

High-power diode laser at 980 nm for the treatment of benign prostatic hyperplasia: ex vivo investigations on porcine kidneys and human cadaver prostates

Michael Seitz · Oliver Reich · Christian Gratzke ·
Boris Schlenker · Alexander Karl · Markus Bader ·
Wael Khoder · Florian Fischer · Christian Stief ·
Ronald Sroka

Received: 20 November 2007 / Accepted: 14 January 2008 / Published online: 13 February 2008
© Springer-Verlag London Limited 2008

Abstract Diode laser systems at 980 nm have been introduced for the treatment of lower-urinary-tract-symptoms (LUTS) suggestive of benign prostatic enlargement (BPE). However, the coagulation and vaporization properties are unknown. We therefore aimed to evaluate these properties in ex vivo models in comparison with the kalium-titanyl-phosphate-(KTP) laser. The diode laser treatment was applied to isolated, blood-perfused porcine kidneys and fresh human cadaver prostates (HCPs) at different generator settings. We performed histological examination to compare the depth of coagulation and vaporization. The diode laser showed larger ablation and coagulation characteristics than the KTP laser did. Ablation of the diode laser was found to be 1.79-times (120 W in porcine kidney, $P < 0.0001$) and 3.0–5 times (200 W in HCP, $P < 0.0005$) larger. The diode laser created a nine-times (120 W in porcine kidney, $P < 0.0001$) and seven-times (200 W in HCP, $P < 0.0001$) deeper necrosis zone. The diode laser vaporization was highly

effective ex vivo. Owing to the laser's deep coagulation zones, in vivo animal experiments are mandatory before the diode laser (980 nm) is applied in a clinical setting, so that damage to underlying structures is prevented.

Keywords Diode laser · Prostate · Benign prostatic hyperplasia (BPH) · Benign prostatic hyperplasia · Bladder outlet obstruction · Benign prostatic enlargement · BPE · Vaporization · Diode · Laser

Introduction

Neodymium:yttrium-aluminum-garnet (Nd:YAG) laser was introduced in 1992 [1] as a potential therapy for bladder outlet obstruction (BOO) due to benign prostatic enlargement (BPE). It was suggested to be associated with less morbidity than the reference standard, transurethral resection of the prostate (TURP). Although the haemostatic characteristics were excellent, the remaining necrotic tissue caused BOO and lower urinary tract symptoms (LUTS) for several weeks after treatment. Immediate tissue ablation was accomplished when Malek et al. [2] introduced a 60 W potassium-titanyl-phosphate laser (KTP laser=kalium-titanyl-phosphate laser) to study the feasibility and functional outcome after vaporization of the prostate. Since the laser's introduction, multiple studies have shown the safety and early efficacy of this user-friendly technique [3].

Recently, a first clinical report on side-fire diode laser treatment in benign prostatic hyperplasia (BPH) was published. Seitz et al. [4] demonstrated that it is feasible to relieve symptoms quickly with a 50 W diode laser

M. Seitz (✉) · O. Reich · C. Gratzke · B. Schlenker · A. Karl ·
M. Bader · W. Khoder · C. Stief
Department of Urology, University Hospital Munich Grosshadern,
Ludwig-Maximilians-University Munich,
Munich, Germany
e-mail: Michael.Seitz@med.uni-muenchen.de

R. Sroka
LIFE Center Laser Laboratory,
University Hospital Munich Grosshadern,
Ludwig-Maximilians-University Munich,
Munich, Germany

F. Fischer
Department of Forensic Medicine, University of Munich,
Ludwig-Maximilians-University,
Munich, Germany

prototype at a wavelength of 1,470 nm. Other diode lasers emitting light at 980 nm are under investigation and are available for the treatment of benign prostatic enlargement. As this wavelength offers the highest simultaneous absorption in water and haemoglobin, it combined high vaporization capacities and coagulation properties in an ex vivo porcine kidney model [5, 6].

The aim of our study was to evaluate the vaporization capacities and coagulation properties of a diode laser at 980 nm in comparison with the KTP laser (532 nm) at different generator settings in two different ex vivo models using isolated, blood-perfused, porcine kidneys and human cadaver prostates.

Materials and methods

Equipment

For the procedures a KTP laser device emitting a wavelength of 532 nm was used with an output power of 80 W. Two different diode laser systems were used, both emitting light at a wavelength of 980 nm. Output power levels for the porcine kidney model were 60 W, 90 W and 120 W, and 100 W, 150 W and 200 W for the fresh human cadaver prostates in continuous wave mode (cw mode). Furthermore, in the porcine kidney investigations, the pulse parameters were set 0.1 s on-time and 0.01 s off-time at 100 W and 120 W. The light was transmitted via a flexible 600 μm side-fire fibre to vaporize the tissue in a non-contact mode.

