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ORIGINAL ARTICLE

Diode laser (980 nm) enucleation of the prostate: a promising alternative to transurethral resection of the prostate

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Abstract With good hemostatic ability, the end-firing continuous-wave diode laser at 980 nm was used to enucleate the prostate (DiLEP) for the treatment of benign prostatic obstruction (BPO). The study compared the patients' demographics and surgical outcomes between DiLEP and transurethral resection of the prostate (TURP). Patients with significant BPO and a total prostatic weight of 40 g or more who had undergone DiLEP (n=74) or TURP (n=52) during the same period at our hospital were enrolled for analysis. DiLEP was performed by a single surgeon (Yang), and TURP by three surgeons (Yang, Hsieh and Chang). The 4-U incision technique was developed for DiLEP. The diode laser ensured bloodless incision followed by blunt dissection using the resectoscope and laser fiber as an 'index finger' to enucleate the prostate. To prevent unexpected deep thermal damage, the power of the laser was set at 80 W and the laser beam was directed towards the bladder neck and not towards the prostatic capsule. Demographic data and perioperative parameters were comparable between the two groups, except that DiLEP resulted in a significantly lower drop in hemoglobin level (0.9±1.0 vs. 1.6±2.4 g/dl, p=0.03), shorter catheterization time (41.2±19.9 vs. 67.7±33.3 h, p=0.01), and shorter postoperative stay (2.9±1.9 vs. 4.1±6.2 days, p=00.01). Delayed postoperative sloughing of necrotic tissue was not observed in the DiLEP group. Improvements in voiding parameters were comparable between the groups, and were sustained during a follow-up of up to 1 year. DiLEP provided better hemostasis than TURP as evidenced by less blood loss. The role of DiLEP treating BPO requires further investigation.

Keyword Benign prostatic obstruction · Prostate · Laser · Diode laser · Transurethral resection of prostate

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Introduction

Transurethral resection of the prostate (TURP) is still the gold standard of surgical treatment for benign prostatic obstruction (BPO), a common cause of lower urinary tract symptoms in men older than 40 years [1, 2]. Despite its promising efficacy in treating BPO, TURP with electrocautery is associated with a risk of significant complications (up to 11–20%) [3, 4], which include postoperative urinary retention, the need of surgical revision, persistent irritative symptoms, hemorrhage requiring blood transfusion, urinary tract infections, ejaculation disorder, erectile dysfunction and bladder neck contracture or stricture as well as severe cardiovascular complications due to transurethral resection syndrome. Therefore, a variety of lasers were clinically adopted to vaporize or cut the prostate in an attempt to reduce the morbidity associated with the procedure [5].

Initially, the diode laser at 980 nm was used to vaporize prostatic adenoma during treatment of BPO because of its outstanding ablation and hemostatic ability. Seitz et al. [6] and Erol et al. [7] showed that the use of the high-power side-firing diode laser leads to a significant improvement in voiding function with low morbidity. In an ex vivo study of human cadaver prostates, the side-firing diode laser at 980 nm was found to result in tissue necrosis seven times deeper than the KTP laser [8]. Recent studies have also demonstrated that high-power (200 W) diode laser vaporization prostatectomy results in delayed sloughing of necrotic tissue, persistent postoperative irritative symptoms, urge incontinence and a high reoperation rate [9, 10]. As a result, diode laser vaporization prostatectomy is not recommended.

Since up to 10% of incidental prostate cancers are diagnosed after TURP [4], many cancer patients may be underdiagnosed following vaporization prostatectomy with either the KTP or diode laser. Alternatively, holmium laser enucleation of the prostate (HoLEP) is a promising technique providing safety, efficacy, and prostatic tissue retrieval [11]. Compared with the Ho:YAG laser which is absorbed only by water, the diode laser at 980 nm is absorbed by both hemoglobin and water, and has been shown to provide better hemostasis in in vivo and ex vivo studies [12]. Also, Wezel et al. [13] reported that the diode laser at 1,318 nm coupled with a bare fiber provides excellent prostate ablation speed. Therefore, we applied the diode laser at 980 nm coupled with a bare fiber to enucleate the prostate (diode laser enucleation of the prostate, DiLEP) by modifying the HoLEP technique [14], and compared the surgical outcomes and perioperative complications with a contemporary series of patients undergoing TURP.

