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REVIEW

Surgery for Peyronie's disease

Laurence A Levine and Stephen M Larsen

Peyronie's disease (PD) is most simply referred to as a fibrotic wound-healing disorder of the tunica albuginea. It is both a physically and psychologically devastating disorder that causes penile deformity, curvature, hinging, narrowing and shortening, which may compromise sexual function. Although a variety of non-surgical treatments have been suggested, none to date offer a reliable and effective correction of the penile deformity. As a result, surgery remains the gold standard treatment option, offering the most rapid and reliable treatment which will be the focus of this article. We review the preoperative evaluation, surgical algorithm, graft materials and postoperative management of PD. Outcomes for tunical shortening, tunical lengthening and penile prosthesis placement for penile straightening are reviewed. Tunica albuginea plication is the preferred method of straightening for men with adequate rigidity and less severe disease defined as curvature less than 70° without narrowing/hinging. Men who have more severe, complex deformity, but maintain strong preoperative erectile function should be considered candidates for straightening with plaque incision or partial excision and grafting. Finally, for those men who have inadequate rigidity and PD, penile prosthesis placement with straightening is the best approach to address both problems.
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INTRODUCTION

Peyronie's disease (PD) is most simply referred to as a fibrotic wound-healing disorder of the tunica albuginea. It is both a physically and psychologically devastating disorder that causes penile deformity, curvature, hinging, narrowing, shortening and painful erections.[1] The perceived loss of length and girth is often more disturbing than the curvature itself, all of which can lead to moderate to severe depressive symptoms, emotional, and relationship problems.[2,3] Despite a myriad of treatment options, PD remains a considerable therapeutic dilemma due to several factors including an incomplete understanding of its etiopathophysiology and the relative paucity of randomized, placebo-controlled trials. A general explanation of this disorder, which has gained acceptance, is that PD is a disorder in which genetically susceptible individuals experience a localized response to endogenous factors such as tumor growth factor-β, which are released in response to microtrauma. This can lead to biological transformation of cells within the tunica albuginea, cell cycle dysregulation, genotypic changes and increased expression of cytokines and free radicals. This inflammatory response leads to unregulated extracellular matrix deposition including fibronectin and collagen, and ultimately plaque scar formation, which does not appear to undergo proper scar remodeling, leaving an inelastic segment in the involved tunica albuginea.[4–9]

Although a variety of non-surgical treatments have been suggested, none offer a reliable and effective correction of the penile deformity.[10] As a result, surgery remains the gold standard treatment option, offering the most rapid and reliable treatment which will be the focus of this article.

PREOPERATIVE EVALUATION

The preoperative evaluation of PD is critical for differentiating simple from complex disease, which will in turn dictate what type of surgical approach will be most beneficial to the patient. Levine and Greenfield[11] suggested a standardized evaluation addressing history, physical examination, diagnostic imaging and non-validated questionnaires. The history should specifically address time of onset, pain, deformity, palpable lump, any trauma that may have preceded the onset of symptoms by days to months, and any previous treatments the patient may have undergone. It is useful to ask the patient to estimate the degree and direction of erect penile curvature. However, it has been demonstrated that only 20% of patients accurately report the degree of curvature with 56% overestimating and 26% underestimating curvature with an average difference of 20°, which is why preoperative objective measures of erect deformity are necessary in order to accurately counsel patients, recommend appropriate treatment and objectively evaluate outcomes.[12] The history should also address the presence of indentation, hinging/buckling with axial forces and amount of shortening. Although curvature is the hallmark symptom of disease, shortening can be the most psychologically devastating, occurring in 70% of patients and ranging from 1 to 10 cm.[2,3] Determining whether there is a family history of PD or other fibrotic disorders such as Dupuytren's is also useful as it does appear to occur more frequently among males in the same family and through generations.

Questions regarding pre-Peyronie's erectile status are important and guide surgical planning. Although diminished rigidity may be associated with several underlying medical conditions such as diabetes, smoking and peripheral vascular disease, it may also be psychogenic in nature given the devastating psychological effects that PD has on the affected individual.[2,13] Questions regarding sexual dysfunction should include ejaculation, orgasm, and change in sensation.

