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INVITED REVIEW

Operational Andrology

Modern treatment strategies for penile prosthetics in Peyronie's disease: a contemporary clinical review

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Peyronie's disease is a common condition resulting in penile deformity, psychological bother, and sexual dysfunction. Erectile dysfunction is one common comorbid condition seen in men with Peyronie's disease, and its presence significantly impacts treatment considerations. In a man with Peyronie's disease and significant erectile dysfunction who desires the most reliable treatment, penile prosthesis placement should be strongly considered. In some instances, such as those patients with relatively mild curvature, prosthesis placement alone may result in adequate straightening. However, many patients will require additional straightening maneuvers such as manual modeling, penile plication, and tunica albuginea incision with or without grafting. For patients with severe penile shortening, penile length restoration techniques may also be considered. Herein, we provide a comprehensive clinical review of penile prosthesis placement in men with Peyronie's disease. Specifically, we discuss preoperative indications, intraoperative considerations, adjunctive straightening maneuvers, and postoperative outcomes.

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INTRODUCTION

Peyronie's disease (PD) is characterized by disordered collagen deposition within the tunica albuginea (TA) of the penis.[1] Local trauma, thought to occur most commonly during sexual intercourse, induces a host of cellular processes characterized by inflammation and fibrosis.[2] The resultant scarring may cause penile curvature or indentation deformity, penile pain, sexual dysfunction, and psychological bother.[3] The incidence of PD varies based on the population studied, but estimates suggest that 0.4%–13% of men are affected.[4–6]

Erectile dysfunction (ED) in and of itself is also common. The Massachusetts Male Aging Study found that approximately 50% of men between the ages of 40 and 70 years reported at least mild ED, with increasing prevalence seen with advanced age and a variety of medical comorbidities (**Table 1**).[7,8] In a man with PD who describes inability to engage in penetrative intercourse, it is necessary to differentiate whether the functional disability is due to penile deformity (such as in the case of severe curve or hinge effect) or to poor erections, as ED is seen in 30%–50% of PD patients.[9,10] Placement of a penile prosthesis with additional straightening maneuvers represents the most rapid and reliable treatment for PD with medication-refractory ED. Further, not infrequently, the presence of penile deformity will only be identified at the time of prosthesis placement, either when an artificial erection is performed at the start of the case or when curvature is appreciated after the cylinders are placed.[11] In the absence of consistent erections, patients may not appreciate underlying penile deformity, and palpable scarring can be subtle and missed during preoperative examination. Thus, it is imperative that all urologists who perform penile prosthesis placement are well versed in treatment options for penile deformity when encountered intraoperatively. Herein, we provide a modern review of the approach to penile prosthesis placement in patients with penile deformity resulting from PD.

PEYRONIE'S DISEASE EVALUATION

Historically, PD has been thought of as two distinct phases. The acute or "inflammatory" phase is characterized by pain and progressive deformity.[12] Mulhall and colleagues[9] found that nearly 50% of patients with untreated PD in the acute phase experienced deformity progression. In contrast, the chronic or "stable" phase is characterized by pain improvement and deformity stabilization. The disease course is highly variable and there are no absolute criteria for defining the transition from the acute to chronic phase. PD can be diagnosed based on history and physical examination alone, but adjunctive testing including formal curvature assessment with injection of an erectogenic agent and penile ultrasonography provide useful information.[1,13] Important historical elements include symptom duration and presence of pain, curvature, indentation-deformity, instability ("buckling" or "hinge"), penile sensory changes, loss of length and/or girth, and history of penile trauma (often during intercourse). All patients should be queried about the presence of sexual dysfunction including premature or delayed ejaculation and ED. In the man who reports ED, a morning serum total testosterone is indicated, with additional screening laboratories to detect underlying medical comorbidities (such as a fasting blood glucose or lipid panel) at the treating physician's discretion.[14]

PEYRONIE'S DISEASE TREATMENT

Noninvasive treatment options for PD vary widely and include a variety of oral therapies, penile traction therapy (PTT), and intralesional injections (ILIs).[15] The decision to pursue one treatment strategy over

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another is dependent on symptom severity and duration of deformity stabilization ("acute" *vs* "chronic" phase) (**Figure 1**). In the man with minor deformity and minimal distress, observation alone is reasonable. This is true regardless of the symptom duration. Data on the natural history of PD suggest that 40%–50% of patients in the acute phase experience symptom progression, and this should be discussed with patients electing observation.[9,16]

Oral therapies suffer from a relative paucity of supportive literature, and the American Urological Association guideline for PD recommends against a variety of oral medications due to a lack of supportive data.[1] Despite this, several oral agents continue to be utilized by many PD authorities.[15] PTT may be used as monotherapy or as part of a multimodal treatment protocol with ILI.[17] There is also mounting evidence to suggest possible improvements in penile length and curvature when PTT is used during either the acute or chronic phases.[18,19] PTT requires a highly compliant and motivated patient; daily use for 3–8 h may be necessary to optimize benefits.[20] ILI with interferon-α2b (INF), verapamil, and collagenase *Clostridium histolyticum* may be used for PD for acute and chronic PD, with studies supporting modest improvements in penile curvature averaging 0°–20°.[21] Verapamil and INF may also be beneficial for treating penile pain in some patients with PD.[22,23]

