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ORIGINAL ARTICLE

Male Health

Adding a vacuum erection device to regular use of Tadalafil improves penile rehabilitation after posterior urethroplasty

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This study aimed to evaluate whether adding a vacuum erection device (VED) to regular use of Tadalafil could achieve better penile rehabilitation following posterior urethroplasty for pelvic fracture-related urethral injury (PFUI). Altogether, 78 PFUI patients with erectile dysfunction (ED) after primary posterior urethroplasty were enrolled and divided into two treatment groups: VED combined with Tadalafil (Group 1, $n = 36$) and Tadalafil only (Group 2, $n = 42$). Changes in penile length, testosterone level, International Index of Erectile Function-5 (IIEF-5) questionnaire, Quality of Erection Questionnaire (QEQ), and nocturnal penile tumescence (NPT) testing were used to assess erectile function before and after 6 months of ED treatment. Results showed that the addition of VED to regular use of Tadalafil preserved more penile length statistically (0.4 ± 0.9 vs -0.8 ± 0.7 cm, $P < 0.01$). IIEF-5 score and QEQ score in Group 1 were higher than Group 2 (both $P < 0.05$). After treatment, 21/36 (58.3%) Group 1 patients and 19/42 (45.2%) Group 2 patients could complete vaginal penetration. Group 1 patients also had markedly improved testosterone levels ($P = 0.01$). Unexpectedly, there was no significant difference in NPT testing between two therapies. For PFUI patients with ED after posterior urethroplasty, the addition of VED to regular use of Tadalafil could significantly improve their conditions – improving erection and increasing penile length – thus increasing patient satisfaction and confidence in penile rehabilitation.

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INTRODUCTION

Pelvic fracture-related urethral injury (PFUI) usually leads to erectile dysfunction (ED).¹ In addition, posterior urethroplasty, often used for repair, may cause secondary damage resulting in poor erectile function.² Although surgical techniques have been adopted to protect the nerves, the incidence of postoperative ED in these patients remains high (20%–80%).³ In addition, psychologically based ED may be triggered in patients who have had no sexual activity or spontaneous erections for a prolonged period before receiving treatment.⁴

Various approaches for ED treatment have been developed, including the use of phosphodiesterase type 5 inhibitors (PDE-5Is),⁵ vacuum erection devices (VED),⁶ drug injection therapy,⁷ low-intensity extracorporeal shock-wave therapy,⁸ autologous stem cells injection therapy,⁹ and penile prostheses.¹⁰ The European Association of Urology guideline (2017) recommended both PDE-5Is and VED as first-line clinical treatments for ED. PDE-5Is, such as Sildenafil and Tadalafil, have been widely accepted as the basic treatment, although up to 35% of patients with ED fail to respond.¹¹ It is therefore necessary to combine oral PDE-5Is with other treatments. VED is a good, noninvasive candidate that can increase penile blood flow by creating negative pressure.¹² Artificial erections induced by VED are thought to minimize

pathophysiological changes such as cavernous tissue fibrosis.^{13,14} The 2018 American Urological Association guideline recommended VED as an effective therapy for the general ED population as well as in men with diabetes, spinal cord injury, and postprostatectomy, among other conditions.¹⁵

With our increasing understanding of ED, the concept of penile rehabilitation has been offered to protect the injured penis from pathophysiological changes.¹⁶ Several studies have reported that application of VED combined with PDE-5Is is beneficial to penile rehabilitation in men with ED due to radical prostatectomy (RP).^{17,18} Compared with prostate cancer patients, however, men with PFUI are generally younger and do not suffer from a cellular regulation disorder. They also have different surgery-related incision and injury sites. Thus, it is not sure whether the same efficacy holds for ED patients after PFUI surgery. To date, we have been unable to find any compelling study that has focused on solving erectile problems in PFUI patients by combining VED with PDE-5Is.

In our previous study, we showed that Sildenafil was effective in these patients.¹⁹ When used as basic treatment, however, the short-acting Sildenafil was far from fulfilling expectations. The frequent use of the medication to maintain an adequate plasma concentration

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could disrupt sexual activity and give rise to side effects. In contrast, long-acting Tadalafil is well tolerated and allows patients and their partners to disconnect the administration of medication from sexual activity.²⁰ Hence, in the present study, based on the use of oral Tadalafil, we evaluated whether the addition of VED could further benefit penile rehabilitation in ED patients who undergo PFUI-related posterior urethroplasty.

