The Twister Fiber: A Comparative Study of Tissue Interaction Between This Novel Fiber and the Side-Firing Fiber Using the 980 nm Laser in Bovine Kidneys

Hassan Shaker, M.D., M.Sc., Ph.D.,1 and Manal Salman, M.D., M.Sc., Ph.D.2

Abstract
Twister fiber has been recently introduced to convey the 980 nm laser. It is an end-firing fiber with terminal angulation. Theoretically, this fiber has many advantages over the standard side-firing fiber. Tissue characterization for such fiber has not been performed until now. It is important to carry out such a task to better understand the performance of this type of laser using this new fiber. Ablation capacity, fiber degradation, and maximum coagulation depth were tested for both the side-firing and the Twister fibers using a 980 nm diode laser system with a maximum output of 300 watts (Ceralas 300 system). The fibers have been tested on bovine kidneys. Laser powers used were 50, 100, 150, and 200 watts. The application time was 3 minutes for each experiment. Each experiment was repeated six times. Ablation rate was directly proportional to laser power reaching $2.4 \pm 0.24$ g/minute for the side-firing fiber and $1.83 \pm 0.23$ g/minute for the Twister fiber when the 200 watts power was reached. There was no statistical significant difference between the two fibers except at the 200 watts power. The side-firing fiber seems to resist degradation better at high power. The maximum coagulation depth was equivalent and did not significantly increase with power increase beyond the 100 watts. At 50 watts, the coagulation depth was significantly lower in the side-firing fiber. Both fibers produced significantly smaller coagulation at the 50 watts power setting compared with higher powers. In conclusion, both fibers performed well with regard to the ablation rate and produced a reasonable coagulation zone beyond the ablation area. The side-firing fiber seems to resist degradation more than the Twister fiber.

Background
The introduction of the 980 nm diode laser with a dual absorption in water and hemoglobin has provided many possible advantages as compared with the holmium and green light lasers. Its higher ablation power as compared with the green laser while maintaining superb hemostasis provided this type of laser with many potential advantages in the treatment of benign prostatic hyperplasia. Tissue interaction to this wavelength has been characterized while conveyed through a side-firing fiber.1 A new type of fibers, commercially available under the name of Twister fiber, has been recently introduced and is thought to have several advantages over the standard side-firing fiber. The Twister fiber is an end-firing fiber with an angulation at its terminal end allowing it to fire at an angle. Both fibers are flexible 600 \( \mu \)m fibers with the only difference in their terminal ends. The standard side-firing fiber has a reflective surface at the end that reflects the laser beam with a 70° angle. The terminal end of the Twister fiber is angulated to form a 30° angled tip. The side-firing fiber operates in a noncontact mode. If it gets in contact with the tissue, it heats up and the reflective tip gets damaged. On the contrary, the Twister fiber works in contact mode, leading to the formation of a hot tip that vaporizes the tissue by contact. During lasing, the angled tip of the Twister degrades and gets shorter with time, which, theoretically, should not affect its performance. Tissue interaction to this innovative fiber has not been characterized yet. It is our belief that it should provide different characteristics, as the power density at the tissue surface should be different.

In this work, it is our aim to test the tissue interaction to the 980 nm diode laser conveyed by the new end-firing Twister fiber as compared with that of the standard side-firing fiber. Degradation of the fiber and its effect on the tissue ablation will also be tested.

Methodology
A Diode Laser system (Ceralas HPD 300 from Biolitec-AG) emitting 980 nm wavelength laser was used as a source of the laser. Two different types of fibers were used to convey the light from the source to the tissues. These fibers were the new
end-firing Twister fiber and the standard side-firing fiber (Biolitec-AG).

Tissue interactions to different laser powers ranging from 50 to 200 watts have been tested for each set of experiments. Exposure time has been limited to 3 minutes for each experiment. Pulse mode was used with on time of 0.1 seconds and off time of 0.01 seconds. Tissues were lased at a near contact distance for the side-firing fiber and in contact mode for the Twister fiber. Each single laser power experiment was repeated on 6 different tissue samples. Experiments were conducted in a stainless steel basin containing 0.9% sodium chloride solution at a temperature of 37°C.

Tissues used for testing were bovine kidneys. They were brought fresh from the slaughter house on the same day of the experiment and were kept in cold saline (temperature 0°C–4°C) until time of experimentation. These kidneys were divided into four quarters, and each quarter was used for a single experiment. Laser was applied to the cortical surface. To test ablation rate, kidneys were weighed before and after each experiment, and weight loss was corrected to time to determine ablation rate.