Materials and methods

The study was approved by the Ethics Committee of our hospital. The study design was to compare contemporary patients with significant BPO and a total prostate weight of 40 g or more who had undergone DiLEP ($n=74$) or TURP ($n=52$) between October 2008 and January 2011. TURP was performed by three surgeons (Yang, Hsieh and Chang) with distilled water irrigation. DiLEP was carried out by a single surgeon (Yang) with normal saline irrigation. The inclusion criteria for operation were a peak flow rate (Qmax) <12 ml/s with a voided volume >150 ml, and an international prostate symptom score (IPSS) of >12. Patients with neurogenic bladder, chronic prostatitis or prostate or bladder cancer were excluded. Patients with elevated PSA were required to have negative biopsy results before surgery. The preoperative parameters, including age, medical history, total prostate and adenoma weight, Qmax, post-void residual urine (PVR) and PSA were obtained from medical charts. The hemoglobin level was checked on the day before surgery and on postoperative day 1. Perioperative parameters including operative time, weight of retrieved prostatic tissue, urethral catheterization time, and postoperative hospital stay were collected. IPSS at 3, 6 and 12 months and uroflowmetry with PVR at 1, 3, 6 and 12 months were compared between groups. Postoperative surgical complications associated with the procedures were documented thoroughly. Temporary urinary retention was defined as failure to void through the urethra after removing an indwelling catheter. The enucleation, tissue retrieval, and overall procedure efficiency were defined as the weight of retrieved prostatic tissue (in grams) divided by enucleation, tissue retrieval, and overall operative time in minutes, respectively.

DiLEP technique

All the procedures were performed under spinal anesthesia. A 27F continuous flow laser resectoscope (Olympus, Tokyo, Japan) was used with normal saline irrigation. The diode laser system (Bio Litec, Jena, German) emitting light at a wavelength of 980 nm coupled with a 600-μm end-firing flexible fiber was used to incise and vaporize tissue in contact mode. The power of the laser was arbitrarily set at 80 W. If bothersome bleeding occurred during the procedure, defocusing the beam by pulling the laser fiber backwards slightly allowed effective coagulation of bleeding vessels. The 4-U incision technique for DiLEP was modified from the HoLEP technique [14].

First, identification of the verumontanum as a landmark is mandatory before performing DiLEP (Fig. 1a). Then, incisions are made lateral to the verumontanum and then extended towards the 5- and 7-o'clock positions of the bladder neck (Fig. 2a). The incisions are deepened until the surgical capsule of the prostate is reached, which is defined by circular fibers running in a transverse direction (Fig. 1b). A transverse incision just proximal to the verumontanum is then made to connect the distal ends of the bladder neck incisions (the first U, Fig. 2a). The laser fiber is kept close to the end of the resectoscope so that the resectoscope beak can be used to separate the tissue during dissection. The beak of the resectoscope is pushed to peel off the median lobe in a retrograde fashion towards the bladder neck. The laser is used to dissect off the connection between the adenoma and prostatic capsule transversely (Fig. 1c), Care must be taken not to go too deep and undermine the bladder neck. Incisions at the 1- and 11-o'clock positions of the bladder neck are made and then a transverse incision is made to connect the distal ends of the two incisions to excise the anterior lobe in a retrograde fashion (the second U, Fig. 2b). Checking the site of the verumontanum frequently is mandatory to avoid injuring the sphincter. The prostatic tissue of the anterior lobe is thin, and overcutting should be avoided. The incision on the apex of the lateral lobe is marked by the laser. The lateral lobes are then undermined on each side by extending the initial bladder neck incision laterally and circumferentially. The depth of the initial bladder neck incision is used as a guide to the surgical capsule and the plane of dissection. Once the plane of the surgical capsule is clearly visible, the lobes can be stripped away