Table 1: Risk factors for erectile dysfunction

Medical history	*Social history*
Hypertension	Smoking
Hyperlipidemia	High alcohol intake[a]
Metabolic syndrome	Opioids
Cerebrovascular accident	Marijuana
Diabetes	
Obstructive sleep apnea	
Coronary artery disease	
Peripheral vascular disease	
Myocardial infarction	
Hypogonadism	
Prostate cancer therapy	
Radical prostatectomy	
Radiation therapy	
Cryotherapy	
Pelvic surgery	
Neurologic disorders	

[a]Moderate alcohol intake may actually improve erectile function

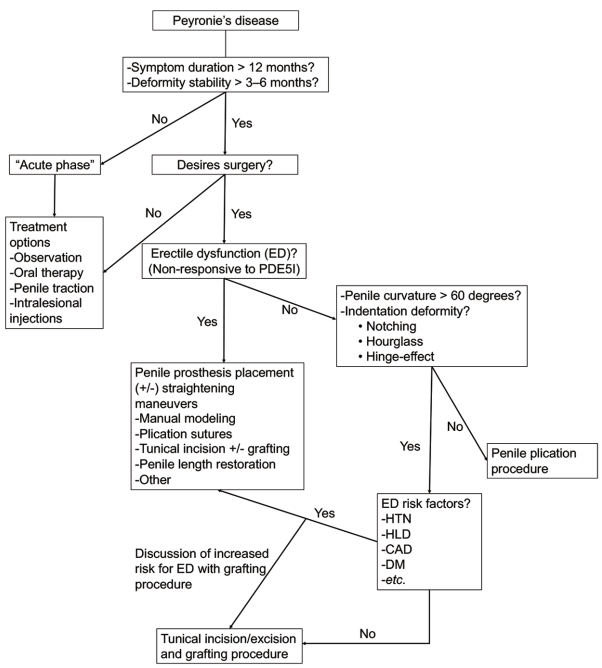

Figure 1: Peyronie's disease treatment algorithm. PDE5I: phosphodiesterase 5 inhibitor; HTN: hypertension; HLD: hyperlipidemia; CAD: coronary artery disease; DM: diabetes mellitus; +/–: with or without.

Despite the availability of nonsurgical options, surgical straightening represents the most rapid and reliable form of deformity correction.[24] Three general approaches are considered based on the degree of deformity and presence of concurrent ED.[25] Specifically, these include penile plication, plaque incision or excision with grafting, and penile prosthesis placement (with or without additional straightening maneuvers) (**Figure 1**). The first step in the PD treatment algorithm for a patient who desires surgical straightening is to determine whether or not ED is present. This involves administration of validated ED questionnaires such as the International Index of Erectile Function (IIEF) or the Erection Hardness Score (EHS).[26,27] Another option is to simply ask the patient some variation of the question: "Based on your current erections, if your penis were straight, would you be able to have satisfactory penetrative intercourse?"[28] If the answer to this question is yes, or if the patient has no or mild ED with or without phosphodiesterase 5 inhibitors (PDE5Is), surgical straightening without a prosthesis is an option.

Plication or grafting should be performed in the man with bothersome deformity that has been present for at least 12 months, with greater than 3–6 months of stable symptoms.[1,25,29] In the patient with mild-to-moderate curvature (<60°), adequate penile length, and absence of severe indentation, hourglass, or hinge effect, a plication procedure is indicated.[25,29] Alternatively, if the deformity is more severe or there is significant concern about additional penile shortening, a grafting procedure with plaque incision or partial excision should be performed.

Grafting procedures carry an increased risk for ED, presumably due to disruption of the veno-occlusive mechanism located at the interface of the tunica albuginea and underlying corporal tissue during plaque incision or excision, with postoperative rates ranging from 0 to 60% or more.[30,31] Factors such as patient age, curvature severity, preoperative venous leak (on penile ultrasound), and larger tunical defects (graft size) have all been suggested to increase the ED risk.[32,33] In contrast, Taylor *et al*.[28] failed to identify a relationship between preoperative medical comorbidities or vascular parameters and postoperative ED. Regardless, a thorough medical history should be performed, and patients with multiple risk factors (**Table 1**) should be counseled about the potential increased risk for postoperative ED.

In those patients with more severe ED despite PDE5Is or in those with severe deformity and risk factors, placement of a penile prosthesis with concurrent straightening maneuvers should be strongly considered.[1,29] ILI or surgical straightening (without prosthesis) and concurrent intracavernosal injections (ICI) with erectogenic medications can be considered as an alternative to prosthesis placement. However, this has the potential disadvantage of predisposing patients to penile fibrosis in response to the injections, thereby exacerbating the deformity.[34]

PENILE PROSTHESIS PLACEMENT AND PEYRONIE'S DISEASE: SPECIAL CONSIDERATIONS

In the man with PD/ED who desires a reliable erection without negative effects on baseline penile sensation, urination, ejaculation, and orgasm,

the penile prosthesis is the treatment of choice.[35,36] Preoperatively, all patients must be thoroughly counseled regarding potential risks including bleeding, infection, injury to surrounding structures, sensory loss, and device mechanical malfunction.[35]