Fiber degradation was determined by using two different fibers of each kind. Each fiber was tested in three consecutive experiments. Each experiment consisted of 3 minutes application of a certain power, after which ablation rate was determined. We started at 50 watts power, then the power was increased by 50 watts, and the process was repeated until we reached 200 watts. The ablation rate of the first experiment of a certain power was considered 100%. Then the ablation rate of the following two experiments of the same power was calculated as a percentage of the first experiment. The mean values, expressed in percentage of the first experiments of different powers, were compared with those of the second and third experiments. In other words, the first set of experiments consists of four experiments, one for each power. The ablation rate of these experiments was considered 100%. The ablation rate for the next set of experiments was calculated as a percentage of that of the first experiment and as same for the third set of experiments. (Fig. 1)

For coagulation depth beyond ablation zone, kidneys were fixed in 4% formaldehyde, embedded in paraffin, then sectioned, and stained by hematoxylin-eosin. The depths of the coagulation zones induced by the lasers were determined under the microscope by image analysis.

SPSS version 16 (SPSS incorporation) statistical software was used for statistical analysis of the results. Statistical data are presented as mean ± standard deviation. Number of experiments for each laser power was determined based on the work of Wendt-Nordahl and colleagues.\(^1\) Comparison between the results of the two fibers at different powers was done using one-way analysis of variance test. A p-value of 0.05 or less was considered statistically significant. Once a statistical significant difference was detected among the examined groups, post-hoc range tests and pairwise multiple comparisons were conducted using Bonferroni test to detect the different mean.

**Results**

Increasing the power of the laser applied to the tissues progressively increased the ablation rate for both types of fibers. This yielded a significant statistical difference in the ablation rate between different powers in the side-firing fiber except when the ablation rate of the 100 watts was compared with that of the 150 watts. Concerning the Twister fiber, the difference reached statistical significance only when the ablation rate for 200 watts was compared with the ablation rates of the lower powers. This is shown in Figure 2. Comparing both fibers together showed that there was no statistical difference except in the 200 watts where the side-firing fiber was more effective.

With regard to fiber degradation, although there was no statistical difference in fiber degradation in response to repeated usage, it appears that the side-firing fiber is more resilient. This is shown in Figure 3. Additionally, both fibers were able to deliver a collective energy of 260 kJ before they cease to properly work. In other words, the reflective surface of the side-firing fiber gets damaged, and the angulated part of the Twister totally degrades.

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**Fig. 1.** Fiber degradation methodology. Set 1 of experiments is considered 100%. Results of Set 2 = Set 2/1%. Results of Set 3 = Set 3/1%.

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The coagulation zone beneath the ablation zone is demonstrated in Figure 4. The maximum coagulation depth was statistically significantly lower using the 50 watts power as compared with all the other higher powers. There was no significant statistical difference between the coagulation depths when using powers of 100, 150, and 200 watts. Comparing power in both fibers, there was no significant difference except for the 50 watts power, where the side-firing fiber produced a smaller coagulation zone.

Discussion

Transurethral resection of the prostate (TURP) is still considered the golden standard for surgical treatment of benign prostatic hypertrophy. The high morbidity and complication rate of TURP has led on the quest of finding a less invasive modality with minimal morbidity.2–4 Recently, several minimally invasive therapeutic concepts have been introduced to treat such a condition.5-7 Several types of laser have been proposed as minimal invasive therapies with several advantages and disadvantages compared with TURP.8–12

Tissue characterization for high power 980 nm diode laser fiber has been conducted in ex vivo settings, which demonstrated its decent capabilities in ablation and hemostasis in addition to a reasonable depth of coagulation zone.1,13 These studies have used the standard side-firing flexible fiber to convey the laser to the tissues. Twister fiber has been recently introduced to be used with this kind of laser. It is an end-firing fiber with a terminal angulation. It works in a contact mode that gives the surgeon a tactile sensation and a technique similar to that of TURP. Little is known about the tissue interaction to this fiber. To our knowledge, this is the first work to characterize the tissue interaction to this novel fiber.