Isolated, blood-perfused, porcine kidney

We used the ex vivo model of isolated, blood-perfused, porcine kidneys, as previously described [7–9]. Since the specific heat capacities in kidney (3.89 kJ/kg per degree kelvin) and prostate (3.80 kJ/kg per degree kelvin) are almost equivalent, isolated, blood-perfused, porcine kidney is a valuable model, especially for the investigation of laser procedures, in which the heat sink is of the utmost importance [10]. A total of five kidneys was taken from pigs within 8 min to 12 min after they had been commercially slaughtered. The organs were immediately perfused with sodium chloride solution (0.9%) via the renal artery. Organs were preserved at 4°C when the effluent from the renal vein was clear. The experiments were started no later than 4 h after the pigs had been slaughtered. For perfusion, autologous blood was harvested, heparinized with 8,000 IU/l heparin, and stored at 4°C. A roller pump conveyed the blood through an 8 Fr catheter intubating the renal artery. The perfusion rate was set at 60 ml/min with a perfusion pressure of 120 cm H₂O. The first experiments

were done strictly with the corresponding autologous blood of each pair of kidneys; in the following investigations normal saline solution was used, since it proved to generate equal results. The organs were placed in a glass basin and irrigated at 20°C with sterile water.

Tissue ablation was performed via a standardized approach to achieve a treated square of 1 cm x 1 cm. A constant working distance and drag speed was provided by our clamping the laser device into a stepper motor driven by custom software [11].

Fresh human cadaver prostates

Three fresh human cadaver prostates (HCP1, HCP2 and HCP3) from three male victims of vehicle accidents, aged 24 years, 49 years and 73 years, donated for research (<24 h), were provided by the Department of Forensic Medicine, University of Munich. The prostates were rinsed with a 0.9% NaCl solution and bisected longitudinally. Subsequently, the prostates were pinned on cork plates and immersed in a glass basin with normal saline solution at 37°C. The laser fibre was positioned to the luminal side, and prostatic tissue was ablated under visual guidance with the KTP laser device at 80 W and with the diode laser device at 100 W, 150 W and 200 W. After application of laser energy the tissue was fixed in 4% formalin for 48 h.

Histology

After fixing in 4% formalin, serial sections of human and porcine tissue were obtained, with a slice thickness of 5–7 μm , embedded in paraffin and stained with haematoxylin–eosin (HE, Sigma Chemical Co., St. Louis, USA). The depths of vaporization as well as coagulation zones were measured after HE staining under the microscope with the use of a calibrated calliper.

Statistical analysis

Comparisons were made with the two-tailed Student *t*-test for continuous data. A *P* value <0.05 was considered to be statistically significant.

Results

The porcine kidneys treated with 80 W KTP laser vaporization showed macroscopically a rather threaded aspect, while the diode laser treated areas had a brownish, smooth, margin. After cross-sectioning, the ablation and coagulation margins are obvious. While the KTP laser left a small coagulation rim (1 mm, range 0.9 mm to 1.2 mm), the diode laser showed a deep coagulation rim of up to 10 mm

(range 7 mm to 10 mm), depending on the output power level of the generator (Fig. 1). Coagulation increased with output power level of the laser generator. The diode laser at 60 W, 90 W and 120 W displayed a mean coagulation zone of 8.43 mm (SD \pm 1.13 mm), 9.15 mm (SD \pm 1.07 mm), and 9.58 mm (SD \pm 0.86 mm), respectively. In comparison with the KTP laser device (1.10 mm, SD \pm 0.13 mm) the diode laser had a 7.7-times to 8.7-times deeper coagulation capacity ($P < 0.0001$). A shift towards the pulsed mode did not change this context ($P < 0.001$). The comparison of the coagulation zone at 120 W cw mode with pulsed mode displays a P value of 0.61. The data are shown in Fig. 2.

When ablation properties are compared, there is also significantly increased tissue vaporization in favour of the diode laser system. At 60 W, 90 W, and 120 W there are 1.14-times (105 mm³, SD \pm 32 mm, $P = 0.24$), 1.57-times (144 mm³ SD \pm 25 mm, $P < 0.0001$), and 1.79-times (165 mm³ SD \pm 20 mm, $P < 0.0001$) larger amounts of tissue removal (in cubic millimetres) than with the KTP laser at 80 W (92 mm³ SD \pm 6 mm). Data are shown in Fig. 3.