Today, two companies account for the majority of penile prostheses that are placed: American Medical Systems/Boston Scientific (Marlborough, MA, USA) and Coloplast (Humlebaek, Germany). Both companies offer three-piece inflatable penile prosthesis (IPP) and malleable models. Boston Scientific also offers a two-piece device (Ambicor). Historically, the IPP has been favored over malleable rods in patients with PD due to concerns regarding persistent deformity, poor concealment, lack of girth enhancement, and partner dissatisfaction.[1,37,38] However, in certain regions of the world, malleable prostheses are more accessible, often due to cost considerations. A recent report from Habous and colleagues[39] found similar rates of curvature correction and patient satisfaction with the malleable device when compared to IPP.

Any of the three standard approaches for prosthesis placement (penoscrotal, subcoronal, and infrapubic) may be used depending on the surgeon preference and the anticipation of adjunctive procedures (see below). Specifically, if severe curvature or indentation-deformity is present, placing the prosthesis through a subcoronal approach allows excellent exposure for both prosthesis placement and grafting without the need for a second incision.[40,41] Both the Boston Scientific CX700® and Coloplast Titan® are excellent options, with similar high rates of penile straightening and patient-reported satisfaction rates.[42] Chung and colleagues[42] compared outcomes between patients treated for ED/PD between these models. They found no significant difference in terms of device survival, penile straightening, and patient satisfaction (approaching 80% overall). In contrast, due to intrinsic properties of the device that allow expansion in both length and girth, the Boston Scientific LGX IPP is not recommended as it tends to take the shape of the corpora and may actually exacerbate the penile deformity, resulting in a higher likelihood of adjunctive straightening maneuvers.[43]

ADJUNCTIVE STRAIGHTENING MANEUVERS

In the case of mild deformity, prosthesis placement alone may be all that is necessary to create a "functionally straight" penis, commonly defined as a residual curvature of <20°–30°.[1,44] The intrinsic pressures within the tunica during subsequent device cycling are thought to provide further straightening. Straightening maneuvers are necessary in 30%–95% of patients and, not surprisingly, are more common with greater starting curvature (specifically >45°).[43–47] Options include manual modeling, corporal plication, and tunical incision with or without graft placement (**Figure 2**). In the following sections, we describe these procedures in greater detail.

Manual modeling

Modeling refers to the forceful bending of the penis in the direction opposite the curvature. This is performed by the surgeon in the operating room under anesthesia. The technique was first reported by Wilson and Delk[48] in 1994 and is indicated when residual penile curvature in excess of 20°–30° is present after prosthesis cylinder placement. As originally described, the cylinders are placed in standard fashion and maximally inflated. Shodded clamps are placed on the cylinder tubing to protect the scrotal pump from high pressures. One hand grasps the glans penis and distal shaft, while the other hand grasps the proximal shaft and uses the fingers to prevent device herniation at the level of the corporotomies (if they have not yet been closed). The penis is then forcefully bent in the direction opposite the curvature and held for up to 90 s. This is repeated several times with the goal of stretching and rupturing the fibrotic bands within the Peyronie's plaque. In their original series, Wilson and Delk reported an 86% success rate with modeling alone, and subsequent series have confirmed an 80%–100% rate of satisfactory straightening.[42,44,48] The authors identified a 3% risk of urethral perforation, underscoring the importance of preventing undue pressures on the distal cylinder tips.[48] This remains the biggest concern surrounding manual modeling. For this reason, some high-volume implanters, including the originator of the technique, no longer utilize manual modeling.[49]

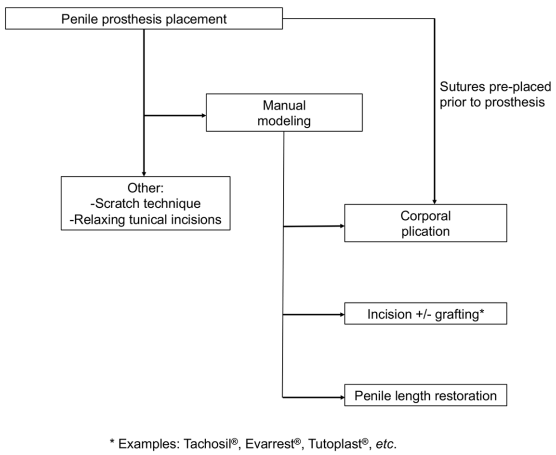

Figure 2: Algorithm for use of additional straightening maneuvers during penile prosthesis placement for men with Peyronie's disease. +/–: with or without.

Levine and colleagues reported a modified-approach to minimize the risk of inadvertent urethral injury.[44,50] Placing the bending hand on the distal penile shaft, as opposed to the glans penis, avoids excessive pressures placed on the cylinder tips (**Figure 3**). The second hand remains on the proximal shaft with the fingers protecting the corporotomies. To date, with this modification, we have not encountered urethral perforation from manual modeling. However, to our knowledge, there has never been a head-to-head comparison between these and other techniques for manual modeling, and in the absence of definitive data, surgeon experience and comfort-level should dictate which modeling technique is utilized. Notably, modeling may be less successful with a malleable prosthesis in place as opposed to an IPP.[45]

If perforation is encountered, the offending cylinder should be removed and a urethral catheter placed. The contralateral cylinder may be left *in situ* if there is no evidence of injury, and in rare circumstances, this may suffice for satisfactory penetration.[51] Otherwise, the ipsilateral cylinder can be replaced after a period of urethral rest (usually 4–6 weeks) to allow for adequate healing.