PATIENTS AND TREATMENTS

Between January 2012 and December 2016, patients who had undergone successful primary posterior urethroplasty for PFUI were recruited at the time their urethral catheter was removed (4 weeks after surgery). Inclusion criteria for the study were the presence of ED after primary posterior urethroplasty for PFUI, a need for active treatment for ED. Patients were excluded if they had a comorbidity (coronary artery disease, hypertension, and diabetes mellitus), resection of the inferior margin of the pubic symphysis during the urethroplasty, and/or a history of ED before the trauma. ED was diagnosed and evaluated using the International Index of Erectile Function-5 questionnaire (IIEF-5) (score <21) combined with a Quality of Erection Questionnaire (QEQ) score, and nocturnal penile tumescence (NPT) testing. Written informed consent was obtained from patients, and the study was approved by the ethics committee of Shanghai Jiao Tong University Affiliated Sixth People's Hospital (No. 2009-106).

Before enrolling in the study, all patients were well informed regarding the treatment options, including a discussion of their benefits and risks/burdens. After the urethral catheters were removed, the patients were grouped according to their intention. Patients in Group 1 were instructed to use the VED without a constriction ring for 10 min twice a day, which was combined with Tadalafil (10 mg by peros) once every other day for 6 months. Patients in Group 2 were treated with Tadalafil (10 mg by peros) once every other day for 6 months. The VED (Osbon; Timm Medical Technologies Inc., Fort Washington, PA, USA) used in this study was manually operated.

Parameters measurement

The posterior urethral stricture length was measured by urethrography (Figure 1). We also measured the length of the urethral stricture in the operation. When it was inconsistent with the urethrography, we recorded the intra-operative measurement as accurate. The information on the time interval from trauma to surgery was collected. Testosterone levels of each patient were determined before and after the 6-month treatment period. Patients were also required to complete the IIEF-5 and QEQ at these two points in time. As a supplement to the questionnaires, after 6 months of treatment, the patients were asked if they could complete vaginal penetration. Vaginal penetration was defined as the ability to penetrate without the help of a VED, regardless of whether the patients ejaculated.

The stretched penile length (SPL) was defined as the distance from the pubo-penile skin junction to the urethral meatus with the glans uncovered.²¹ With the patient in supine position, the SPL was measured with the penis perpendicular to the body before (SPL0) and after (SPL1) 6 months of ED treatment. Penile length change was then calculated by the formula $SPL1 - SPL0$. The ruler was positioned firmly against the pubo-penile skin junction to ensure maximum pressure of the prepubic fat pad. Duplicate measurements were performed each time.

Normal NPT testing was conducted using the RigiScan Plus Assessment System (version 5.02; Timm Medical Technologies Inc., Eden Prairie, MN, USA), which was manipulated according to the

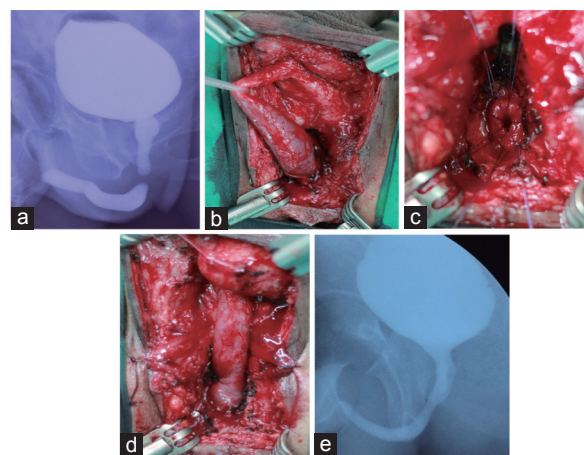


Figure 1: A representative case of posterior urethroplasty. (a) Posterior urethral atresia shown by urethrography. (b) During the operation, the bulbar urethra was separated from corpus cavernosum. (c) After urethral scar was removed, proximal normal urethra was sutured with 8-needle sutures. (d) Then, the distal urethra was sutured to the proximal urethra by end-to-end anastomosis. (e) After the urethral catheter was removed (4 weeks postoperatively), the urethral anastomotic site was wide enough on the urethrography.

manufacturer's instructions. The number of erectile events, event duration, and average event rigidity were recorded.

