182(1):348–354
15. Akar EC, Knudsen BE (2015) Evaluation of 16 new holmium: yttrium-aluminum-garnet laser optical fibers for ureteroscopy. Urology 86(2):230–235