Physical examination of the penis is clearly critical. A stretched penile length must be obtained because of the concern for further

Department of Urology, Rush University Medical Center, Chicago, IL 60612, USA
Correspondence: Dr LA Levine (drlevine@hotmail.com)

shortening that may occur with this scarring disorder and/or as a result of surgery. The technique described by Wessells *et al.*[14] is recommended. With the patient in the supine position, the glans is grasped and pulled to full stretch at 90° from the plane of the body.[14] A rigid ruler is used by pressing down on the suprapubic fat pad to the pubic bone, and the penis is measured dorsally to the corona or meatus depending on physician preference.

Preoperative penile sensitivity can be assessed with light touch and biothesiometry, though no standard evaluation of this parameter has been established. Biothesiometry has been suggested to be an indirect measure of penile sexual sensation, as vibratory nerves travel with penile sexual sensory nerves. Intact vibratory sensation should correlate with sexual sensation.

The most important part of the clinical diagnosis and preoperative evaluation is to visually evaluate the penis in the erect state so that objective measures can be made of the deformity. Pharmacologically induced erection *via* injection of vasoactive agent such as papaverine alone, Tri-Mix (papaverine, phentolamine and prostaglandin E1), or prostaglandin alone is the most reliable method when compared to vacuum induced or photograph of office or home erection.[15] This is also useful as it is an indicator of vascular integrity and erectile response to the injected vasoactive drug. If a full erection does not occur, redosing is recommended to try to obtain an erection which is equal to or better than that which can be obtained at home with sexual stimulation. Pressure can also be applied to the base of the penis if needed as psychogenic inhibition during direct observation can be significant. Curvature is then measured in the erect state with a goniometer or protractor, while a simple string can be used to measure girth at the base, subcoronal area and any area of indentation/hourglass narrowing. Duplex ultrasound can also be incorporated in the flaccid condition looking for corporal fibrosis and plaque calcification.[16,17] Recent reports have suggested that up to 30% of men with PD will have plaque calcification, and contrary to previous reports, this can occur early after initial onset of the plaque formation and therefore, may not be an indicator of mature disease.[18] This same study found when using a new Plaque Calcification grading system that 50% of men with extensive calcification underwent surgery of which 77% had plaque incision with grafting.

Indications for surgical reconstruction for men with PD include: (i) stable disease, defined as at least 1 year from onset and at least 6 months of stable deformity; (ii) compromised ability to engage in coital activity due to deformity and/or inadequate rigidity; (iii) failure of conservative therapy; (iv) extensive plaque calcification; and (v) patient desires most rapid and reliable correction once disease is stable. Penile pain is a relative contraindication except when it may be due to a strong erection imparting torque-like pressure on the penis.[19]

Obtaining preoperative consent is a critical aspect of PD management mainly because most patients with PD are distressed and emotionally devastated. It is important to have a frank discussion so that he understands the possible limitations of the operation, and set appropriate expectations regarding outcomes to optimize patient

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I. When rigidity adequate preoperatively with or without oral pharmacotherapy:
  A. Tunica plication when
    i. Curvature < 60°–70°
    ii. No destabilizing hour-glass or hinge
    iii. Predicted loss of length < 20% erect length
  B. Plaque Incision/ Partial Excision and grafting when
    i. Curvature > 60°–70°
    ii. Destabilizing hinge
II. When rigidity suboptimal
  A. Penile prosthesis implantation

Box 2 Peyronie's disease surgical algorithm.

satisfaction.[19,20] One must address the possibility of persistent or recurrent curvature, change in penile erect length, diminished rigidity and decreased sexual sensation (**Box 1**).

Persistent or recurrent curvature is unusual, but has been shown in up to 16% of men.[19,21] The patient should understand that the goal is to make him 'functionally straight', which expert opinion defines as a residual deformity of 20° or less. Change in penile erect length is more likely in plication *vs.* grafting though all surgical correction procedures have been associated with some length loss. This is extremely important for the patient to understand preoperatively as 70%–80% of PD patients initially present with loss of length due to the fibrotic disease process.[19,20] Erectile rigidity will not likely be made better by the procedure, and therefore, consideration for penile prosthesis should be discussed if the patient already has significant erectile dysfunction (ED) preoperatively.[19,21] Decreased sexual sensation has been examined and reported upon infrequently, but it does appear that around 20% of men will describe some reduction in penile sensitivity, rarely interfering with orgasm or ejaculation. Sensory change whether it is hypesthesia or hypoesthesia may occur in the acute postoperative period but tends to resolve over the ensuing months.[22]