Plication

Plication is indicated for patients with penile curvature >30° that is less likely to be corrected with prosthesis placement with or without manual modeling alone. Sutures should be placed before cylinder placement. Any of the established techniques may be utilized such as the Nesbit, Lue 16-dot, and tunica albuginea plication. Penile plication was first reported by Rahman *et al.*[52] in 2004. The authors describe placing a pair of permanent sutures through the tunica in the area opposite the curvature to adequately straighten the penis. The sutures are left untied and the prosthesis is placed at which time they can be secured with adequate tension to fully straighten the penis. Alternatively, if penile

prosthesis placement with or without manual modeling adequately straightens the penis, the plication sutures can simply be removed. With a minimum of 22-month follow-up, the authors reported adequate correction of penile deformity in all five patients.

Chung *et al.*[53] subsequently described a modified technique in a single-surgeon cohort of 18 patients. A penoscrotal incision is retracted distally to allow for plication sutures to be placed in the TA before prosthesis placement without the need for formal degloving. The mean preoperative curve of 39° was corrected to <12° in all patients using a median of four plication sutures, and all patients were satisfied. A subsequent report from the same group reported satisfactory straightening to <10° in 30 patients.[11]

Historically, plication procedures for penile straightening have been associated with penile shortening, which is already a significant concern for PD patients undergoing prosthesis placement.[54] Chung *et al.*[53] found that 75% of patients perceived postoperative shortening. This may be more pronounced in the setting of ventral curvature and more severe deformity.[55] Furthermore, plication may actually exacerbate severe indentation deformity such as hourglass, creating an unstable erection.[25] For these reasons, we tend to favor manual modeling for less severe curvature and plaque incision with or without grafting for more severe curvature or in those with severe indentation or hinge effect.

Grafting

Plaque incision with or without grafting is recommended when there is residual curvature >30° after manual modeling or when there is shaft instability due to indentation deformity, despite the presence of the prosthesis cylinders. Plaque incision limits the theoretical risk for additional shortening that is present with plication suture placement, particularly in the setting of more severe curvature.[55] Among patients undergoing prosthesis placement for concomitant ED and PD, 12%–20% may ultimately require plaque incision with grafting to achieve satisfactory straightening.[44,56] The prosthesis can be placed in a standard fashion via a penoscrotal or subcoronal approach. We favor the subcoronal approach for patients with more severe starting deformity (>60° of curvature with or with indentation or hourglass), as we have found there is high likelihood that incision and grafting will be necessary. If a penoscrotal approach is used, and residual curvature beyond 20°–30° ("functionally straight") is identified despite other less invasive adjunctive straightening maneuvers as described above, an additional subcoronal incision may be required for adequate exposure to elevate the neurovascular bundle and expose the area of deformity. Alternatively, a vertical penoscrotal incision with elevation of the skin, Dartos, and Buck's fascia has been described.[57] Once the tunic has been exposed, a transverse incision using electrocautery is performed over the point of maximum curvature to expand the tunical defect. Based on *in vivo* and *in vitro* studies, Hakim and colleagues[58] found that using electrocoagulation current at ≤35 W minimized the risk for underlying cylinder injury. Electrocoagulation is favored over cutting current due to the greater dispersion of heat during energy application. Moreover, it is the heating of the surrounding tissues that appears to predispose the device to injury rather than direct application of energy on the device cylinders. We routinely utilize electrocautery current at 30 W or less as we have found this to provide a satisfactory hemostasis. The edges of the tunical incision may be darted from the lateral aspect of the incision both distally and proximally at 45° (creating a "Y-type" appearance on both sides of the incision) to allow for lateral expansion which will further correct girth irregularities (**Figure 4**). While incision without grafting may provide adequate straightening in 4%–26% of men, if the resulting defect is >2 cm, graft or patch material should be placed for hemostasis and to reduce the risk of cylinder herniation and recurrent curvature, particularly in the setting of IPP placement.[56,59] Due to the lack of device expansion with malleable devices (and thus lower or absent risk for device aneurysm), the surgeon may consider foregoing graft placement despite a larger defect in this setting.[45,60] However, this may predispose to greater risk for bleeding from the underlying exposed corporal tissue in the absence of a graft. As an alternative, some authors have found