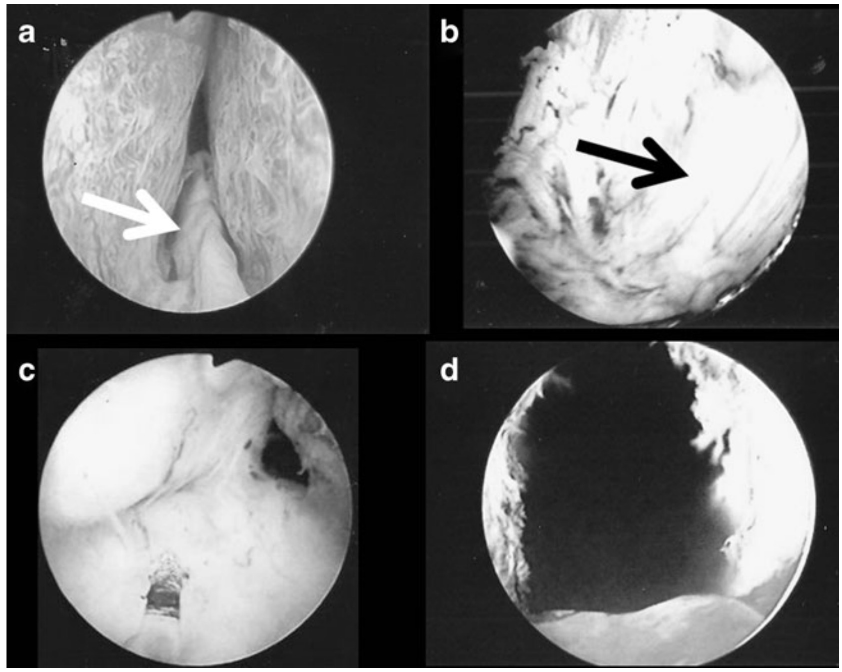

Fig. 1 Intraoperative views during the DiLEP procedure. **a** Preoperative view at the verumontanum (*white arrow*). **b** Circular fibers of the surgical capsule (*black arrow*). **c** Enucleating the adenoma by pushing the beak of the resectoscope towards the bladder neck. **d** Postoperative view showing wide open prostatic urethra

easily. A sweeping motion is used to continue the incision circumferentially laterally, as well as distally, until the resectoscope can be partially withdrawn, and the upper and lower enucleation planes can be visualized and connected (the third and forth U, Fig. 2c, d). A smooth and widely open prostatic urethra is created immediately after the procedure (Fig. 1d).

The mushroom technique of Hochreiter et al. [15] was applied to remove the enucleated tissue. Attachment of the prostatic adenoma was kept after it had been peeled off the surgical capsule. The enucleated prostatic tissue was cut into small pieces by electroresection and then removed from the bladder. After July 2010, a tissue morcellator system (VersaCut;

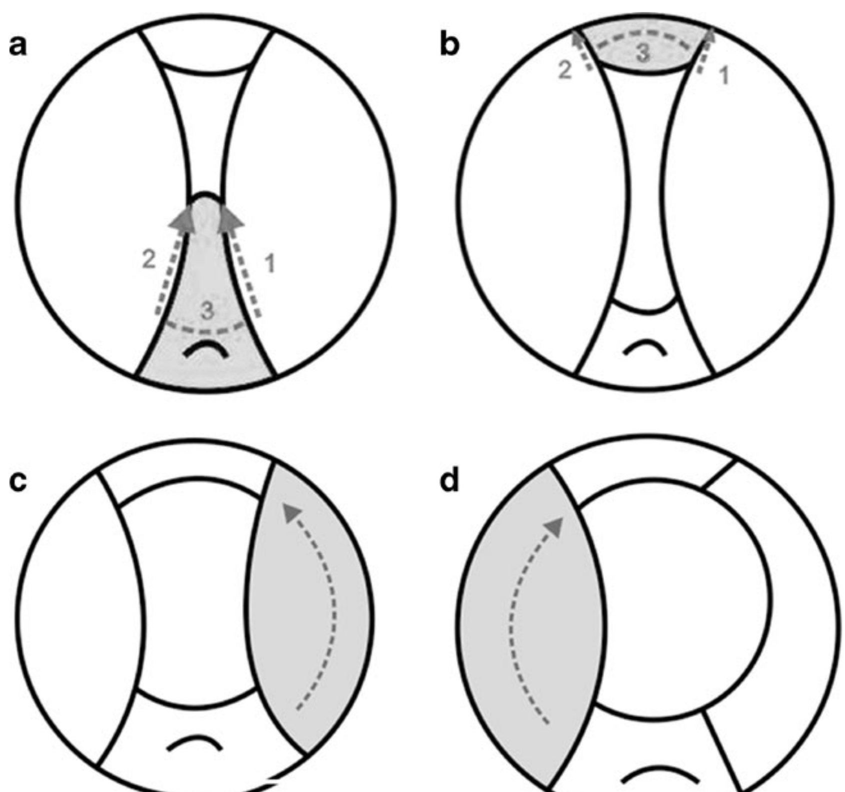

Fig. 2 Illustrations of the 4-U incision technique for DiLEP. **a** Sequence of incision lines to enucleate the median lobe (first U incision). **b** Sequence of incision lines between the 1- and 11-o'clock positions on the anterior lobe (second U incision). **c**, **d** Marking the distal margin on the lateral lobe and connecting the incision lines of the median and anterior lobes (third and fourth U incisions)

