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ORIGINAL PAPER

Comparative analysis of MOSES™ technology versus novel thulium fiber laser (TFL) for transurethral enucleation of the prostate: A single-institutional study

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Summary

Introduction: *Novel laser technologies have been developed for the minimally invasive surgical management of benign prostatic hyperplasia (BPH). The objective of this study was to assess the safety and efficacy of MOSES™ technology versus the thulium fiber laser (TFL) in patients with BPH undergoing transurethral enucleation of the prostate.*

Methods: *We conducted a retrospective review of prospectively collected data of eighty-two patients who underwent transurethral enucleation of the prostate using MOSES™ or TFL technologies from August 2020 to September 2021. Preoperative and intraoperative parameters, in addition to post-operative outcomes, were collected and analyzed.*

Results: *Twenty patients underwent transurethral enucleation of the prostate with TFL, while 62 had MOSES™ HoLEP. No statistically significant difference in preoperative characteristics was observed between the groups. Patients in the TFL group had longer median enucleation, hemostasis, and morcellation times ($p < 0.001$) than those in the MOSES™ cohort. The longer morcellation time of TFL is mostly related to less visibility. The postoperative outcomes IPSS, QoL, Q_{max}, and post void residual (PVR), were comparable between the groups at 1, 3 and 6 months. The incidence of urge urinary incontinence ($p = 0.79$), stress urinary incontinence ($p = 0.97$), and hospital readmission rates ($p = 0.1$) were comparable between the two groups.*

Conclusions: *A satisfactory safety and efficacy profile with comparable postoperative outcomes was demonstrated for both techniques; though, MOSES™ technology was superior to TFL in terms of shorter overall operative time.*

KEY WORDS: *Benign Prostatic Hyperplasia; Laser; Enucleation.*

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INTRODUCTION

A wide range of laser technologies have been developed for *anatomical endoscopic enucleation of the prostate* (AEEP), which adopts the principle of *open prostatectomy* (OP). The efficacy and safety of AEEP have been widely demonstrated, regardless of the energy source utilized (1).

Holmium laser enucleation of the prostate (HoLEP) is a safe and effective treatment option for patients experiencing symptoms of an enlarged prostate. The HoLEP procedure has comparable results to *transurethral resection of the prostate* (TURP) and OP, with a low morbidity rate and shorter hospital stay (2-6). HoLEP also demonstrated an acceptable steep learning curve (7). Improvements in outcome parameters following HoLEP are durable, and the late complications and reoperation rates reported are very low, up to 18 years (8). Recent evidence suggests that MOSES-™ technology has further revolutionized HoLEP with modulated pulsed energy transmission (9). Enhanced energy delivery is believed to increase efficiency during HoLEP and reduce the operative and catheterization times, as well as blood loss (10). HoLEP performed using MOSES™ technology has been shown to provide faster hemostasis than HoLEP with a standard 100-W holmium laser (9).

Thulium fiber laser enucleation of the prostate (ThuFLEP) is an emerging technology for endoscopic prostate enucleation. One of the advantages of the *thulium fiber laser* (TFL) is its wavelength (1940 nm), which has a photothermal effect and a more shallow penetration depth. This allows for precise tissue cutting and reduces the carbonization effects associated with Thulium:YAG lasers (11-13).

Recent data demonstrate that ThuFLEP is an effective minimally-invasive technique for the surgical management of *benign prostatiec hyperplasia* (BPH), with treatment outcomes comparable to TURP and OP (13, 14). The objective of this study was to assess the safety and efficacy of TFL in patients who underwent ThuFLEP compared to those that underwent MOSES™ HoLEP at our institution.

PATIENTS AND METHODS

After obtaining Research Ethics Board approval, we conducted a retrospective review of prospectively collected data of eighty-two patients who underwent transurethral enucleation of the prostate at our institution from August 2020 to September 2021. Patients were dichotomized depending on whether they underwent enucleation of the prostate using a 120-W MOSES™ (*Lumenis, Yoknaem,*

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Israel) or TFL (*Soltive Premium, Olympus, USA*). A 550-µm laser fiber and a 28-F continuous flow resectoscope (*Karl Storz SE & Co. KG, Tuttlingen, Germany*) were used for both procedures. We included patients with a prostate size > 80 g that presented with severe lower urinary tract obstruction that did not respond to medical treatment, refractory urinary retention, refractory hematuria due to prostate enlargement, and bladder stones secondary to BPH.