SURGICAL ALGORITHM FOR THE MANAGEMENT OF PD
Several surgical algorithms have been published and are summarized in **Box 2**.[23–25]

In men who have rigidity which is adequate for coital activity with or without pharmacotherapy, tunica plication techniques *vs.* plaque incision or partial excision and grafting (PEG) techniques may be employed. Tunica plication techniques are recommended for those who have a simple curve of less than 60–70°, absence of hourglass or hinge effect, and when the anticipated loss of length would be less than 20% of the total erect or stretched length. Plaque incision or partial excision and grafting is recommended for those men with more complex curves of greater than 60–70° and/or have a destabilizing hourglass or hinge effect. These men should have strong sexually induced rigidity to reduce the likelihood of postoperative ED.[26,27] (**Box 3**).

In the man with PD who also has ED that does not respond to medical therapy, published surgical algorithms have indicated that penile prosthesis placement is the procedure of choice.[23,25,28] This allows for correcting the deformity while addressing the ED as well. If curvature is not satisfactorily corrected after the prosthesis is inflated at the time of placement, additional straightening maneuvers may be performed. The recommended first step is manual modeling, as

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Set expectations regarding outcome
● Persistent/Recurrent curvature
  –Goal, "Functionally straight" < 20°
● Change in length
  –More likely shorter with plication *vs.* grafting
● Diminished rigidity
  –≥ 5% in all studies, especially with grafting
  –Dependent upon pre-op erectile quality
● Decreased sexual sensation
  –Common but infrequently reported to compromise orgasm/ejaculation

Box 1 Preoperative surgical consent issues.

● No significant loss of erectile capacity
● Curvature >60°-70°
● Severe indentation causing unstable erection (hinge effect)
● Extensive calcification
● Understands increased risk of postoperative erectile dysfunction

Box 3 Indications for surgical correction with grafting.

initially reported by Wilson and Delk.[29] If after modeling, there is residual curvature in excess of 30°, then an incision in the tunica albuginea overlying the area of maximum curvature can be made. It is recommended that if the incisional defect is greater than 2 cm in any dimension, then a biograft should be placed over the defect to prevent cicatrix contracture of the incision or herniation of the prosthesis (**Box 4**).[28]

TUNICAL SHORTENING PROCEDURES

Multiple surgical plication techniques have been offered for PD, beginning with the Nesbit procedure, which is a form of excision of tunica on the contralateral side of the curvature.[30] In the setting of a ventral curvature, once Buck's fascia has been elevated, small wedges of the contralateral dorsal tunica albuginea are excised and then the defect is closed, typically with permanent suture. Variations on this approach have evolved, including the Yachia procedure, which utilizes the Heineke–Mikulicz technique.[31] In the setting of a dorsal curvature, a short full-thickness vertical incision is made on the ventral shaft tunic opposite the area of maximum curvature, which is then closed transversely to shorten the ventral aspect and correct the curvature.

The 16-dot procedure has also been presented where there is no incision, but the tunica albuginea is plicated with permanent suture using an extended Lembert-type suture technique.[32,33] Another variation is the Levine modification of the Duckett–Baskin tunica albuginea plication (TAP) which was originally used for children with chordee and has been modified for PD. A partial thickness incision is made transversely on the contralateral side to the point of maximum curvature.[34,35] A pair of transverse parallel incisions are made from 1 to 1.5 cm in length down through the longitudinal fibers, but do not violate the inner circular fibers of the tunic. These incisions are separated by 0.5–1.0 cm and the longitudinal fibers between the two transverse incisions are removed so as to reduce the bulk of the plication. This procedure can be done with a combination of permanent and absorbable sutures.

The key is that all plication procedures shorten the long side of the penis and therefore can result in loss of length on that aspect. Studies have examined the loss of penile length using the TAP technique where the factors which predicted loss of length were the direction of curvature and degree of curvature.[36] Therefore, those men who have a ventral curvature of greater than 60° tend to have the greatest potential loss of penile length.