The shift towards the pulsed mode (100 W, 120 W) showed a highly significant ($P < 0.0001$) reduction in ablation volume without a reduction of necrosis zone in comparison with the cw-mode experiment (Figs. 2 and 3).

The human cadaver prostate tissue, which was treated with 80 W KTP laser vaporization, displayed, macroscopically, the white cotton-wool aspect, while diode laser treatment had a smooth, brown, carbonization effect on human tissue. Also, the amount of tissue ablated was obviously larger with diode laser energy than with the KTP laser.

In the three human cadaver prostates (HCP1, HCP2, HCP3), KTP laser and diode laser (980 nm) energy of 2 kJ was also applied to a zone 13–16 mm in length. In terms of vaporization, the KTP laser at 80 W with 2 kJ energy applied to a zone 13–16 mm in length showed a mean vaporization thickness of 1.39 mm (\pm 0.16 mm), 2.28 mm (\pm 0.09 mm) and 2.36 mm (\pm 0.11 mm) for HCP1, HCP2 and HCP3, respectively. In comparison, with 2 kJ of diode laser energy at 100 W, the ablation features increased to 4.0 mm (\pm 0.16 mm), to 4.7 mm (\pm 0.15 mm), and to



Fig. 1 Macroscopic cross-section of a pig's kidney treated with a diode laser at 980 nm with 60 W generator output power. *Top margin* side of laser treatment, *bottom margin* renal pelvis, *dark brown tissue* normal tissue/texture of the kidney, *light brown* coagulated/necrotic tissue. *Black bar* represents 10 mm

4.2 mm (\pm 0.18 mm). At 150 W these values increased to 5.5 mm (\pm 0.14 mm), 4.9 mm (\pm 0.14 mm) and 5.7 mm (\pm 0.20 mm) for HCP1, HCP2 and HCP3, respectively. At 200 W the vaporization zone even reached values beyond 6 mm (6.1 mm \pm 0.16 mm for HCP1, 6.2 mm \pm 0.24 mm for HCP2, 6.1 mm \pm 0.16 mm for HCP3). In summary, the vaporization effect of the diode laser at 980 nm was found to be 2.15-times larger at 100 W ($P < 0.005$), 2.65-times larger at 150 W ($P < 0.005$) and 3.05-times larger at 200 W ($P < 0.0005$) than that with the KTP laser. Data are shown in Fig. 4.

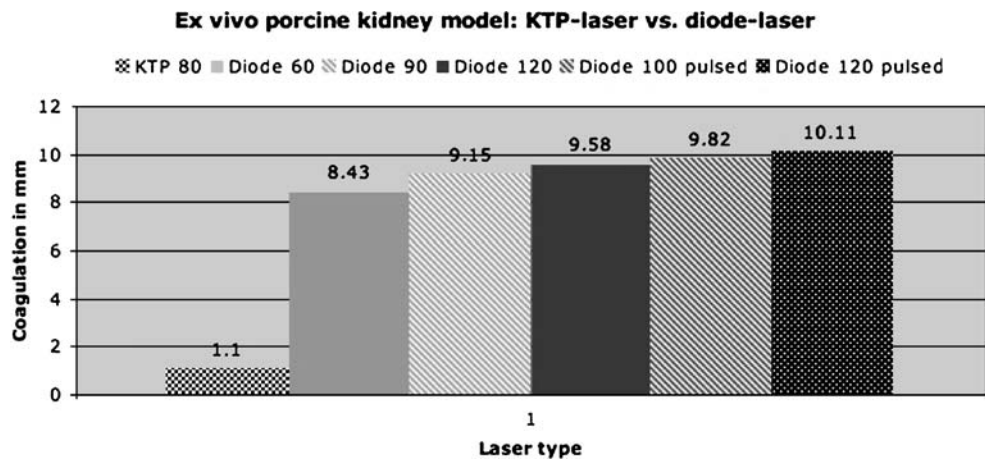
There was no qualitative difference, but a quantitative difference between the coagulation margins produced by KTP and the diode laser was shown in histological analysis. Beyond the vaporized tissue, blurred and destroyed/coagulated connective tissue and glandular structures were seen. Beyond this zone there was an area of completely disrupted connective tissue and glandular structures (Figs. 5 & 6).