Lumenis, Yokneam, Israel) was used to remove the enucleated tissue. A 22F three-way Foley catheter was inserted after the procedure. Continuous irrigation with normal saline was instituted until the next morning. The Foley catheter was removed 24–48 h postoperatively.

After DiLEP, one piece of prostatic tissue was electro-resected for histological examination in three patients. After fixing in 4% formalin, sections of prostatic tissue were obtained serially. The slices were embedded in paraffin and stained with hematoxylin-eosin stain (H&E). The depths of the coagulation zones of electroresection and DiLEP were compared.

Statistical analysis

The data are expressed as means ± SD and were analyzed using commercial statistical software (SPSS, version 16.0; SPSS, Chicago IL).The parameters were compared between the two groups with an independent *t* test (continuous variables) or the Mann-Whitney *U* test (ordinal variables). Nonlinear regression analysis was used to test which curves were the best fit for the relationships between order of operation and operation time and overall procedure efficiency. Mixed models were used to compare subjective and objective follow-up parameters between the two surgical techniques. A *p*-value of less than 0.05 was considered to be significant.

Results

One and two incidental prostatic cancers were detected in the DiLEP and TURP groups, respectively. These three patients were excluded from the following analysis. Table 1 lists the demographics and perioperative parameters of the remaining 126 patients. The mean follow-up period was 6.9 months and comparable between the groups. There were no statistically significant differences in the age (70.7 vs. 71.3 years), estimated total weight of the prostate (70.0 vs. 66.8 g), estimated adenoma weight of the prostate (40.1 vs. 37.3 g), retrieved weight of the prostate (28.9 vs. 26.8 g), and operation time (95.2 vs. 90.0 min) between the two groups of patients. Postoperative catheterization time, time to void after operation, and hospital stays were significantly shorter in the DiLEP group than in the TURP group (41.2 vs. 67.7 h, 2.2 vs. 4.1 days, and 2.9 vs. 3.6 days, respectively; all $p<0.01$). There was less decrease in hemoglobin level on the first postoperative day in the DiLEP group than in the TURP group (mean 0.9 vs. 1.6 g/dl, $p=0.03$; Fig. 3). Figure 4 depicts the voiding outcomes in the DiLEP and TURP groups. One year after DiLEP, the IPSS had decreased from 21.8 to 5.0, Qmax had increased from 6.9 to 16.0 ml/s, and PVR had decreased from 103.2 to 36.6 ml (all $p<0.01$). The subjective and objective improvements were comparable between the DiLEP and TURP groups and were sustained during a follow-up of up to 1 year ($p>0.05$).

Table 2 shows the surgical complications in the DiLEP and TURP groups. The rate of postoperative transient urinary retention was comparable between the groups. The blood transfusion rate tended to be lower, but not significantly, in the DiLEP group than in the TURP group (2.8% vs. 5.8%, $p=0.40$). No patient in the DiLEP group had a total prostatic weight of less than 100 g requiring blood transfusion. Bladder blood clot tamponade tended to occur less frequently in the DiLEP group than in the TURP group (1.4% vs. 7.7%, $p=0.16$). Among the patients undergoing DiLEP, two (2.7%) developed transient urge incontinence which had subsided by 1 month postoperatively. There were no cerebral vascular events, nor deep vein thrombosis in either group. Seven patients had unexpected bladder mucosal injury during retrieval of the enucleated prostatic tissue with the electrocautery wire loop (six patients) or morcellator

Table 1 Demographic data and perioperative parameters in the DiLEP and TURP groups