Statistical analysis

All results were expressed as means \pm standard deviation (s.d.). All samples were analyzed using either the *t*-test or analysis of variance using SPSS version 19 software (IBM, Inc., Armonk, NY, USA) within and between the groups. $P < 0.05$ was considered to indicate statistical significance.

RESULTS

Altogether, 78 patients who underwent primary posterior urethroplasty (Figure 1) for PFUI and who experienced postoperative ED were enrolled and divided into two treatment groups: VED combined with Tadalafil (Group 1, $n = 36$) and Tadalafil only (Group 2, $n = 42$). No recurrence of urethral stricture was observed during the study, and the voiding flow rate reached a normal level ($>15 \text{ ml s}^{-1}$) in both groups (Supplementary Figure 1). Several patients complained of pain or discomfort due to improper use of the VED. Once they became experienced with the equipment (with guidance from doctors), however, no further treatment-related adverse events were reported. The patients exhibited little mobility and good compliance. None of the patients in either group dropped out of the study. As shown in Table 1, there were no statistically significant differences between the two groups at baseline for patient age ($P = 0.34$), body mass index ($P = 0.11$), length of the urethral stricture ($P = 0.39$), or interval from trauma to surgery ($P = 0.49$).

After ED treatment, the mean IIEF-5 score was significantly higher in Group 1 than in Group 2 ($P < 0.01$, Table 2). The overall improvement in the IIEF-5 score was approximately 8 points in the VED group. Moreover, the QEQ data suggested that the erectile scores in Group 1 were significantly higher than those of Group 2 ($P = 0.01$, Table 2). In addition, more patients in the treatment-combination group commented on how they felt empowered and were more amenable than those in the other group to take an active role in later treatments.

After treatment, 21/36 (58.3%) patients in Group 1 and 19/42 (45.2%) in Group 2 could complete vaginal penetration. Some patients

Table 1: Patients' characteristics

	Group 1 (n=36)	Group 2 (n=42)	P
Age (year), mean±s.d. (range)	32.3±7.1 (20.0–47.0)	33.9±7.2 (20.0–48.0)	0.34
BMI (kg m ⁻²), mean±s.d. (range)	23.2±2.2 (17.9–27.7)	22.5±1.8 (17.6–27.1)	0.11
Length of urethral stricture (cm), mean±s.d. (range)	3.1±0.8 (2.0–5.0)	2.8±0.7 (2.0–5.0)	0.39
Interval from trauma to surgery (month), mean±s.d. (range)	7.0±2.5 (4.0–14.0)	7.5±2.9 (3.0–15.0)	0.49

s.d.: standard deviation; BMI: body mass index

Table 2: Self-reported indexes for the two groups

	Group 1 (n=36)	Group 2 (n=42)	P
Vaginal intercourse, n (%)	21 (58.3)	19 (45.2)	0.25
IEFF-5 score, mean±s.d. (range)			
Before treatment	8.3±3.1 (4.0–16.0)	8.5±3.2 (4.0–17.0)	0.79
After treatment	16.8±4.2 (9.0–30.0)	13.9±4.2 (3.0–21.0)	0.00*
QE score, mean±s.d. (range)			
Before treatment	9.3±3.0 (6.0–18.0)	9.6±3.6 (6.0–21.0)	0.73
After treatment	18.1±4.0 (9.0–26.0)	15.8±3.6 (9.0–24.0)	0.01*

*P<0.05 indicates statistical significance. s.d.: standard deviation; IEFF-5: International Index of Erectile Function-5; QE: quality of erection questionnaire

who had successful vaginal penetration in both groups, however, could not sustain as much rigidity as desired. Interestingly, when we evaluated the circulating testosterone levels, we found marked improvement in both groups. At the end of the follow-up, however, the combination-treatment group had a significantly higher testosterone level ($P = 0.01$, **Table 3**).

To further assess the therapeutic effect of adding the VED to the Tadalafil, we analyzed the results of objective measurements. Notably, the change in penile length showed a significant difference between the two groups after ED treatment ($P < 0.01$). There were no statistically significant differences between two groups regarding the number of erectile events, duration of erections, or average tip rigidity (**Table 3**). After treatment, the average tip rigidity was more improved in the combination-treatment group. NPT testing results for representative cases are shown in **Supplementary Figure 2**.

DISCUSSION

PFUI and surgical interventions usually lead to impaired erectile function. Although an impressive micturition success rate has been achieved with this operation,²² the ED has not been well solved, which is a devastating consequence for young patients. In the present study, however, we showed that the addition of VED to regular use of Tadalafil could achieve extra benefits on penile rehabilitation in ED patients who underwent PFUI-related posterior urethroplasty.