The quantitative difference in coagulation between KTP and high-power diode laser was tremendous. The mean coagulation zone reached 1.5 mm (\pm 0.12 mm), 2.41 mm (\pm 0.12 mm), and 2.32 mm (\pm 0.15 mm) with the KTP laser device at 80 W in HCP1, HCP2 and HCP3, respectively. In the diode laser setting (100 W, 2 kJ, cw mode) the coagulation depth increased significantly to 4.0 mm (\pm 0.20 mm), to 4.6 mm (\pm 0.26 mm), and to 4.2 mm (\pm 0.20 mm) in HCP1, HCP2, and HCP3, respectively ($P < 0.0001$). A further increase of the coagulation zone was seen in the 150 W setting for HCP1, HCP2 and HCP3, with a depth of 6.3 mm (\pm 0.11 mm), 5.5 mm (\pm 0.21 mm), and 5.9 mm (\pm 0.22 mm), respectively ($P < 0.0001$). At 200 W these values were 7.0 mm (\pm 0.17 mm), 7.00 mm (\pm 0.14 mm), and 7.3 mm (\pm 0.30 mm) for HCP1, HCP2 and HCP3, which was also highly significant ($P < 0.0001$). In summary, the coagulation zone with the diode laser at 980 nm was found to be 2.0-times larger at 100 W, 2.8-times larger at 150 W, and 3.4-times larger at 200 W than that with the KTP laser device ($P < 0.0001$). Data are shown in Fig. 7.

Discussion

Benign prostatic enlargement (BPE) is the most common cause of bladder outlet obstruction (BOO) and the most frequent pathological condition necessitating surgical treatment in men. Among the surgical techniques, TURP has been applied with great success for decades as the “gold standard” treatment. It significantly improves lower urinary tract symptoms such as urinary flow. Despite its general acceptance and widespread application, complications are seen in up to 20% of patients following a successful intervention [12, 13]. Currently, a number of minimally

Fig. 2 Coagulation in millimetres in the ex vivo perfused porcine kidney model. KTP laser compared with diode laser at 980 nm. *KTP 80* 80 W KTP laser, *diode 60* diode laser 60 W, *diode 90* diode laser 90 W, *diode 120* diode laser 120 W, *diode 100 pulsed* diode laser 100 W pulsed mode, *diode 120 pulsed* diode laser 120 W pulsed mode



invasive procedures are available as effective alternatives, having concentrated on the haemostatic removal of tissue at the time of surgery to avoid the complications of transurethral resection of the prostate and to prevent the 5- to 7-day catheterization time required with neodymium:yttrium-aluminum-garnet (Nd:YAG) laser coagulation. Among these, promising surgical techniques are any kind of visual laser ablation procedures, such as KTP laser vaporization, holmium:yttrium-aluminum-garnet (Ho:YAG) laser enucleation of the prostate (HoLEP) and diode lasers [12–14].

The treatment outcomes with these lasers are strongly dependent on several physical factors, including wavelength, power, duration, and technique. In contrast to laser surgery with the Nd:YAG laser (1,064 nm) with its excellent deep coagulation (7 mm) with haemostatic properties without any tissue removal [1], some tissue characteristics make Ho:YAG lasers an attractive alternative to TURP. Ho:YAG at a wavelength of 2,140 nm is absorbed more strongly in prostatic tissue and water, leading to instant vaporization with no considerable coagulation necrosis [15]. KTP lasers, on the other hand, are able to

achieve good visual tissue ablation and haemostasis with a small coagulation rim. The 532 nm wavelength is strongly absorbed by haemoglobin, so that the heat produced is concentrated in a small volume. This causes rapid vaporization of well blood-perfused tissue such as the prostate.

The diode laser has been introduced lately with a first clinical pilot study in the treatment of benign prostatic enlargement. At a wavelength of 1,470 nm, strong absorption by water allows tissue penetration of 2–3 mm [4]. Other diode laser systems working on a wavelength of 980 nm are available, and ablation as well as coagulation capacities are still under investigation. The wavelength of 980 nm offers the highest simultaneous absorption in water and haemoglobin. Therefore, it is thought that the diode laser is able to combine high tissue ablation properties with the benefit of excellent haemostasis. Regarding the vaporization capacities, there is consistency in the literature, while, in terms of coagulation depth, studies are inconsistent. Wendt-Nordahl et al. [6] estimated the coagulation depth in an ex vivo model of an isolated blood-perfused porcine kidney at ~200 μm to 300 μm (output power levels of 30 W, 60 W, 80 W, 100 W and 120 W). In contrast, our

Fig. 3 Ablation in cubic millimetres in the ex vivo perfused porcine kidney model. KTP laser compared with diode laser. *KTP 80* 80 W KTP laser, *diode 60* diode laser 60 W, *diode 90* diode laser 90 W, *diode 120* diode laser 120 W, *diode 100 pulsed* diode laser 100 W pulsed mode, *diode 120 pulsed* diode laser 120 W pulsed mode