	Overall	DiLEP group	TURP group	*p*-value
No. of patients	126	74	52	–
Age (years)	71.0±8.3	70.7±7.8	71.3±9.1	0.66
Follow-up (months)	6.9±6.6	7.3±5.2	6.4±8.2	0.42
Total prostate weight (g)	68.7±27.0	70.0±28.4	66.8±25.1	0.59
Adenoma weight (g)	38.7±20.4	40.1±21.2	37.3±19.2	0.45
Resected prostate weight (g)	27.7±19.5	28.9±21.7	26.8±17.9	0.55
Preoperative hemoglobin (g/dl)	13.9±1.5	14.0±1.5	13.7±1.4	0.29
Operative time (min)	93.0±41.2	95.2±47.8	90.0±30.0	0.49
Catheterization time (h)	52.0±29.2	41.2±19.9	67.7±33.3	<0.01
Time to void after surgery (days)	3.0±4.3	2.2±1.9	4.1±6.2	<0.01
Postoperative hospital stay (days)	3.2±1.2	2.9±1.2	3.6±1.2	0.01

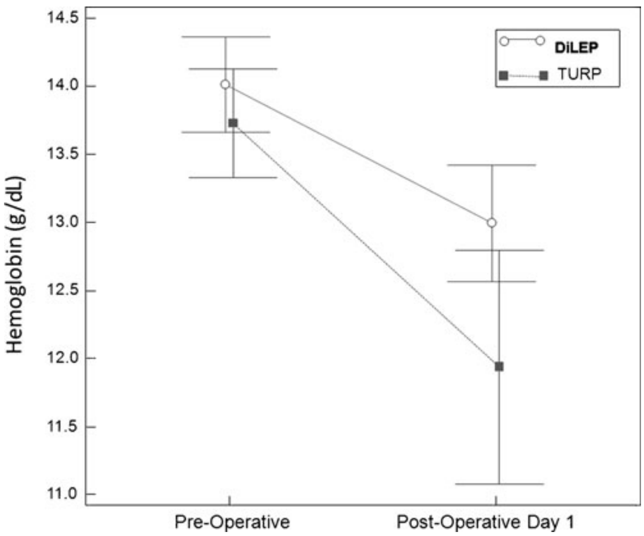

Fig. 3 Pre- and postoperative hemoglobin levels in patients undergoing DiLEP or TURP

(one patient). As the mucosal injury was minor, it did not have a negative effect on surgical outcomes, such as the time to remove the indwelling catheter, or postoperative hospital stay. The depth of cauterization on the TURP side of the prostate was approximately twice that on the DiLEP side of the prostate (Fig. 5).

Learning curves

As the DiLEP procedures were performed by a single surgeon, the learning curve for the procedure was calculated. In patients undergoing DiLEP, the enucleation, tissue retrieval, and overall procedure efficiency were 0.55±0.40, 0.91±0.54, and 0.28±0.13 g/minute, respectively. As the experience of the surgeon increased or the order of the patient increased, the overall operative time decreased (Fig. 6a, $p<0.01$) and the overall efficiency of the procedure increased (Fig. 6b, $p<0.01$). The operator had gained quite good experience after the first 20 procedures.

Discussions

This study of DiLEP showed that procedure is associated with less intraoperative hemorrhage in patients with a total prostatic weight of more than 40 g as evidenced by a lower decrease in hemoglobin level on the first postoperative day in the DiLEP group than in the TURP group (0.9 vs. 1.6 g/dl, $p=0.03$). Compared with the results of HoLEP reported by Montorsiet al., in our study DiLEP was associated with a lower drop in hemoglobin levels than HoLEP (−0.9 vs. −1.32 g/dl, total prostate size 70.0 vs. 70.3 g) [16]. Though a greater drop in hemoglobin levels was observed in the DiLEP group of the current study than in the study by Hochreiter et al. of HoLEP [15] (0.9 vs. 0.6 g/dl), this could be explained by the larger prostate weight in our patients than in the patients of Hochreiter et al. (median weight 61.3 vs. 38 g). In the current study, the rates of blood transfusion and blood clot tamponade tended to be lower, but not significantly, in the DiLEP group than in the TURP group. Large-scale, prospective randomized controlled studies are required to prove the benefits of DiLEP in reducing blood loss and the subsequent blood transfusion rate.