The drawbacks of any tunica plication procedure for PD are that it does not correct shortening and potentially may enhance loss of penile shaft length. It does not address hinge or hourglass effect and may exacerbate it, resulting in an unstable penis. Penile narrowing or induration has been reported in 0%–17%. In addition, there can be pain associated with the knots, suture granulomas and, as noted, a potential for tactile and sexual sensitivity changes in 0%–21%.[19,22,37] Surgical straightening with a variety of plication procedures can be expected in 85%–100% of patients with a satisfaction rate of 67%–100%. Recurrence of penile curvature deformity (>30°) has been reported at a rate of 8%–11%, the reported risk of new ED ranges from 0% to 23% and diminished sensation is reported in 4%–21%, with follow-up of up to 89 months. Lastly, hematoma can be seen in 0%–9%, urethral injury in 0%–1.4% and phimosis in 0%–5%.[37]

The International Consultation of Sexual Medicine published their recommendations regarding plication procedures, and reported that

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- Placement of inflatable prosthesis
- Manual modeling
- Tunica incision
- Grafting of incision defect if > 2 cm with biograft

Box 4 Algorithm for prosthesis placement.

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there was 'no evidence that one surgical approach provides better outcomes over another, but curvature correction can be expected with less risk of new ED' compared to grafting procedures.[19] See **Table 1** for a summary on the outcomes for tunical shortening procedures.

TUNICAL LENGTHENING PROCEDURES (INCISION OR PARTIAL EXCISION AND GRAFTING)

Indications for incision or PEG for surgical correction of PD include greater complexity of disease with several or all of the following: curvature greater than 60°–70°, shaft narrowing, hinging and extensive plaque calcification. Most importantly, for a patient to be a candidate for incision or partial excision and grafting, they must have good preoperative erections.[26] This can be determined during the patient interview, where he is asked directly: 'if your penis was straight, would the quality of rigidity that you currently have allow intercourse?'. Should the patient hesitate, the incision and grafting procedure should not be performed, unless they fully understand the risk of more advanced postoperative ED and the possible need for subsequent prosthesis placement to attain adequate rigidity.

Other factors have emerged in the literature as possible predictors of postoperative ED, including age >55 years, evidence of corporal veno-occlusive dysfunction on duplex ultrasound analysis, with a resistance index of less than 0.80, ventral curvature, and possibly the severity of the curvature.[27,38,39] These predictors have been suggested as a result of single-center studies with a limited number of patients in each cohort. Larger scale studies indicate that the most critical criterion for any grafting procedure appears to be the quality of their preoperative erections.[26,27,39]

Surgical grafting techniques include plaque incision or partial plaque excision. Historically, total excision of the plaque was practiced to 'cut out the disease', resulting in onlays of large grafts with an unacceptably high rate of ED.[40] Therefore, plaque incision was introduced, where a modified H or double-Y incision is made in the area of maximum curvature.[41] This allows the tunic to be expanded in this area, thereby correcting the curvature and shaft caliber. Occasionally, multiple incisions with grafting are needed to obtain satisfactory straightening, or plication may be used for optimal correction of deformity.

Partial plaque excision has also been suggested, where the area of maximum deformity is excised particularly if it is associated with severe indentation. The corners of the defect are darted in a radial fashion to enhance correction of narrowing in that area.[42] Geometrical principles have been applied to the grafting technique in an effort to obtain a reliably sized graft, this approach appears unnecessarily complex and there have been reports of a higher rate of ED when this technique is used.[27,43] Egydio et al.[44] reported the results of the incomplete circumferential incision of a penile plaque and the use of a bovine pericardial graft. The authors achieved an 88% rate of penile correction in 33 PD patients, with a mean increase of 2.21 cm in penile length.[44] Alternatively, Kargi et al.[45] reported on a relaxing incision and fascia lata grafting for the surgical correction of penile curvature in men with PD. Autologous fascia lata grafts were harvested from the lateral thigh in 12 patients with preoperative curvature measuring 30°–40°. No ED or penile angulation was observed after one or more years of follow-up, and all had statistically significant penile lengthening.[45] Regardless, it is recommended that the defect should be expanded so as to allow correction of curvature and indentation. The key to these operations is to limit the trauma to the underlying cavernosal tissue to maintain the veno-occlusive relationship between the cavernosal tissue and the overlying tunic and graft.