VEDs are associated with high rates (>80%) of patient and partner satisfaction.¹⁵ The overall 1-year dropout rate, however, ranges from 10% to 56%.⁶ The main reasons for discontinuing VED usage were bruising and petechiae (5%), numbness (5%), and pain (10%) related to the constriction ring.¹⁷ We did not recommend that patients use these rings during their treatment, which greatly reduced the occurrence of these symptoms. Several patients still experienced discomfort because of their improper use. With physicians' guidance, they eventually became more experienced and adhered to the treatment. Second, penile shortening is a common problem in patients with posterior urethral anastomosis. Our patients chose to continue to use VED when they were told that using it might protect the penile length and prevent further penile shortening. Finally, the treatment options were carefully

considered by the patients from the aspect of expenditure before they enrolled in this study.

In a prospective cohort of patients suffering from Peyronie disease, Antonini *et al.*²³ suggested that 3 min twice daily of VED after inserting the inflatable penile prosthesis was sufficient to continue penile curvature correction. However, in the literature, we found that a VED regimen of 10–15 min daily was generally adopted.^{10,24,25} Unlike with Peyronie disease or RP, the ED after PFUI urethral surgery was mainly traumatic, and the erectile function of these young patients declined or even disappeared within a short time.

The present study appears to be the first clinical study using VED combined with Tadalafil to treat ED after PFUI, so there was no regimen to follow regarding the appropriate duration of treatment. According to the experience at our center, 10 min twice daily was easy for patients with PFUI to follow, with some flexibility. If patients experienced pain or discomfort, they could discontinue the treatment for enough time to relieve the pain and then restart and continue to increase each session until 10 min was achieved.

For PFUI patients, the recovery of erectile function after ED treatment is certainly the most concerning issue. Is it more difficult to recover with a longer stenosis? Although it is likely that the longer the stricture, the more difficult is the recovery of erectile function, there is little evidence currently on which to base an answer to this question. Fu *et al.*¹⁹ noted that the severity of the urethral injury influenced the occurrence of traumatic ED, and longer urethral strictures might be associated with a higher incidence of ED. In the present study, the average stricture was relatively short, and the response of patients to ED treatment was favorable. After ED treatment, the self-reported scores indicated that the regular use of Tadalafil effectively promoted the recovery of erectile function in these patients, although they could further benefit from the addition of a VED. Compared with pretreatment, the erection duration and average tip rigidity had clearly improved in both groups after ED treatment, indicating that the patients in both groups responded well to their regimens. Furthermore, there was no more improvement in nocturnal erection in the combination group than in the Tadalafil-only group.

Another issue of great concern to patients is penile shortening. In most PFUI patients, scar removal and urethral end-to-end anastomosis during urethroplasty results in reduced penile length. It is noteworthy that if no treatment strategy is adopted to promote penile rehabilitation after posterior urethroplasty, penile length would be further shortened because of fibrotic changes in the corporeal bodies due to cavernosal hypoxia and penile denervation.^{21,25} To avoid or mitigate such negative changes, early and effective interventions should be recommended to patients who are concerned about their penile length. Both Tadalafil and VED had been proved to be effective for preserving penile length. In a prospective study, investigators analyzed the role of Tadalafil rehabilitation after RP. At 6 months, significant loss of length was noted between the control and Tadalafil groups (11 mm vs 7 mm).²⁶ In another study, investigators concluded that the early use of VED (4 weeks after RP) preserved approximately 0.8 cm more penile length than in the nonintervention