Tissue interaction is dependent on many factors. This includes the laser’s wavelength, the power density delivered to the tissues, the wave modulation, and the exposure time. Since this particular wavelength is absorbed in water in addition to hemoglobin, the distance from the tissue is detrimental due to absorption of the laser in the irrigation media, decreasing the power delivered to the tissues. The final tissue effect is mainly thermal and is dependent on tissue temperature. At 60°C, tissue starts getting coagulated, then at 100°C carbonization occurs. When the temperature reaches 300°C, tissue vaporization or melting occurs, which results in tissue ablation. Another effect, plasma-induced ablation, occurs at a higher degree. This is usually not reached except at a higher energy level.14

The ablation power of the side-firing fiber using the 980 nm laser in our experiments seems to perform in a similar fashion compared with previous experiments conducted by other groups.1,13 It appears that this type of laser is able to ablate the tissue even at power as low as 50 watts. Increasing the power increases the ablation rate proportionally. The Twister fiber behaves similarly with almost similar ablation rates at different powers except at the 200 watts, where the ablation was significantly less than the side-firing fibers. The reason for that is not clear to us. Still, the ablation rates of the Twister at
powers lower than the 200 watts are excellent and increase proportionally to the power.

The degradation of the fibers as a result of repeated use was tested in our work. Very few articles have addressed this issue.\textsuperscript{13,16} It appears that the side-firing fiber is more resistant to degradation. In contrast to the side-firing fiber, which works in a near contact mode, the Twister fiber works in a contact mode. Although this gives the surgeon the advantage of having the same tactile sensation of that of the TURP, this may explain the faster degradation of the fiber, especially at higher power. We believe that the contact mode of operation of this fiber brings its tip to a much higher temperature compared with that of the side-firing fiber. Unfortunately, there was no recommendation from the manufacturer for the upper power limit for either of these two fibers. Hermanns and colleagues\textsuperscript{16} tested fiber degradation secondary to its use during laser vaporization of the prostate using green light laser. They have shown that power output of the fiber significantly decreases in inverse proportion to energy delivered by the fiber to the tissues. Similarly, both fibers in our experiments degraded with time in response to 980 nm laser energy use. Further, it was apparent from our study that it is not only the cumulative effect of energy use that matters in fiber degradation but also laser power used to deliver this energy.

The coagulation zone deep to the ablation area is a matter of controversy in the literature for this laser wavelength. Wendt-Nordahl and colleagues\textsuperscript{1} found that this coagulation depth is equal to that of the TURP, which was less than 300 μm in all different powers up to 120 watts. This was less than half of the coagulation depth of the green laser used in that experiment. This work contradicts the findings of Seitz and colleagues, who found that although the 980 nm wavelength laser is three to five times more ablative than the green laser, it causes a seven to nine times deeper necrosis zone. Our results of the side-firing fibers support the work of Wendt-Nordahl and colleagues for lower power. When we increased the power to 100 watts, the coagulation depth almost doubled as compared with that of the 50 watts and to the work of Wendt-Nordahl and colleagues. The only difference in the parameter setting between the two experiments was that we used pulse mode in contrast to continuous mode used by the other group. Using power higher than 100 watts did not significantly increase the coagulation depth compared with that of the 100 watts. The Twister fiber performed similarly to the side-firing fiber except for the 50 watts power, where it produced more than double the coagulation depth of that of the side-firing fiber.

There is another aspect that may add to the complexity of this issue. The model that we used in our experiments is a chromophore-deprived tissue, which may have affected our results. Since the 980 nm laser wavelength has a dual absorption in both water and hemoglobin, the use of a chromophore-endowed model would have resulted in a different outcome with regard to both the ablation rate and the coagulation depth. This has been shown in previous studies and may explain some of the controversies present in the literature. It may as well present our need to have a chromophore-endowed model which may give results that mimic in a better way our everyday clinical practice.\textsuperscript{13,17}

Some assumptions can be inferred from our study. The use of either fiber is left to the discretion of the surgeon, as both performed superbly with regard to ablation. Appar-ently, the Twister fiber ablates in a good way at lower power settings but degrades faster at higher power settings. The side-firing seems to be more resistant to degradation. From our experiments, it appears to be safer to use the side-firing fiber for bladder, ureteric, and renal pelvis tumors at power settings not exceeding 50 watts due to the small coagulation depth.

It is clear from this study that further tissue characterization is needed using different settings such as continuous mode and different settings of the pulse mode, different tissue distances, different types of tissues, and different laser application time.

Conclusion

The Twister fiber seems to behave equally good to the side-firing fiber with regard to the ablative power but degrades faster. The coagulation zone appears to be lower for the side-firing fiber at lower power as compared with the Twister fiber. This coagulation zone, although similar in both fibers, becomes significantly deeper at higher power settings.

Disclosure Statement

No competing financial interests exist.

References


Address correspondence to:
Hassan Shaker, M.D., M.Sc., Ph.D.
Department of Urology
Ain Shams University
17, Elemam Ali St.
Heliopolis
Cairo 11341
Egypt
E-mail: hassanshaker@live.com

Abbreviation Used
TURP = transurethral resection of the prostate
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