DiLEP provided comparable short-term and medium-term surgical outcomes to TURP which is the gold standard surgical treatment for BPO. During DiLEP most of the obstructive prostatic tissue was immediately removed. As a result, the catheterization time and postoperative hospital stay were shorter in the DiLEP than in the TURP group (Table 1). The improvements in both subjective symptoms (IPSS) and objective parameters (Qmax and PVR) were immediate and comparable between the TURP and DiLEP group (Fig. 4). These improvements in IPSS, Qmax and PVR were sustained during a follow-up of up to 1 year, which is comparable to the findings of Seitz et al. [6] and Erol et al. [7] using the high-power side-firing diode laser. Recently, Buisan et al. [17] reported the use of the end-firing diode laser at 980 nm to enucleate the prostate with a short follow-up time. They concluded that the technique was feasible and safe and resulted in sustained improvement in peak flow rate and IPSS during a 3-month follow-up.

DiLEP resulted in a high tissue retrieval rate (72.1%), which is in line with a previous report by Naspro et al. that 63.7% of adenoma was retrieved during HoLEP [18]. Incidental prostatic cancer, which has been noted in 5–10% of patients undergoing TURP or HoLEP [4, 18], was not missed in the current series of DiLEP and TURP. Since prostatic cancer is vaporized during pure vaporization techniques and underdiagnosed during vaporization resection techniques, and the high tissue retrieval rate of DiLEP and HoLEP, these procedures will be the recommended laser techniques in patients suspected of having cancer of the prostate.

Although the diode laser can produce a power up to 120 W, we arbitrarily set the power at 80 W to avoid unexpected tissue damage and to ensure adequate retrieval of obstructed prostatic tissue. The side-firing diode laser was initially developed to vaporize the obstructed prostatic tissue because ex vivo studies showed that the diode laser provides a more rapid ablation rate than the KTP laser [12]. Several clinical studies have confirmed the vaporizing effects of side-firing diode laser [6, 7]. However, deep tissue penetration of the high-power diode laser (120 to 200 W) raised