Table 3: Objective indexes for the two groups

	Group 1 (n=36)	Group 2 (n=42)	P
Penile length change (cm), mean±s.d. (range)	0.4±0.9 (-1.6–1.8)	-0.8±0.7 (-2.3–0.8)	0.00*
Testosterone (nmol l ⁻¹), mean±s.d. (range)			
Before treatment	10.3±3.4 (5.5–17.7)	11.2±4.3 (4.6–22.5)	0.34
After treatment	18.2±3.6 (11.1–25.6)	16.0±4.0 (10.1–26.1)	0.01*
NPT testing			
Event number before treatment, mean±s.d. (range)	2.9±2.3 (0–10.0)	2.6±2.0 (0–7.0)	0.48
Event number after treatment, mean±s.d. (range)	3.1±1.7 (0–7.0)	3.0±1.6 (0–6.0)	0.66
Event duration before treatment (min), mean±s.d. (range)	6.8±4.1 (0–17.0)	7.1±4.1 (0–17.0)	0.80
Event duration after treatment (min), mean±s.d. (range)	12.3±4.2 (5.0–20.0)	13.0±4.8 (6.0–24.0)	0.44
Event rigidity before treatment (%), mean±s.d. (range)	17.7±10.7 (0–41.0)	18.3±12.2 (0–45.0)	0.81
Event rigidity after treatment (%), mean±s.d. (range)	29.2±11.2 (8.0–55.0)	25.0±10.2 (6.0–45.0)	0.09

*P<0.05 indicates statistical significance. s.d.: standard deviation; ED: erectile dysfunction; NPT: nocturnal penile tumescence

group at 6 months.²⁵ In the present study of PFUI patients, we showed that the addition of VED preserved more penile length. The most plausible explanation is that VED mimics the daily spontaneous erections experienced by men with normal erectile function. Treatment with Tadalafil results in more well-oxygenated blood being regularly provided to the penis by a vacuum effect. This might play a vital role in inhibiting fibrotic changes as well as preserving penile tissue health.²⁷

VED combined with Tadalafil achieves extra benefits by providing well-oxygenated components through active and passive relaxation of the smooth muscles in the corpus cavernosum. It has been proved that the oxygen pressure in the corpus cavernosum was significantly higher during the erectile state than in the flaccid state.¹⁷ Therefore, the absence of spontaneous erections would result in a relatively hypoxic environment in the corpus cavernosum. In a rat model, researchers found that a long-term single daily dose of Tadalafil prevented reduction of the corporal smooth muscle cell content due to cavernosal nerve damage.²⁸ Tadalafil actively relaxed cavernosal smooth muscles and arteries through the classic nitric oxide–cyclic guanosine monophosphate pathway, thus increasing arterial blood to penile tissue. The vacuum effect of VED would cause passive relaxation of penile tissue. In the rat RP-induced neuropraxia model, Yuan *et al.*¹³ showed that the use of VED could effectively improve local cavernous blood oxygen tension by bringing more arterial inflow and preserving erectile function through anti-hypoxic, anti-apoptotic, and anti-fibrotic mechanisms. In another study conducted to assess the changes in penile tissue oxygenation, use of VED significantly increased corporal blood oxygen by 55% for 60 min compared with baseline.²⁹ Overall, regular use of Tadalafil actively relaxed the corporal smooth muscle cells to improve the oxygen supply, which was partly augmented by addition of VED.

In a recent study, researchers found that 65 (57%) of 115 men in an urethral stricture group were in a state of low testosterone (total testosterone ≤10.4 nmol l⁻¹), compared with 28% of age-matched men in a public database.³⁰ In this study, we also observed low circulating testosterone levels in ED patients before undergoing treatment. After treatment, the testosterone level was significantly higher in the combination-treatment group than in the Tadalafil-only group. It is likely that the early use of VED facilitated sexual activity, thereby increasing the confidence and enthusiasm of both the patients and their partners, which subsequently resulted in more sex hormone secretion that could assist in facilitating penile rehabilitation.

Our study has several limitations. It was a nonrandomized study. The grouping procedure reflected the choices of patients, which might lead to a selection bias. There may have been wealthy patients or patients with higher testosterone levels who were more motivated

to be in the combination-treatment group. Also, the Tadalafil dosage was experimental for the patients with ED as it had not been established in the European Association of Urology or the American Urological Association guideline. After follow-up, the patients had good compliance with this dosage (10 mg once every other day). The results would be more convincing if a VED monotherapy group had been included, but it would have been difficult because the significant benefits of penile rehabilitation using PDE-5Is were already known. Finally, we could not determine the proportion of natural recovery of erectile function in PFUI patients as all the patients wanted to engage in rehabilitation therapy.

CONCLUSIONS

We uniquely showed that VED combination therapy could achieve extra benefits for penile rehabilitation in patients who had undergone PFUI-related posterior urethroplasty. The addition of VED to regular use of Tadalafil significantly reduced their subjective concerns associated with ED and preserved more penile length, thereby increasing patient satisfaction and confidence in penile rehabilitation. Future clinical studies with larger cohorts and longer follow-up periods are needed to validate our findings.