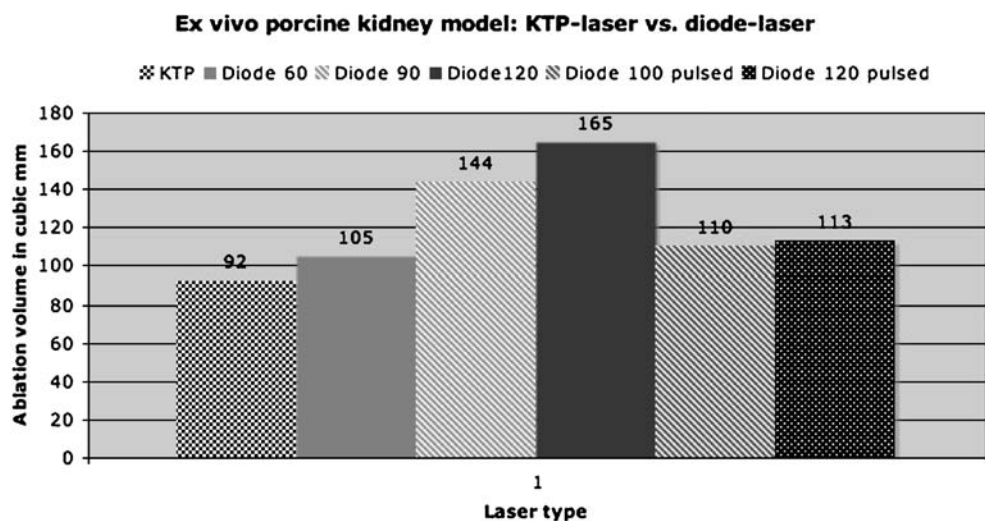
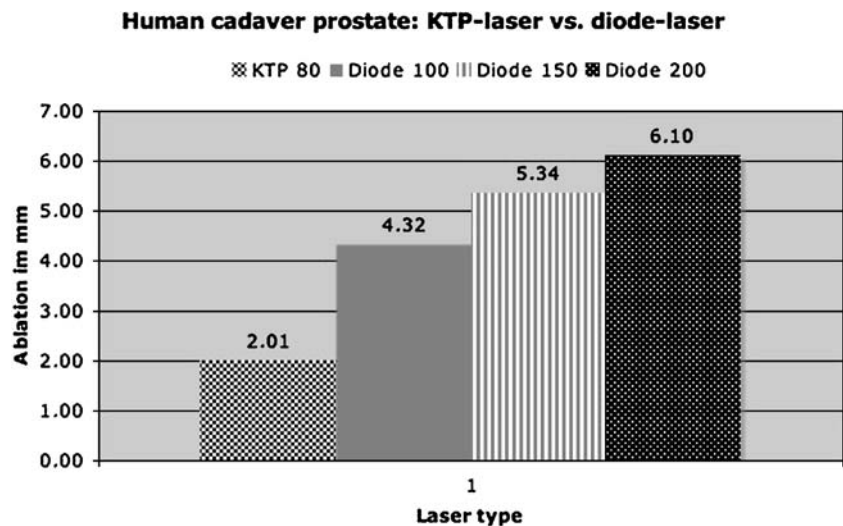


Fig. 4 Ablation in millimetres in the ex vivo fresh human cadaver prostate. KTP laser compared with diode laser at 980 nm. *KTP 80* 80 W KTP laser, *diode 100* diode laser 100 W, *diode 150* diode laser 150 W, *diode 200* diode laser 200 W



previous investigation [5] found a more than ten-times larger coagulation thickness of 5.7 mm and 10.2 mm in the same ex vivo porcine model (output power level of 30 W, 60 W and 100 W).

Therefore, in this report, we reinvestigated the diode laser at 980 nm in the ex vivo model of the isolated blood-perfused porcine kidney with clinical relevant output power levels of 60 W, 90 W and 120 W in cw and pulsed mode. These data show that the coagulation depth has always been beyond 7 mm, irrespective of whether the cw mode or the pulsed mode is used. It is debatable whether the results of this ex vivo model of porcine kidney is transferable to human prostate tissue. However, the model provides a well-established tool to evaluate systematically different laser types [5, 6, 16]. Ablation and coagulation capacities seem to be more distinctive in the diode laser than in the standard KTP laser. The amount of vaporized tissue increases with higher generator output power, and ablation properties of the diode laser at 980 nm are significantly higher than those

of the KTP laser. At the same time, the coagulation zone increases by a factor of 7.7 to 8.7.