Preoperative evaluation included patient demographics, a complete medical history, physical examination including a *digital rectal exam* (DRE), the use of antiplatelets and anticoagulants, history of urinary retention, and previous prostate surgery. Symptom assessment was completed using the *International Prostate Symptom Score* (IPSS) and *quality of life* (QoL) questionnaires. Patients underwent *prostate-specific antigen* (PSA) testing, uroflowmetry, a *post-void residual* (PVR) bladder scan, and a transrectal ultrasound for prostate volume estimation.

Patients with PSA values above normal or those with abnormal DRE findings underwent a preoperative biopsy to exclude prostate cancer. A preoperative cystoscopy was performed in individuals who previously underwent TURP to exclude urethral strictures and *bladder neck* (BN) contracture. Surgical parameters including enucleation time, enucleation efficiency, morcellation time, laser energy, resected weight, intraoperative complications, and the need for blood transfusion were recorded. Enucleation efficiency is defined as the weight of enucleated prostatic tissue (grams) divided by the enucleation time (minute).

Early postoperative complications included clot retention, a failed *trial of void* (TOV) and hospital readmission. Preoperative and postoperative hemoglobin levels were measured. Late postoperative complications included *urge urinary incontinence* (UUI), *stress urinary incontinence* (SUI), urethral strictures, and BN contraction. SUI was evaluated with a detailed history regarding the involuntary passage of urine while coughing or sneezing or the use of pads to avoid wetting. Clinical evaluation of SUI was conducted by asking the patient, with a full bladder, to cough and by observing the passage of any urine. All patients had postoperative follow-ups at 1, 3, 6 and 12 months. Our evaluation included IPSS, QoL, Q_{max}, and PVR. PSA levels were measured at three months postoperative.

Surgical technique

Our top-down enucleation techniques using the holmium laser or TFL were reported in previous publications (15, 16).

Postoperative care

Until August 2020, we performed standard 100-W HoLEP, and our practice was an overnight hospital admission with a next-day TOV (< 24 hours). After acquiring MOSES™ technology in December 2020, we implemented same-day discharge and same-day TOV for patients that underwent MOSES™ HoLEP. The standard practice for TFL prostate enucleation was an overnight admission and next-day TOV (< 24 hours). Patients who met predetermined discharge criteria following an assessment by the surgeon were offered same-day catheter removal 3 hours postoperatively. They were informed that our standard practice was an overnight admission or same-day discharge with outpatient catheter removal on *postoperative day one* (POD1). Patients with an unfit medical condition (e.g., uncontrolled cardiovascular disease, cognitive disorder, and anticoagulant or antiplatelet therapy) were excluded from early discharge. Those without a caregiver or residing beyond city limits were also excluded. Patients were not excluded based on PVR, the presence of an indwelling catheter or other subjective criteria. All patients were counselled regarding the option to decline same-day catheter removal and discharge if they felt uncomfortable. If medically feasible, patients were instructed to temporarily hold their antiplatelet and anticoagulant medications before surgery for 7 and 3 days, respectively. A same-day TOV was not offered to patients who could not withhold their antiplatelet or anticoagulant therapy.

All patients had a three-way Foley catheter (22 F, with 75 ml of sterile water in the balloon) inserted postoperatively and were kept on mild traction with *continuous bladder irrigation* (CBI). The cases were postoperatively transferred to the *Post Anesthesia Care Unit* (PACU) for observation. For MOSES™ patients, CBI was continued for 2 hours and was then stopped for an additional hour to evaluate the degree of hematuria. While patients who underwent TFL were admitted overnight with CBI. Routine blood testing, including a complete blood count and basic metabolic profile, were conducted in the PACU. Voiding trials were performed 3 hours postoperatively for MOSES™ patients and next day for the TFL group. Following TOV, all patients were assessed by the urologist for suitability for discharge.

A TOV was performed by filling the catheter with 300-500 mL of saline or until the patient felt the urge to urinate. The urine colour, volume voided, and PVR were assessed to ensure there was no concern for hematuria or possible clot retention. Predetermined discharge criteria included: if the patient was deemed medically fit, was not on anticoagulants or antiplatelets, had a caregiver, and met discharge criteria (17).