AUTHOR CONTRIBUTIONS

LJS and QF conceived of the study, carried out the surgeries, and participated in its design, coordination, and statistical analysis. DLZ and ZC carried out the collection and analysis of the data and drafted the manuscript. FXW carried out the collection of data. JZ and HX carried out the surgeries and participated in its follow-up. ZYW and YBG helped carry out this study and edit the manuscript. All authors have read and approved the final version of the manuscript and agree with the order of presentation of the authors.

COMPETING INTERESTS

All authors declared no competing interests.

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Supplementary Information is linked to the online version of the paper on the *Asian Journal of Andrology* website.

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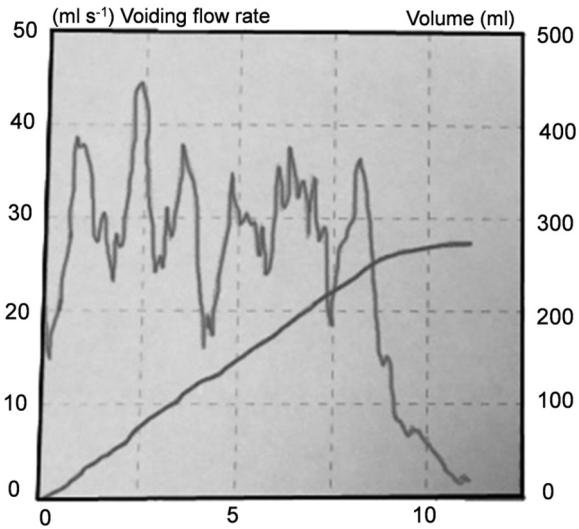
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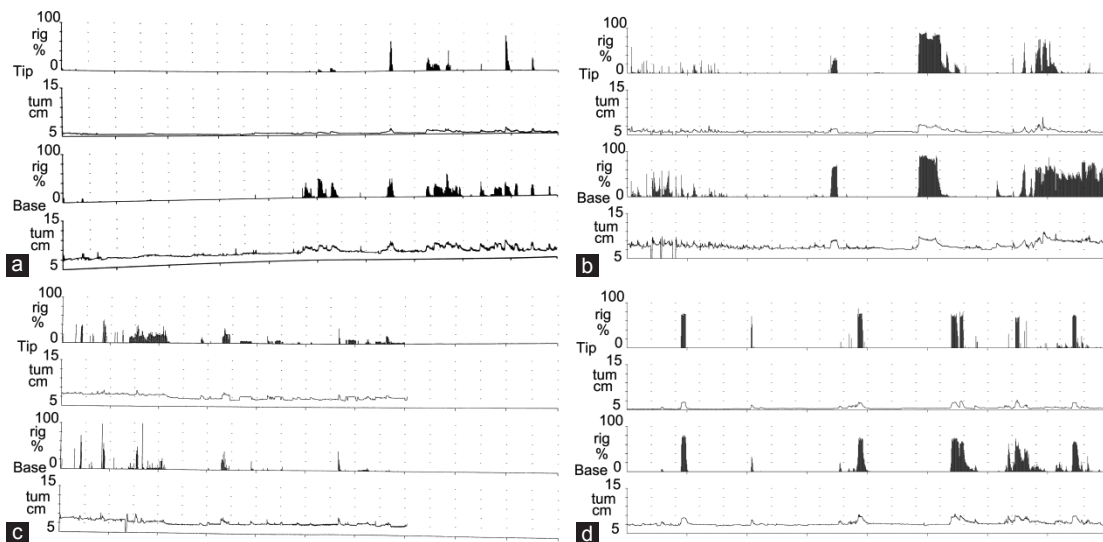
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Supplementary Figure 1: The patient was the same case represented in **Figure 1** who had undergone a successful posterior urethroplasty. The voiding flow rate reached a normal level ($>15 \text{ ml s}^{-1}$).



Supplementary Figure 2: NPT testing results of typical cases. Typical case in Group 1: 25-year-old man, 6 months after traffic accident. Compared with before treatment (**a**), the event duration and average event rigidity were obvious improved after undergoing 6 months of ED treatment (**b**). Typical case in Group 2: 30-year-old man, 7 months after injury. Conditions before (**c**) and after (**d**) treatment were observed. Both patients reported better erectile function after ED treatment. ED: erectile dysfunction; NPT: nocturnal penile tumescence.