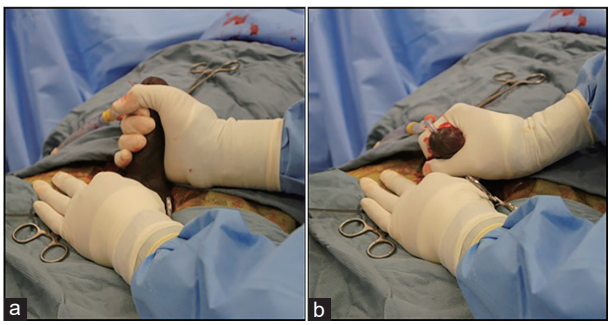

Figure 3: Modified manual modeling technique for residual curvature after inflatable penile prosthesis placement. (**a**) The bending hand is placed on the distal shaft (proximal to the glans) in order to avoid excessive pressure on the cylinder tips and minimize risk for corporal blowout and urethral injury. The second hand remains on the proximal shaft with the fingers over the corporotomies to prevent device herniation. (**b**) The penis is bent in the direction opposite the curve and held for a period of time until the performing physician experiences hand fatigue and is unable to provide consistent force, which is usually in the range of 30–90 s. During this time, there may be an audible "pop" or the sensation of tissue "cracking" within the Peyronie's plaque as the collagen fibers are disrupted.

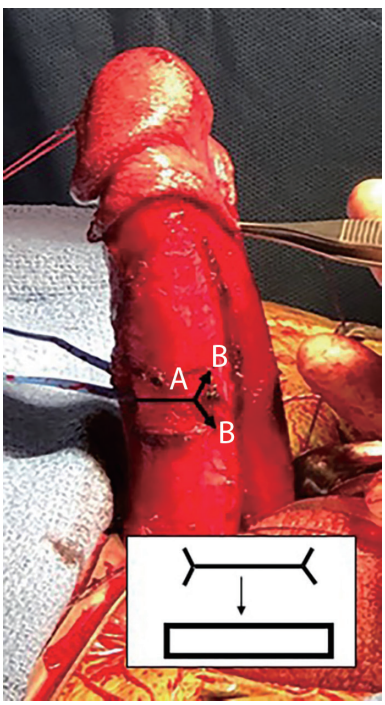

Figure 4: Here, we see the defect after tunical incision with the penile prosthesis cylinders in place for a patient with dorsal penile curvature. The initial transverse incision (A) results in curvature correction, and subsequent 45° "darting" incisions (B) made both proximally and distally at the lateral aspects of the transverse incision results in further expansion and correction of any indentation deformity.

success by creating a series of smaller tunical incisions without graft placement for both malleable and inflatable devices.[60]

Conventionally, a variety of graft materials have been utilized to cover the tunical defect after plaque incision or excision including autologous (vein, tunica vaginalis), cadaveric (human dura mater or pericardium), porcine (small intestinal submucosa [SIS] or pericardium), and synthetic materials, among others.[61] The use of dermal grafts should be avoided at the time of prosthesis placement as they are associated with an increased risk of infection.[62] The most common grafts used today are porcine SIS (Surgisis ES, Cook Urological, Spencer, IN, USA), autologous saphenous vein, and human cadaveric pericardium (Tutoplast, Coloplast Corp.).[31,61] SIS may be prone to graft contraction and is associated with recurrent curvature in approximately 35%–55% of cases.[63,64] Autologous grafts are readily available, yet they may be associated with increased operative time and possibly morbidity from the harvest site.[65] Moreover, the size of the graft is limited. Therefore, we prefer to use Tutoplast human pericardium allograft because it undergoes minimal contraction, holds suture, and is strong and thin much like the TA.[66] This is processed into an acellular matrix that minimizes the inflammatory response and allows for ingrowth of native tissue to support the IPP cylinder over time.[67] The graft can be sized 10% larger than the defect in the TA and can be carefully sutured into place with absorbable suture material.

Traditional graft materials must be sutured to the TA, putting the cylinders at risk for needle puncture. In an effort to avoid suturing, there have been recent reports on the use of hemostatic patches. Hemostatic patches do not require suturing, so they eliminate the risk of needle injury to the IPP (not applicable in the setting of malleable prosthesis placement) and reduce operative time by up to 25 min without an increased risk of IPP herniation.[68] Equine collagen fleece (TachoSil, Baxter Int., Deerfield, IL, USA) has been described for patching the defect with and without IPP placement.[40,68–70] Outcomes appear favorable, with over 80%–100% of patients reporting satisfactory penetrative intercourse postoperatively after IPP and TachoSil grafting.[40,68] For those who find TachoSil difficult to procure, we have found success with Evarrest, a cellulose mesh with thrombin and fibrinogen on the one side (Ethicon Inc., Somerville, NJ, USA). In our experience, the optimal patch size is 0.5 cm larger than the defect on all sides to cover the exposed cylinders with adequate tunical overlap (**Figure 5**). Hemostatic patches such as this are most effective when there is adequate Buck's fascia to cover the patch, as this holds the patch in place to allow for hemostasis (physical compression to prevent bleeding from the exposed corporal tissue at the interface between the prosthesis and the incised tunical edges) and structural support as the surrounding native tunica grows into the gap left by the tissue incision. Graft absorption times are variable but may be as short as 8 weeks for Evarrest and even shorter for other agents such as Nu-Knit.[71] Importantly, to date, we have not encountered a cylinder aneurysm at the site of the hemostatic patch with agents such as Evarrest. However, for longitudinal defects larger than 4 cm, we currently prefer to use pericardium allografts despite the need for suture placement and the longer operative time, as rat models have shown that this graft may persist for periods of 4–6 months or longer.[72,73]

Scratch technique

Perito and Wilson[74] have described another approach, known as the "scratch" technique, as an adjunct maneuver to manual modeling. After creating an artificial erection to identify the plaque location, an infrapubic incision is made and the corpora cavernosa are dilated. Through the corporotomies, the plaque is reportedly disrupted in multiple planes first by spreading transversely across the plaque location with a nasal speculum and subsequently by internally "scratching" the plaque with a hook-bladed scalpel or Metzenbaum scissors. A recent study of 145 patients who underwent the scratch technique, modeling, and IPP placement followed by vacuum device therapy reported an average 55° improvement at nearly 1 year after surgery, without any severe complications.[75] Despite these promising early results, further research including comparative studies and external validation is necessary.