Patients with a minimum score of 9 on the modified *Post Anaesthetic Discharge Scoring System* were considered ready for discharge. A score of ≥ 2 was required for vital signs, pain and surgical bleeding criteria, whereas a minimum score of 1 was required for all other criteria.

Before discharge, patients were also required to have acceptable laboratory results, hematuria scores (without CBI or the presence of clots) (18), tolerate diet, and ambulate independently. A TOV was considered successful if the patient had a PVR < 300 and if the residual volume was less than half the voided volume, and there was no concern for hematuria or possible clot retention.

Statistical analyses

Data collection and statistical analyses were performed using *Statistical Package for the Social Sciences* (SPSS®) version 26.0 (*Chicago, IL, USA*) and JMP® Pro16 software (*SAS Institute Inc., Cary, NC*). Continuous data were presented using medians and *interquartile ranges* (IQR) and compared with the Mann-Whitney U Test. Numbers and

percentages were used to describe categorical data, which was compared using the Chi-Square test. The p-value was considered statistically significant if $p < 0.05$.

Results

Of the 82 patients included in the study, 62 underwent MOSES™ HoLEP, and 20 had transurethral enucleation of the prostate with TFL. The preoperative characteristics of the two groups are listed in Table 1.

There was no difference between treatment modalities in terms of compared preoperative parameters. Patients who underwent TFL prostate enucleation had longer median enucleation, hemostasis, and morcellation times ($p < 0.001$) compared to MOSES™ (Table 2).

Moreover, the enucleation efficiency was significantly higher using MOSES™ technology ($p = 0.006$).

No intraoperative complications were recorded for both technologies. Two patients (10%) in the TFL cohort required hospital readmission compared to one (1.6%) in the MOSES™ group ($p = 0.1$). All three cases of hospital readmission were due to hematuria.

All patients in our study had their catheters removed postoperatively and were discharged from the hospital within 24 hours; though, patients who underwent MOSES™ HoLEP had their catheters removed within 3 hours postoperatively with a hospital stay ≤ 6 hours.

Table 1.
Preoperative characteristics of both groups.

	MOSES™ (62 patients)	TFL (20 patients)	P-value
Age at surgery (median/IQR) yrs	71.4 (64.5-80.1)	73.8 (66.2-82.6)	0.2
Indication Urine retention n (%)	12 (19.4)	7 (35)	0.15
LUTS/hematuria n (%)	50 (80.6)	13 (65)	
Comorbidities n (%)	51 (82.3)	13 (65)	0.1
Prostate volume (median/IQR) cc	109 (87-122)	102 (91.5-118.75)	0.97
Preoperative IPSS (median/IQR)	25 (22-28)	25.5 (23.3-28.5)	0.55
Preoperative QoL (median/IQR)	5 (4-5.25)	5 (4.25-6)	0.34
Preoperative Q_{max} (median/IQR) ml/min	7.7 (5.7-10.6)	7.95 (6.4-11)	0.74
Preoperative PVR (median/IQR) ml	223 (130-323)	234 (99.5-440)	0.82
Preoperative PSA (median/IQR) ng/dl	4.8 (3.6-7.4)	4.8 (4.2-5.5)	0.89
Preoperative hemoglobin (median/IQR) g/L	145 (140-151)	139 (131.3-143)	0.052

Table 2.
Operative parameters comparing MOSES™ to TFL technologies in prostate enucleation.

	MOSES™ (62 patients)	TFL (20 patients)	P-value
Enucleation time (median/IQR) min	46.5 (40-54)	61.5 (55-68.7)	< 0.001
Hemostasis time (median/IQR) min	3 (2-4)	5 (5-6.7)	< 0.001
Morcellation time (median/IQR) min	10 (6.7-12)	15 (10.2-22.7)	< 0.001
Laser energy (median/IQR) KJ	79.7 (65.4-99.7)	78.4 (67.8-95.3)	0.75
Prostate enucleated weight (median/IQR) g	70 (60-90)	79 (58.5-90.8)	0.51
Hemoglobin drop (median/IQR) g/L	10 (7-14)	10.5 (7.3-14)	0.6
Enucleation efficiency (median/IQR) g/min	1.6 (1.3-2)	1.4 (1-1.6)	0.006
Readmissions n (%)	1 (1.6)	2 (10)	0.1

Patients who underwent TFL enucleation of the prostate had their catheters removed within 24 hours and had a hospital stay of ≤ 24 hours. None of the patients in our study required postoperative blood transfusion.