Penile straightening after an incision/excision procedure plus grafting was achieved in 63%–100%.[46–48] The reported patient satisfaction

Table 1 Outcome of tunical shortening procedures for Peyronie's disease

Procedure type	Reference number	Number of patients	Mean follow-up duration (months)	Straight at latest follow-up (%)	Erectile dysfunction (%)	Satisfaction rates (%)
Nesbit	104	218	89	86	12	84
	105	40	81	88	5	NA
	106	42	84	91	2	76
	107	359	21	82	2	NA
	108	28	22	79	4	79
	109	9	31	NA	NA	67
Yachia	108	30	12	100	NA	83
	110	14	24	93	7	79
	111	26	22	73	8	78
	109	8	31	NA	NA	63
Tunica albuginea plication	32	124	31	85	6	96
	112	44	49	29	36	NA
	113	28	34	57	3.5	82
	114	29	34	79	38	81[a], 62[b]
	115	28	34	82	35	68
	116	21	30	57	10	NA
	23	22	20	91	9	NA
	117	48	<24	NA	2	93
	99	26	⩾12	65	11	65
	118	76	71	42	60	NA
	119	15	21	87	NA	93

Abbreviation: NA, not available.

[a] Percent satisfied with cosmetic result.

[b] Percent satisfied with functional results; Mean postoperative curvature of 15° (0°–25°).

rate with these procedures ranges from 41% to 96%, partner satisfaction has been reported at 77% and rigidity adequate for coitus reported from 79% to 100%.[22,46,48–51] ED is reported in 0%–35% with a trend toward increased risk of ED in men over the age of 60 years, as well as a higher risk of ED when grafting is performed to correct ventral curvature.[22,48] Depending on the graft material used, recurrence of greater than 30° curvature can be seen from 0% to 16% with plaque incision/excision and grafting procedures.[48,51]

Graft materials
The concept of the ideal graft has been debated. At this time, no graft has been identified as the ultimate one. Multiple grafts have been used historically, including fat, dermis, tunica vaginalis, duramater, temporalis fascia, saphenous vein, crura and buccal mucosa, which are harvested from the patient.[52–59] These have fallen out of favor because of a need for extended surgery to harvest the graft as well as a second surgical site, which possesses its own potential complications of healing, scarring and possible lymphedema. Synthetic polyethylene terephthalate (Dacron) and polytetrafluoroethylene (Teflon) grafts have been used historically and are not recommended now as there is a potential risk of infection, localized inflammatory response and fibrosis.[60] Finally, 'off-the-shelf' allografts and xenografts have emerged, including processed pericardium from a bovine or human source, porcine intestinal submucosa and porcine skin. The two most common grafts currently used are Tutoplast (Coloplast US, Minneapolis, MN, USA) processed human and bovine pericardium, and small intestinal submucosa (SIS) grafts (Surgisis ES, Cook Urological, Spencer, IN, USA).[61,62] The pericardial grafts are thin, strong, do not contract and have virtually absent reported infection or rejection rate. Chun et al.[63] performed a comparison of dermal and non-tutoplast processed human cadaveric pericardial grafts in the modified Horton–Devine procedure. Overall, 92% were able to achieve successful coitus with or without assistance. They reported a 33% overall recurrence rate with 26% of patients receiving dermal grafts and 44% of patients receiving pericardial grafts experiencing recurrence. However, this study

did not report on the severity of recurrence, and all of these patients were able to achieve erections suitable for coitus. Satisfaction rates were similar and those who underwent pericardial grafting enjoyed shorter operative times as well as decreased morbidity associated with the absence of a graft donor site.[63] The SIS grafts have similar advantages to pericardium, except that there have been reports of graft contraction of up to 25% with associated recurrent curvature in the 37%–75% range.[22,47,64–67] Other reported postoperative complications with SIS grafts include hematoma at 26% as well as an infection rate of 5%.[47]

Tissue engineered graft materials such as adipose tissue-derived stem cell seeded SIS, human acellular matrix tunica albuginea grafts, and autologous tissue engineered endothelialized tunica albuginea grafts are being investigated for incision/excision procedures.[68–71] Imbeault et al.[71] demonstrated in vitro creation of artificial tunica albuginea using human dermal fibroblasts and human endothelial cells. They concluded that this tissue-engineered endothelialized tubular graft was structurally similar to normal tunic with a high burst pressure and adequate mechanical resistance. Furthermore, the autologous property of this model could represent an advantage comparatively to other available grafts.[71] Such studies may help elucidate future surgical treatments for PD using tissue engineered grafts for reconstruction of the tunica albuginea. The biomechanical properties, compatibility with tunica albuginea, and the effective neovascularization of the tissue engineered grafts need to be investigated further before such basic research can be applied by the reconstructive urologist.