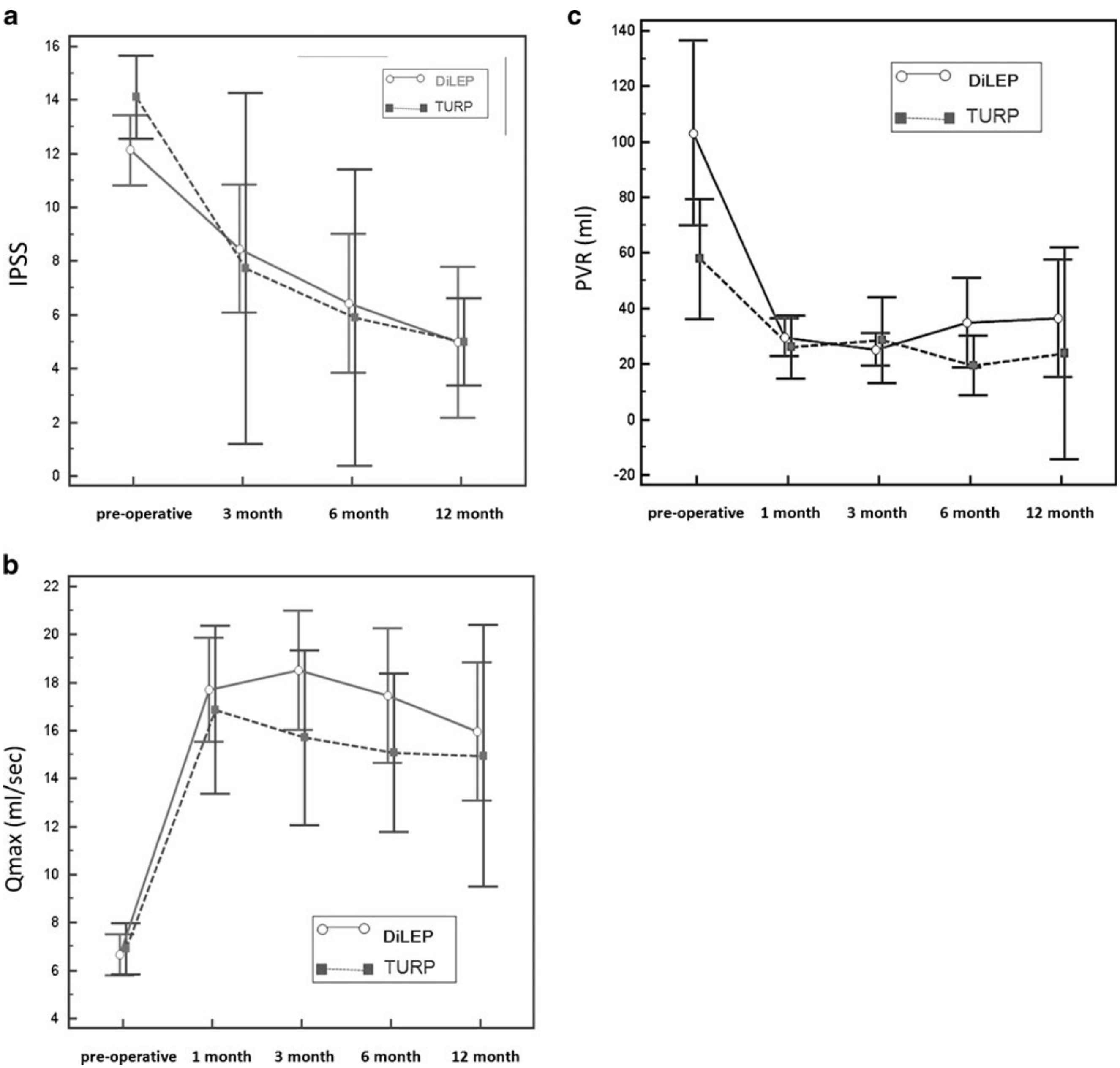

Fig. 4 Subjective and objective parameters in the DiLEP and TURP groups at baseline and during follow-up. The improvements in IPSS (**a**), Qmax (**b**), and PVR (**c**) are not significantly different between the groups (all $p>0.05$)

concerns about unexpected tissue damage during the procedures and delayed sloughing of the prostate after the procedure [9, 10]. In the beginning, we set the laser power at 100 W and found that the grade of coagulation could be too deep and the speed of cutting was too fast. Identification of the surgical capsule was not so certain. We then set the laser power at 80 W and found that we were comfortable with the speed of cutting and the grade of coagulation, and the surgical capsule could be easily recognized (Fig. 1b). No tissue debris adhered to the fiber tip, and generally no time was needed for cleaning. The aiming beam of the diode laser was directed toward the bladder or tangentially upward to the base of the prostatic adenoma, but not directed toward the prostatic

Table 2 Surgical complications in the DiLEP and TURP groups

	DiLEP	TURP	p-value
No. of complications	74	52	–
Transient urinary retention	7 (9.5%)	4 (7.7%)	1.0
Blood transfusion	2 (2.8%)	3 (5.8%)	0.4
Bladder blood clot tamponade	1 (1.4%)	4 (7.7%)	0.16
Bladder mucosal injury	7 (9.5%)	0	0.04

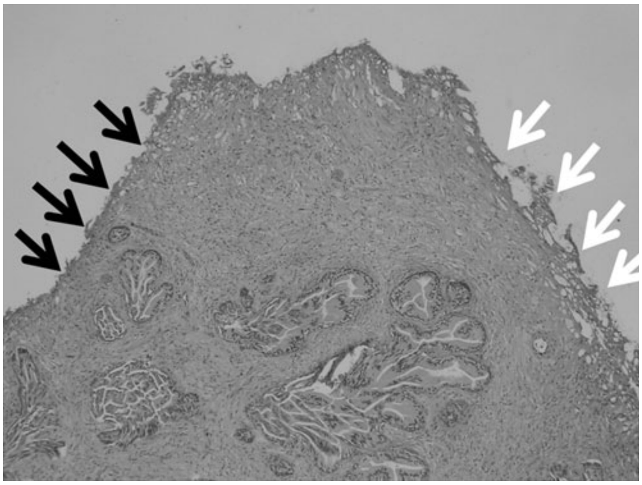

Fig. 5 Histological section shows that the depth of cauterization following TURP (*white arrows*) is approximately twice that following DiLEP (*black arrows*) (H&E stain, ×20)