Following catheter removal, one patient (5%) in the TFL group and 3 individuals (4.8%) in the MOSES™ group experienced SUI ($p = 0.97$).

The incidence of UUI post-catheter removal was 10% (2 patients) and 8.1% (5 patients) in the TFL and MOSES ™ groups, respectively ($p = 0.79$). All cases of SUI and UUI were resolved at 3-months follow-up.

The postoperative functional outcomes were comparable between the two groups including median Q_{max} at 1, 3 and 6 months ($p = 0.55$, $p = 0.32$, $p = 0.82$), respectively and median PVR at 1, 3, and 6 months ($p = 0.88$, $p = 0.92$, $p = 0.31$), respectively. The median IPSS at 1, 3 and 6 months ($p = 0.6$, $p = 0.26$, $p = 0.11$), respectively and median QoL at 1, 3 and 6 months ($p = 0.6$, $p = 0.32$, $p = 0.71$), respectively were also comparable between the groups (Figure 1).

At 6-months follow-up (Figure 2), there were no differences between the groups in terms of improvement in percentages of IPSS ($p = 0.38$), QoL ($p = 0.77$), Q_{max} ($p = 0.84$), and PVR ($p = 0.33$).

Discussion

Over the last few years, emerging laser technologies have been introduced for BPH management. This study compared two well-known technologies: MOSES™ and the novel TFL. Both modalities demonstrated promising results in the management of primary and recurrent enucleation of BPH (19).

Though MOSES ™ and TFL were individually studied with other modalities in the literature, the two technologies were not previously compared. MOSES™ technology was associated with a shorter operative time compared to conventional HoLEP. This may be due to the enhanced hemostatic properties of MOSES™ (9, 10, 20).

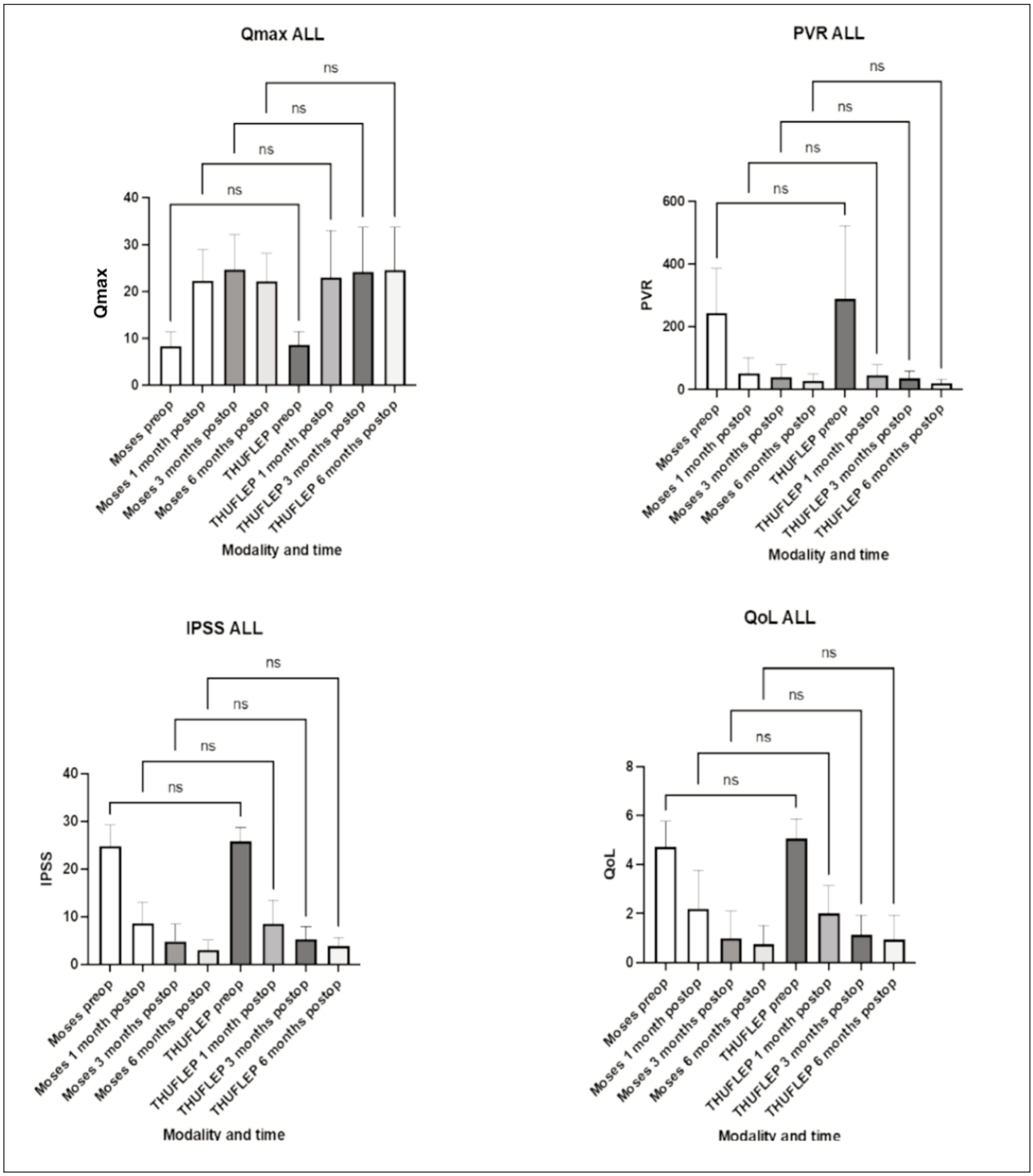
Compared to OP, TFL was associated with a shorter hospital stay and earlier return to normal activities (14). Moreover, TFL was comparable to conventional monopolar TURP in the management of moderate-sized prostates (< 80 cc). At 12-months follow-up, TFL was associated with a greater reduction in PSA levels, indicating enhanced removal of the prostatic adenoma (13).