Postoperative management
The postoperative rehabilitation period is critical to reduce the risk of postoperative ED and length loss as well as optimize straight healing. Typically a patient is seen 2 weeks after surgery, at which point, massage and stretch therapy is initiated.[72,73] The patient is instructed to grasp the penis by the glans and gently stretch it and then with his other hand massage the shaft of the penis for 5 min twice per day for 2–4 weeks. The massage and stretch can be performed by the patient's

partner for the second 2 weeks if possible. This will reinitiate the sexual experience for the couple and hopefully diminish the fear of reinjuring the penis, for which the partner may feel responsible. Investigators have recommended the use of nocturnal PDE5 inhibitors to enhance postoperative vasodilation, which may help support graft take as well as reduce cicatrix contraction.[57] Finally, external penile traction devices have been encouraged and have been recently shown to reduce length loss postoperatively and can even enhance the likelihood of further length gain with both grafting and plication procedures. In a recent study accepted for publication, stretched penile length in patients who used postoperative traction therapy was shown to increase after TAP and PEG procedures by +0.85 and +1.48 cm respectively versus changes of −0.53 and +0.24 cm in the TAP and PEG groups who did not use postoperative traction. In fact, 50% of the TAP and 89% of the PEG patients using postoperative traction had measured length gain. The reported average daily use was 2.5 h, for 4.5 days a week, for an average duration of 3.8 months. There was no patient-perceived postoperative length loss among those who used postoperative traction therapy, and although not statistically significant, there was a trend of higher satisfaction for erect length in the groups who used postoperative traction.[74]

In a review of the published reports on grafting for PD over the past 12 years, satisfactory straightening was found in 74%–100% of patients, but postoperative ED, which does not have a uniform definition in the literature, has been reported in 5%–53% of patients. Diminished sensation after grafting has been reported in a few series with a follow-up of less than 5 years.[21] In the few single-center surgical outcome reviews with 5 or more years of follow-up, ED has been reported in up 24%, with recurrent or persistent curvature in the 8%–12% range.[50,66,75] See **Table 2** for a summary of the outcomes for penile straightening with plaque incision/excision and grafting.

PENILE PROSTHESIS FOR MEN WITH PD
Indications
As described above, in men with PD and concurrent ED refractory to PDE5 inhibitors, penile prosthesis placement is the procedure of choice.[23–25,28] Manual modeling may then be performed if necessary as only patients with mild curvature or presence of hinging without curvature will be fully corrected with prosthesis placement alone. Incising the tunica albuginea is then indicated if residual curvature is in excess of 30° after modeling attempts. Grafting of this incisional

Table 2 Outcomes for plaque excision/incision and grafting

Graft material	Reference number	Number of patients	Mean follow-up duration (months)	Straight at latest follow-up (%)	Erectile dysfunction (%)	Satisfaction rates (%)
Dermal grafts	63	10	11	60	6	70
	65	15	17	73	12	70
	87	48	19.6	80	25	73
	88	50	45	94	NA	NA
Saphenous vein grafts	50	113	12	86	15	96
	86	112	⩽18	96	12	92
	96	51	16	82	8	92
	97	50	32	80	6	88
	98	50	>60	72	22	60
	99	20	>12	85	35	NA
Buccal mucosa	48	15	12	100	0	100
	59	26	38.4	92.3	7.7	NA
Proximal crura	58	7	6	85.7	0	85.7
	91	31	NA	83.8	19.3	93.5
	92	27	NA	96.2	3.7	70.4
Tunica vaginalis	55	15	4–16	87.5	0	100
	89	25	42.2	88	68	NA
Dura mater	56	40	12–72	95	15	NA
	93	40	12–24	100	25	NA
Temporalis fascia	90	12	NA	100	0	100
Fascia lata	45	12	10	100	0	100
	100	14	31	79	7	93
Pericardial graft	44	33	19	87.9	0	NA
	63	9	6	55	11	88
Stratasis grafts	65	13	7.8	76.9	NA	84.6
Small intestinal submucosa (SIS)	47	19	15	63	53	NA
	62	162	38	91	9	NA
	94	33	14	67	11	79
	95	13	NA	100	54	NA
Tutoplast	22	81	58	79	20	78
Pericardial graft	51	19	22	84	16	74
	61	11	14	91	NA	NA
	65	11	19	91	0	NA
	85	13	30	100	NA	NA
	101	40	22	98	30	92
Acellular dermis	102	5	6	100	0	100
Syntnetic Materials	103	9	17.5	100	0	100