Penile length restoration

Penile length loss is a common concern for patients with PD, and further, perceived length deterioration after surgical intervention can be devastating. It is important to discuss this with patients during preoperative counseling, as at least 30%–40% of patients who undergo IPP placement for ED and/or PD report significant shortening and dissatisfaction with length.[76,77] Safe, reliable, and reproducible techniques for penile length improvement remain the Holy Grail for penile prosthetic surgeons. Various strategies can be used to preoperatively address penile shortening with PD. For instance, when used as monotherapy, PTT has been shown to increase stretched penile length (SPL) by a mean of 0.4–1.5 cm.[78] Moreover, Rybak and colleagues[79] showed that PTT also significantly improves SPL when used as part of a postoperative rehabilitation program after tunica plication (+0.8 cm improvement for mean) and partial excision and grafting (+1.5 cm improvement for mean). Vacuum therapy is another option that may improve penile length by up to 2 cm when used before penile prosthesis placement in the setting of corporal fibrosis.[80]

Several intraoperative options for length optimization at the time of penile prosthesis placement have been described. Unfortunately, using a length-expanding inflatable (LGX IPP; Boston Scientific) penile prosthesis does not appear to result in postoperative length gain.[81] Shaeer and colleagues[82] recently described a dorsal phalloplasty technique whereby a nonabsorbable suture is used to "pin" the dermis under the infrapubic skin to the pubic symphysis. This may improve perceived penile length for the patient, but the true anatomic length is unchanged. Aggressive corporal dilation and measurement of the corpora cavernosa with the penis on full stretch will allow for appropriate cylinder sizing, and subsequent variations of postoperative device cycling protocols have been used to promote stretching of the tissues, but the results are variable.[83,84] Ultimately, it should be emphasized that length gain with these approaches is limited by the intrinsic lack of penile elasticity seen in many patients with ED and in particular those with concurrent PD where the tunical scarring results in a lack of tissue pliability. To address this, multiple penile length restoration procedures have been developed. The majority of these techniques involve various tunical incision patterns that allow for greater tunical stretching with the penile prosthesis cylinders in place. Regardless of the technique performed, the intrinsic elasticity of the neurovascular bundle and/or urethra is the limiting factor with length maximization.

Sansalone *et al.*[85] described a technique for plaque incision with grafting at the time of IPP placement in a series of 23 men with concurrent PD, ED, and associated penile shortening. The approach involves both subcoronal and penoscrotal incisions to allow for the urethra and Buck's fascia along with the neurovascular bundle to be dissected off the TA. A circumferential tunica incision is made at the point of maximum curvature and a circumferential tunical graft is sewn into place. The mean length gain in this series was 2.8 cm and 90% of patients were satisfied with the procedure, despite 20% reporting diminished glans sensitivity. Egydio *et al.*[86] subsequently

described an alternative grafting technique for penile lengthening that does not routinely involve mobilization of the urethra. Through a subcoronal incision, a semi-circumferential tunical incision is started at the concave aspect of the point of maximum curvature. The urethra is mobilized only if it is further limiting length. In their series of 105 men, the mean length gain was 3.6 cm and 89% of men were satisfied with the outcome. At a mean follow-up of 18 months, 99% were able to participate in penetrative intercourse. Three patients (3%) developed graft retraction causing recurrent curvature of <30° in all cases.

The sliding technique is another approach with demonstrated success in several series. First introduced by Rolle *et al.*,[87] this approach should be considered only by experienced, high-volume surgeons. Once the penis is degloved via combined penoscrotal and subcoronal incisions, and the neurovascular bundle and urethra are elevated, longitudinal incisions (>4 cm) are made in each TA. These incisions are connected by hemicircular incisions along the dorsal aspect proximally and along the ventral aspect distally. The penis can then be stretched to the full length of the neurovascular bundle, and the resulting rectangular defects in the TA can be grafted either after malleable penile prosthesis placement or before IPP placement. SIS and porcine dermal matrix grafts were used in the setting of IPP, while collagen fleece was used over malleable penile prostheses. Among 28 patients included in a multi-institutional study, the mean length gain was 3.2 cm.[88] One patient (3.5%) on anticoagulation required a blood transfusion, and two men (7%), both diabetic, underwent penile prosthesis removal for infection. There were no reports of glans necrosis and all hematomas were managed conservatively.