In the current study, MOSES™ HoLEP was associated with significantly less enucleation and hemostasis times than TFL. This could be explained by better hemostasis achieved with MOSES™ technology than TFL. Doizi and colleagues found incision depth and coagulation areas were greater with the holmium laser than TFL. Moreover, they noticed that the holmium laser had no carbonization zone while it was constant with the TFL (21).

In this study, MOSES™ technology had better enucleation efficiency than TFL (1.6 *vs* 1.4 g/min, $p = 0.006$). Our reported TFL enucleation efficiency is comparable to other studies. *Enikeev et al.* had an enucleation efficiency of 1.04 g/min using TFL (14). *Nevo and colleagues* reported a mean enucleation efficiency of 1.7 g/min with MOSES™ 2.0 technology (10).

We found that morcellation time was shorter in the

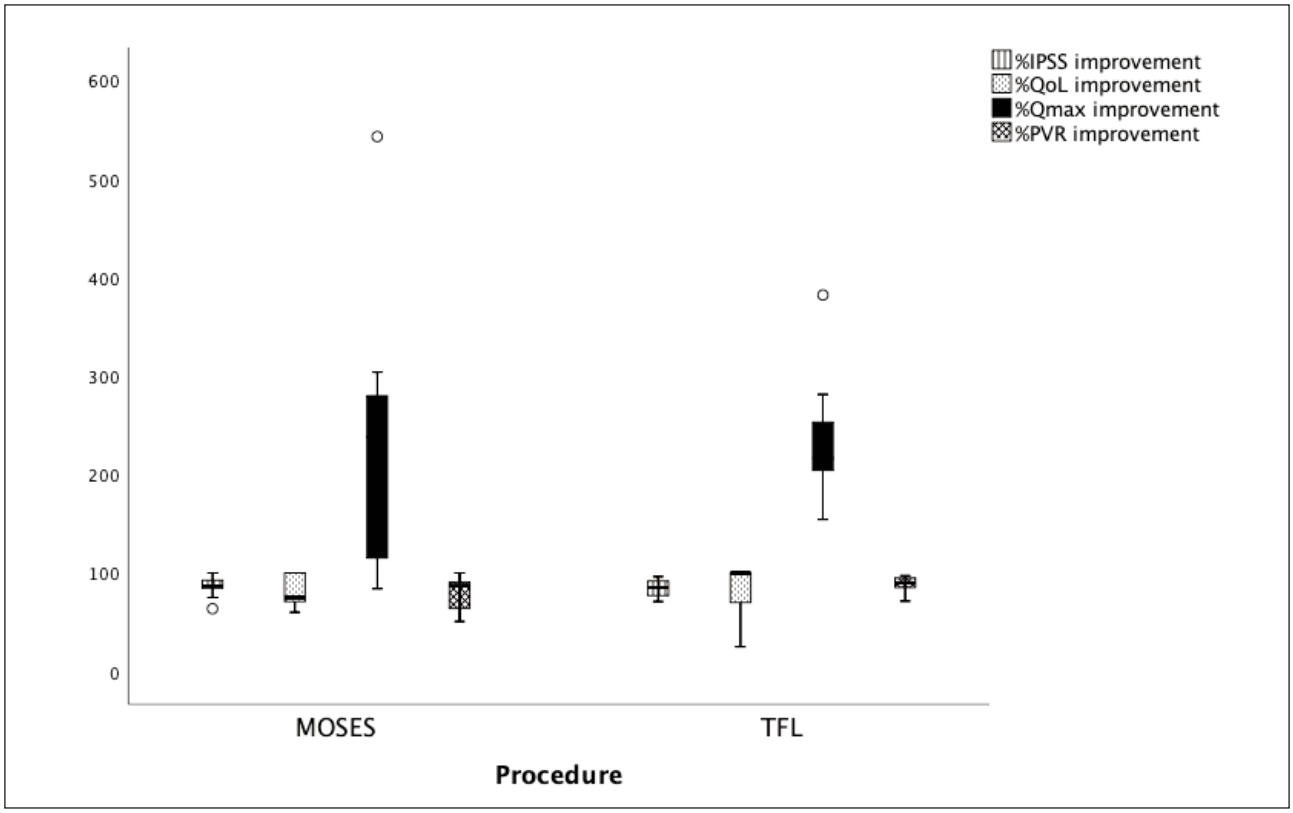
Figure 1.
Functional outcomes comparing MOSES™ to TFL technologies for prostate enucleation.



MOSES™ group compared to the TFL cohort, 10 *vs* 15 minutes, respectively ($p < 0.001$). We observed a higher clarity of vision with MOSES™ due to better hemostasis that facilitated faster morcellation of the adenoma.
Our morcellation time is similar to that of *Large and colleagues* (mean time = 10.4 min) (9). The morcellation time following TFL prostate enucleation is not well documented in the literature.

We cannot compare TOV for MOSES™ and TFL because we adopted a same-day TOV for the MOSES™ cohort, whereas patients who underwent TFL were kept overnight. Similarly, the hospital stay cannot be compared as TFL patients were routinely admitted and discharged the following day. In the current study, same-day TOV following MOSES™ enucleation was successful in about 93.5% of patients.

Figure 2.
Percentage of improvement in IPSS, QoL, Q_{max}, and PVR at 6-months follow-up.



This result seems promising if we compare it with the 88% successful same-day TOV rate, reported by *Slade et al.*, following conventional HoLEP (22).
Although the intraoperative enucleation parameters were better with MOSES™ technology, both TFL and MOSES™ had comparable postoperative outcomes at 6 months follow-up (Figures 1, 2).
Other studies reported similar results for both laser technologies (9, 10, 13, 14).
Our study has some limitations, including its retrospective nature, though it is a retrospective analysis of prospectively collected data. A second limitation is the small number of patients in the TFL group. A similar number of procedures were used to evaluate laser enucleation of the prostate in other studies (10). Moreover, the hospital stay and same-day TOV of both technologies could not be compared.
Our study has a relatively short follow-up period; however, similar follow-up intervals were used in the literature (9, 14). Additional studies with larger sample sizes and more extended follow-up periods are warranted.

Conclusions

To the extent of our knowledge, this is the first study comparing MOSES™ and TFL technologies for transurethral prostate enucleation. A satisfactory safety and efficacy profile with comparable postoperative outcomes was demonstrated for both techniques; though, MOSES™ technology was superior to TFL in terms of shorter overall operative time.

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