The evaluation in human cadaver prostates showed similar results. The ablation effect of the diode laser at 980 nm was two-to-three-times larger than the vaporization zone of the KTP laser ($P < 0.0005$). In analogy to the ex vivo porcine kidney model, our study on ex vivo human cadaver prostates demonstrate a distinct deeper coagulation (2 to 3.4-times) than with the KTP laser device at 80 W.

The predicted laser behaviour in porcine and human tissues at a wavelength of 980 nm with the highest simultaneous absorption in water and haemoglobin has been confirmed. The diode laser is able to combine very high tissue ablation properties with the benefit of excellent haemostasis due to deep coagulation.

The advantage of laser surgery in comparison with that of TURP in the treatment of benign prostatic enlargement is the almost bloodlessness and the absence of fluid absorption (TUR syndrome) of the procedure. The drawbacks of

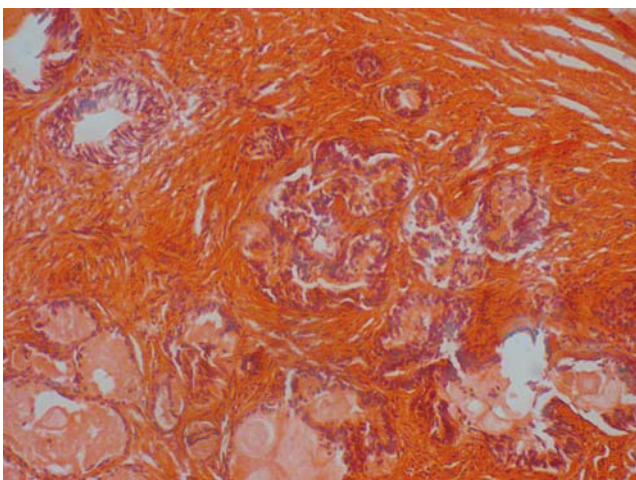


Fig. 5 Blurred and coagulated connective tissue and glandular structures. HE, $\times 40$

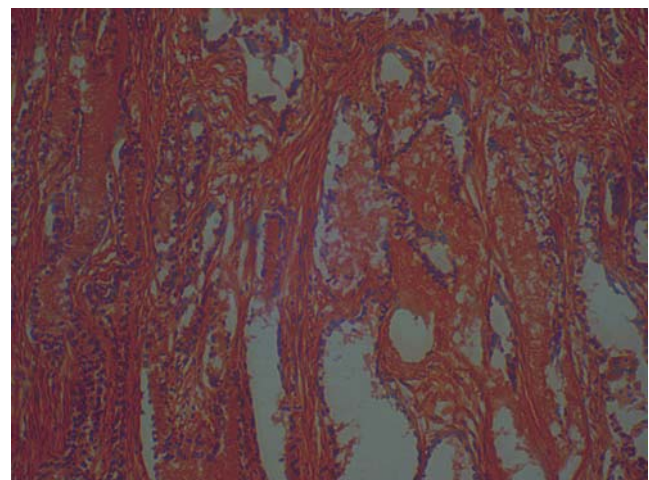
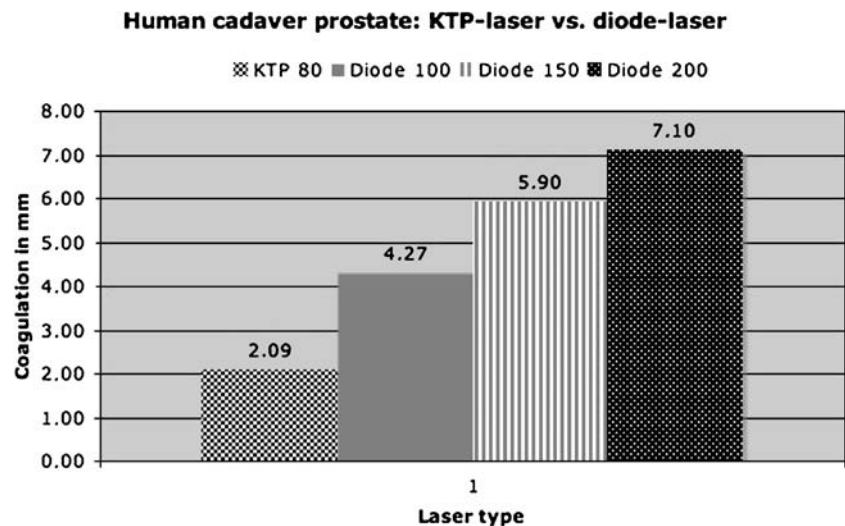