This approach was further adapted as the modified sliding technique (MoST).[89] A single subcoronal incision is made to allow for penile degloving. A similar set of tunical incisions is made, but no graft material is utilized. Instead, Buck's fascia is used to cover the proximal, dorsal defect and the distal, ventral defect is covered by compressed corpus cavernosum and spongiosum. The mean length gain was 3.1 cm among the 143 men who underwent the MoST procedure.[89] All patients were able to engage in penetrative intercourse postoperatively, and there were no device infections.

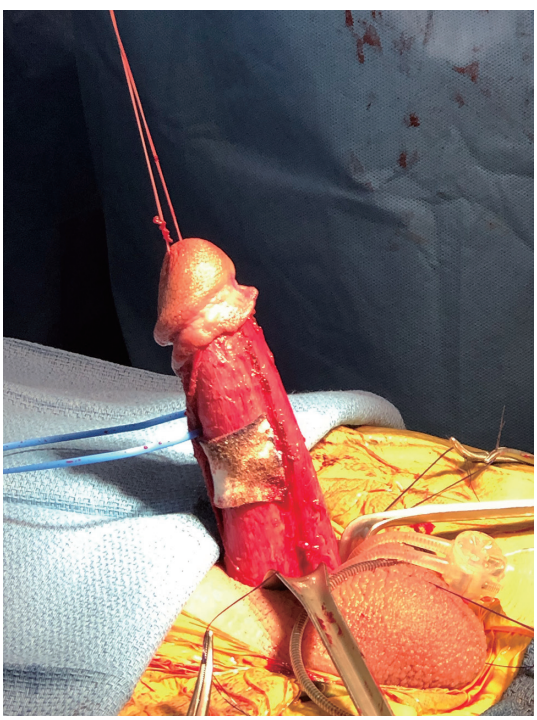

Figure 5: Placement of Evarrest hemostatic patch to cover the tunical defect in conjunction with penile prosthesis placement.

Most recently, an additional modification termed the multiple slice technique (MuST) was reported.[90] This procedure utilizes multiple paired hemicircumferential tunical incisions in conjunction with two longitudinal incisions, thus resulting in a series of smaller tunical defects to theoretically avoid device bulging that can be seen without the placement of a formal graft with the MoST technique. At a median follow-up of 15 months, Egydio and Kuehhas[90] reported an average length gain of 3.1 cm in a cohort of 103 patients, including 60% with PD. No penile prosthesis infections were encountered, but there was one patient who experienced glans necrosis. This rare but devastating complication results from vascular compromise in response to disruption of the glanular arterial supply from the dorsal penile arteries (neurovascular bundle mobilization) and terminal spongiosal arteries (urethral mobilization; **Figure 6**).[91] Suggested risk factors for glans ischemia with IPP placement include various vascular comorbidities (diabetes, cardiovascular disease, and smoking), as well as subcoronal approach, concomitant circumcision, and the sliding technique for length restoration. Other length restoration approaches that involve urethral mobilization and elevation of the neurovascular bundle may also put the glans at risk.[90] To date, fewer than 30 cases of glanular ischemia related to penile prosthesis placement have been reported in the literature, although this is felt to be an underestimation of the true incidence.[92] Prompt identification is of the utmost importance. In the setting of ischemia, the glans will often progress to a dusky purple appearance with or without blistering. The presence of pain is variable. Initial management includes removal of the indwelling urethral catheter and penile wrap (if present). If the device was left partially inflated, it should be immediately deflated to the full extent. Finally, in the absence of obvious and rapid improvement, the penile prosthesis should be removed in an expedited fashion.[92] In fact, in their review of 21 patients with glanular ischemia after penile prosthesis placement, Wilson and colleagues noted that conservative management (observation without device removal for >24 h) invariably resulted in tissue loss and glans necrosis, whereas prompt device removal allowed for glans preservation in all instances if recognized and acted upon within 24 h.[91] This has important implications not only for patient safety but also from a medico-legal perspective. While penile revascularization could be considered, to date, there is a paucity of data to support this as a means of salvaging an ischemic glans, particularly once severe necrosis has set in. Moreover, the insult associated with prosthesis placement and adjunctive maneuvers is likely a global ischemia rather than a focal defect that can be managed with arterial bypass such as in the setting of ED after pelvic trauma.[93] Whether or not these patients can and should receive a subsequent prosthesis after

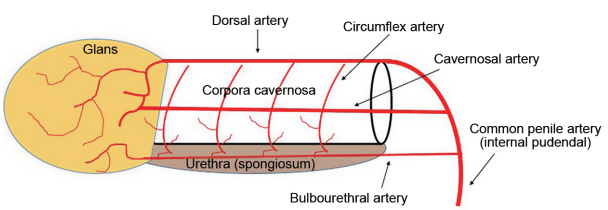

Figure 6: Penile vascular anatomy – the common penile artery branches into the dorsal penile artery, cavernosal artery, and bulbourethral artery. Note the blood supply to the glans penis can be altered by prosthesis placement and mobilization of the urethra and neurovascular bundle, thereby predisposing to glans ischemia.

a period of healing remains unknown, although anecdotal experiences suggest that this may be considered after a period of healing and with careful counseling, presumably due to the development of collateral blood supply to the glans.[91]