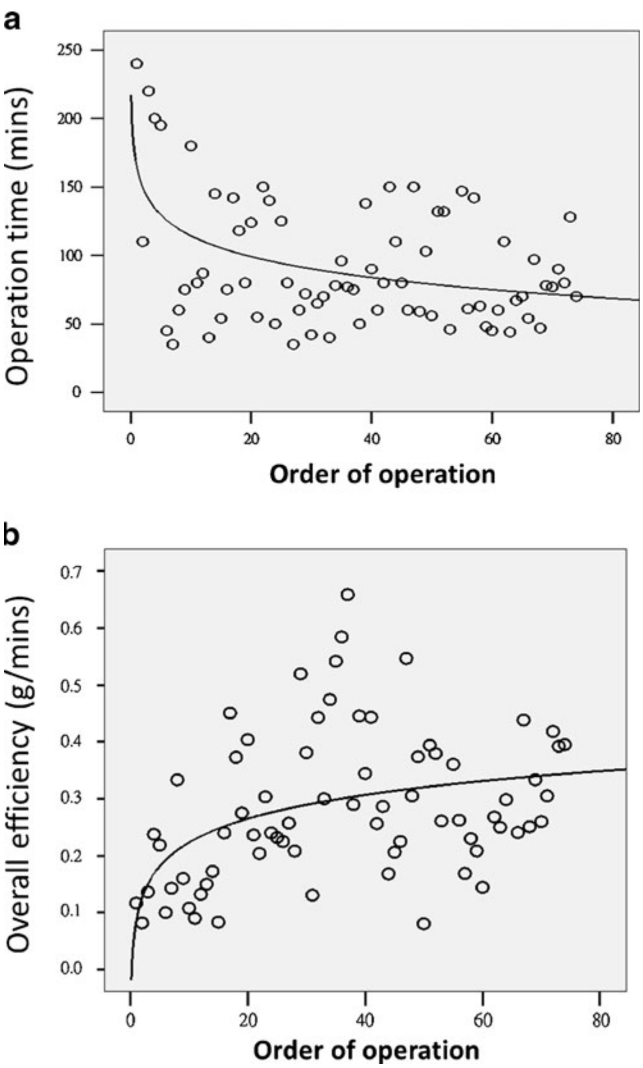

Fig. 6 Learning curves for DiLEP illustrating the correlation between operation time (**a** $p<0.01$), overall procedure efficiency (**b** $p<0.01$) and the sequential number of the procedure

capsule. In addition, enucleation rather than vaporization was used in DiLEP. As a result, deep coagulation of the prostatic tissue were not observed with DiLEP (Fig. 5). Most bleeding vessels were coagulated with the laser in contact mode. The defocused laser beam could be used to stop occasionally bothersome bleeding from large bleeding vessels. The appropriate energy suitable for DiLEP needs further investigations.

The DiLEP technique had been mastered after the first 20 procedures and the mean operation time decreased significantly thereafter (Fig. 6). Shah et al. [19] reported that the operator became familiar with the HoLEP technique after the first 20 procedures and that the technique may be consistent after 50 procedures. The prolonged learning curve was considered to be one of the major disadvantages of HoLEP and prevented its widespread use [20, 21]. Surgeons already in clinical practice may not be willing to tolerate the learning curve if the technique is not overwhelmingly advantageous compared to traditional TURP. In the classic HoLEP, the anterior lobe may drop down after incision only at 12 o'clock. The 4-U incision technique in DiLEP excised the adenoma between 1 and 11 o'clock to prevent the check-valve effect of the residual adenoma (Fig. 2b). Laser treatment of the anterior lobe brings down the lateral lobes and facilitates their subsequent enucleation. An early mark on the distal margin of the lateral lobe is helpful in preventing unexpected injury to the sphincter (Fig. 1c, d). Further studies are warranted to prove that the diode laser provides better hemostasis than the Ho:YAG laser and may thus shorten the learning curve of DiLEP.

Cost effectiveness is another concern of modern technology using various lasers. Green laser light, one of the most popular lasers for prostatectomy, has been accepted for single use, with limited total energy to be used in each procedure [22]. In the US, the KTP laser has been associated with a lower medical cost due to fewer admission days and lower complication rates, although there are additional costs of laser generators and single-use laser fibers [22, 23]. An end-firing fiber is cheaper than a side-firing fiber. In addition, an end-firing diode laser fiber can be repeatedly used for several procedures until breakdown of the fiber. DiLEP could potentially be an economic solution to the high cost of the modern technology used in treating BPO.

Conclusion

Compared with TURP, the preliminary results of DiLEP are promising because of its hemostatic ability, high tissue retrieval rate, and satisfactory postoperative outcomes for up to 1 year. Large-scale, prospective randomized controlled trials with long-term follow-up are warranted to prove the superiority and durability of DiLEP.

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