Fig. 6 Completely disrupted connective tissue and glandular structures. HE, $\times 40$

Fig. 7 Coagulation in millimetres in ex vivo fresh human cadaver prostate. KTP laser compared with diode laser at 980 nm. *KTP 80* 80 W KTP laser, *diode 100* diode laser 100 W, *diode 150* diode laser 150 W, *diode 200* diode laser 200 W



laser surgery vary, depending of the wavelength used. While some lasers display deep coagulation but no instant tissue removal (Nd:YAG), others show excellent tissue ablation capabilities but almost no haemostasis (Ho:YAG). The capacity to vaporize tissue with a minimal coagulation rim of underlying structures is a feature that makes KTP laser surgery an ideal tool for immediate transurethral removal of prostatic tissue in a haemostatic environment [16, 17]. Owing to its easy-to-learn property, this side-fire laser technique has become a commonly used procedure. However, due to the time-consuming tissue vaporization, KTP laser surgery of the prostate is limited to patients with small to midsize glands [16, 18, 19]. The steep learning curve of holmium laser enucleation of the prostate (HoLEP) as a time-efficient technique limits its widespread use in the urological community [20]. Both HoLEP and KTP laser prostatectomy have a very low peri-operative complication rate and produce results similar to those of TURP [21, 22].

In our ex vivo models (porcine kidneys and human cadaver prostates) we could demonstrate a twofold to threefold tissue removal property for the diode laser in the side-fire technique in comparison with the KTP device. This could overcome the time-consuming aspect. At the same time, due to the deep coagulation rim beyond 7 mm in the porcine kidney model and 3.5 mm to 7.9 mm in the human cadaver prostate, excellent haemostasis is guaranteed. On the other hand, this rather large coagulation zone could possibly harm underlying structures, such as the neurovascular bundles and the external sphincter, causing erectile dysfunction and incontinence. Both the porcine kidney and the human cadaver prostate model do not reflect the in vivo human prostate in every aspect. However, since the specific heat capacities in kidney (3.89 kJ/kg per degree kelvin) and prostate (3.80 kJ/kg per degree kelvin) are almost equivalent, isolated, blood-perfused, porcine kidney is a valuable model, especially for the investigation of laser

procedures, in which the heat sink is of the utmost importance [10, 16]. On the other hand, the value of the cadaver prostate experiments is limited, since there is no blood perfusion. This might misrepresent the KTP laser properties, since the latter are dependent on haemoglobin absorption at 532 nm. However, Malek et al. [2] demonstrated in an in vivo experiment on canine prostates with a 60 W KTP device minimal tissue necrosis of 2 mm, which is in concordance with our results.

The histological evaluation showed two distinct zones within the coagulation necrosis. Next to the vaporized tissue, blurred and coagulated connective tissue and glandular structures were seen. Beyond this zone there was an area of completely disrupted connective tissue and glandular structures. Reasons for this phenomenon are still unclear.

Our results for both laser systems suggest that the diode laser energy is absorbed by water and haemoglobin, resulting in high ablation capacity and deep coagulation, whereas the KTP laser energy is predominately absorbed by haemoglobin, resulting in lower ablation and coagulation. Furthermore, in our investigations, the coagulation depth increased by the output power level but could not be influenced by our changing the cw mode into the pulsed mode, which also has been reported in the literature [6].

In conclusion, our findings indicate that diode laser vaporization is highly effective in porcine kidneys and human prostates ex vivo. Thus, this technique might be a promising tool in the treatment of LUTS suggestive of BPH in vivo. However, due to the laser's deep coagulation zones, in vivo animal experiments are mandatory before the application of the diode laser at 980 nm in a clinical setting, so that there is no harm to underlying structures such as the neurovascular bundles and the external sphincter, which may cause erectile dysfunction and incontinence.

Acknowledgement The authors received no funding and no grants.