DEVICE OUTCOMES

Device survival: mechanical reliability and infection

In general, reliable long-term survival data are lacking due to significant limitations in the currently available literature – this includes the retrospective nature of most studies and a high prevalence of single-surgeon series. Ten-year IPP device survival is estimated at approximately 65%–90%.[94] Mechanical reliability may be higher with the AMS Ambicor (Boston Scientific) and malleable devices. Several studies suggesting 2–3-year mechanical survival rates exceeding 95%, although long-term outcomes data are lacking.[95,96]

Penile prosthesis infection occurs in approximately 1%–3% of devices after primary placement, with a reported rate of 5%–10% seen with revision cases.[97–99] Even in the absence of clinical infection, bacteria and biofilm are present in up to 80% of devices. Historically, organisms such as *Staphylococcus aureus* and *epidermidis* were thought to contribute to the majority of clinical infections.[100] However, in the modern era, Gross and colleagues found a high prevalence of atypical organisms such as anaerobes (10%), *Candida* species (11%), and methicillin-resistant *Staphylococcus aureus* (9%), suggesting the need to revisit empiric antimicrobial therapy.[101]

To date, there is no strong evidence to suggest that PD predisposes to adverse device survival. In fact, in a cohort of 1009 patients undergoing IPP placement, Wilson and colleagues found similar 5-year device survival rates among those patients undergoing penile prosthesis placement for ED with and without concurrent PD.[102] Furthermore, the use of adjuvant straightening maneuvers for PD was not found to increase the risk for device infection in a large cohort of patients.[103] The impact of utilizing more invasive adjunctive maneuvers such as grafting or penile length restoration techniques on overall device survival and infection rates is unknown, and long-term comparative studies are needed.

Satisfaction

The metrics used to assess patient satisfaction with penile prosthesis placement vary widely, yet the overall satisfaction rates are consistently high.[104–106] Modern series report satisfaction rates that exceed 80%–90% by most measures, regardless of technique or type of device used.[39,107–110] In addition, partner satisfaction rates exceed 80% in most series, and the majority of patients acknowledge that they would undergo penile prosthesis placement again if necessary.[77,110–112] Surgeon experience is associated with a greater likelihood of postoperative patient satisfaction, possibly due to the impact of provider experience on patient counseling and expectation setting, surgical technique, cosmetic results, and decreased risk for reoperation.[113]

Several studies have specifically evaluated satisfaction rates in patients undergoing penile prosthesis placement with PD. In their multi-institutional study, Khera and colleagues found that more than 80% of patients with PD were somewhat or very satisfied with their device, and nearly 90% of devices were in-use at 2-year follow-up.[109] Moreover, there was no significant difference in patient satisfaction when compared to those patients who underwent prosthesis placement without PD. Not surprisingly, patients with less residual curvature were more likely to be satisfied. There was also a nearly 50% decline in the rate of patient-reported depression symptoms in men with PD who underwent IPP placement, which has important implications for this disorder that is known to cause severe psychological distress.[3,109]

Penile curvature improvement is another important outcome that contributes to patient satisfaction. As noted earlier, Habous and colleagues reported high satisfaction rates in a cohort of PD patients undergoing penile prosthesis placement using a five-point Likert scale (1: dissatisfied to 5: very satisfied).[39] The majority of patients were satisfied with a similar mean satisfaction score in those who underwent either malleable (mean = 4.4) or inflatable penile prosthesis placement (mean = 4.3; $P = 0.32$). In 2010, Levine and colleagues found that only 73% of patients undergoing IPP for PD were satisfied with their degree of penile straightening.[44] These findings changed our senior author's preoperative counseling and intraoperative decision-making. If the patient has relatively minor curvature and will be satisfied with 20°–30° of penile curvature ("functionally straight), we will stop at manual modeling if this goal is reached. Alternatively, if the patient desires to be "arrow straight," we are more likely to perform additional procedures such as incision and grafting. A recent analysis from our group in 2015 reported outcomes in a cohort of 390 patients undergoing surgical intervention for PD.[25] With a mean follow-up of 17 months, residual bothersome curvature was present in only 9% of patients who underwent IPP, representing a significant improvement in satisfaction related to straightening.

CONCLUSIONS

ED and PD are frequently comorbid conditions. In the patient with penile deformity and ED who desires the most reliable treatment for both conditions, the placement of a penile prosthesis with additional penile straightening maneuvers is an excellent treatment option. Both inflatable and malleable penile prosthesis devices may be used. Prosthesis placement alone may result in satisfactory outcomes, but additional intraoperative interventions such as manual modeling, penile plication, and tunical incision with or without grafting may be indicated to achieve satisfactory penile straightening. Despite limitations in the available literature, penile prosthesis placement for patients with PD is associated with high rates of patient satisfaction.

AUTHOR CONTRIBUTIONS

MJZ and LAL conceived the study and participated in its design and coordination. MJZ, MRF, and LAL helped draft the manuscript. All authors read and approved the final manuscript and agreed with the order of presentation of the authors.

COMPETING INTERESTS

LAL is a paid consultant for Boston Scientific and Coloplast corporations. This in no way impacted the study design, manuscript composition, or decision to submit the current review for publication.

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