References

- Costello AJ, Bowsher WG, Bolton DM, Braslis KG, Burt J (1992) Laser ablation of the prostate in patients with benign prostatic hypertrophy. *Br J Urol* 69:603–608
- Malek RS, Barrett DM, Kuntzman RS (1998) High-power potassium-titanyl-phosphate (KTP/532) laser vaporization prostatectomy: 24 hours later. *Urology* 51:254–256
- Te AE, Malloy TR, Stein BS, Ulchaker JC, Nseyo UO, Hai MA, Malek RS (2004) Photoselective vaporization of the prostate for the treatment of benign prostatic hyperplasia: 12-month results from the first United States multicenter prospective trial. *J Urol* 172:1404–1408
- Seitz M, Sroka R, Gratzke C, Schlenker B, Steinbrecher V, Khoder W, Tilki D, Bachmann A, Stief C, Reich O (2007) The diode laser: a novel side-firing approach for laser vaporisation of the human prostate—immediate efficacy and 1-year follow-up. *Eur Urol* 52:1717–1722
- Seitz M, Ackermann A, Gratzke C, Schlenker B, Ruszat R, Bachmann A, Stief C, Reich O, Sroka R (2007) Diode laser: ex vivo studies on vaporization and coagulation characteristics. *Urologe A* 46:1242–1247
- Wendt-Nordahl G, Huckele S, Honeck P, Alken P, Knoll T, Michel MS, Häcker A (2007) 980-nm Diode laser: a novel laser technology for vaporization of the prostate. *Eur Urol* 52:1723–1728
- Kohrmann KU, Back W, Bensemann J, Florian J, Weber A, Kahmann F, Rassweiler J, Alken P (1994) The isolated perfused kidney of the pig: new model to evaluate shock wave-induced lesions. *J Endourol* 8:105–110
- Michel MS, Kohrmann KU, Weber A, Krautschick AW, Alken P (1996) Rotoresect. new technique for resection of the prostate: experimental phase. *J Endourol* 10:473–478
- Reich O, Schneede P, Corvin S, Zaak D, Sroka R, Hofstetter A (2003) Combination of interstitial laser coagulation and transurethral resection of the prostate: ex vivo evaluations. *Urology* 61:1172–1176
- Cooper TE, Trezek GJ (1972) A probe technique for determining the thermal conductivity of tissue. *J Heat Transf* 94:133
- Reich O, Corvin S, Oberneder R, Sroka R, Muschter R, Hofstetter A (2002) In vitro comparison of transurethral vaporization of the prostate (TUVP), resection of the prostate (TURP), and vaporization-resection of the prostate (TUVRP). *Urol Res* 30:15–20
- Madersbacher S, Alivizatos G, Nordling J, Sanz CR, Emberton M, de la Rosette JJ (2004) EAU 2004 guidelines on assessment, therapy and follow-up of men with lower urinary tract symptoms suggestive of benign prostatic obstruction (BPH guidelines). *Eur Urol* 46:547–554
- Kaplan SA (2004) AUA guidelines and their impact on the management of BPH: an update. *Rev Urol* 6 [Suppl 9]:S46–S52
- Reich O, Seitz M, Gratzke C, Schlenker B, Bachmann A, Stief C (2006) Benign prostatic syndrome (BPS). Ablative treatments. *Urologe A* 45:769–780; quiz 781–782
- Gilling PJ, Fraundorfer MR (1998) Holmium laser prostatectomy: a technique in evolution. *Curr Opin Urol* 8:11–15
- Reich O, Bachmann A, Schneede P, Zaak D, Sulser T, Hofstetter A (2004) Experimental comparison of high power (80 W) potassium titanyl phosphate laser vaporization and transurethral resection of the prostate. *J Urol* 171:2502–2504
- Reich O, Bachmann A, Siebels M, Hofstetter A, Stief CG, Sulser T (2005) High power (80 W) potassium-titanyl-phosphate laser vaporization of the prostate in 66 high risk patients. *J Urol* 173:158–160
- Sandhu JS, Ng CK, Gonzalez RR, Kaplan SA, Te AE (2005) Photoselective laser vaporization prostatectomy in men receiving anticoagulants. *J Endourol* 19:1196–1198
- Bachmann A, Schürch L, Ruszat R, Wyler SF, Seifert HH, Müller A, Lehmann K, Sulser T (2005) Photoselective vaporization (PVP) versus transurethral resection of the prostate (TURP): a prospective bi-centre study of perioperative morbidity and early functional outcome. *Eur Urol* 48:965–971
- Wilson LC, Gilling PJ, Williams A, Kennett KM, Frampton CM, Westenberg AM, Fraundorfer MR (2006) A randomised trial comparing holmium laser enucleation versus transurethral resection in the treatment of prostates larger than 40 grams: results at 2 years. *Eur Urol* 50:569–573
- Elzayat EA, Habib EI, Elhilali MM (2005) Holmium laser enucleation of the prostate: a size-independent new “gold standard”. *Urology* 66:108–113
- Te AE, Malloy TR, Stein BS, Ulchaker JC, Nseyo UO, Hai MA (2006) Impact of prostate-specific antigen level and prostate volume as predictors of efficacy in photoselective vaporization prostatectomy: analysis and results of an ongoing prospective multicentre study at 3 years. *BJU Int* 97:1229–1233