Abbreviation: NA, not available.

defect is recommended if it is greater than 2 cm in any dimension to reduce cicatrix contracture and cylinder herniation.

Techniques for straightening when placing penile prosthesis for PD

An inflatable penile prosthesis appears to be the preferred surgical implant, as the pressure within the cylinders allows for superior correction of curvature with manual modeling, as well as improved girth enhancement. Malleable prostheses when used for PD historically, were associated with narrow, cold and less than natural erections.[76]

Manual modeling *via* the penoscrotal approach is recommended with a high-pressure inflatable cylinder, but all available three-piece and two-piece devices have been used successfully to correct deformity. Our approach is to place the prosthesis cylinders first, and then the corporotomies are closed. Using a surrogate reservoir attached to the pump tubing, the prosthesis can be filled to full rigidity, which will allow visualization of the deformity. To protect the pump from the high pressures that may occur during manual modeling, shodded hemostat clamps can be applied to the tubing between the pump and the cylinders. The penis is then bent in the contralateral direction to the curvature. It is recommended to try to hold the penis in this position for 60–90 s, but experience has suggested that around 30 s may be all that is possible. Regardless, once the modeling is performed, the penis can be reassessed by inflating more fluid, reapplying the hemostats, and then performing the modeling procedure repeatedly until satisfactory curvature correction is attained. The modeling technique should be a gradual bending rather than a violent maneuver, as this will reduce the likelihood of inadvertent tearing of the tunic or injury to the overlying neurovascular bundle. Urethral injuries while performing this technique by distal extrusion of the prosthetic cylinders at the fossa navicularis has been reported by Wilson *et al.*[29,77] To reduce the likelihood of this occurring, the bending hand should be placed on the shaft of the penis rather than the glans, to avoid downward pressure on the tips of the cylinders. The other hand should be grasping the base of the penis with pressure over the corporotomies, which will provide support to this area and reduce the likelihood of disruption of the suture line.

Published reports on the use of modeling have indicated that sensory deficits after manual modeling are rare, but are a potential complication that should be discussed with the patient preoperatively.[78] Although it would appear that for more severe curvature that more advanced techniques will be necessary, published experience has suggested that manual modeling may be used as first-line therapy for correction of curvature after prosthesis implantation. An alternative to this would be to perform a tunic plication such as the 16-dot suture technique contralateral to the curvature before placement of the prosthesis so as to correct curvature.[79]

When there is residual curve of greater than 30° or residual indentation causing the inflated cylinder to buckle, tunical incision is recommended after elevating Buck's fascia in that area. The transverse penoscrotal skin incision will allow access to virtually the entire shaft, except when the curvature is distal on the shaft, so degloving the penis is not always necessary. The tunical incision is made with the cylinders deflated, using the cautery to release the tunic with an effort to preserve the cavernosal tissue over the implant. When Coloplast (Coloplast) cylinders are used, the energy should be less than 30 W to reduce potential cylinder injury.[80] Once the incision is made, the cylinders are re-inflated and further modeling can be performed to optimize deformity correction.

Although there is not a clearly accepted approach, grafting over the defect is recommended when the defect measures greater than 2 cm in any dimension.

Historically, synthetic grafts were used, but currently biografts of pericardium or porcine SIS are recommended. Use of locally harvested dermal grafts is not recommended, as there is risk of transferring bacteria to the prosthesis.

There have been limited publications looking at the long-term results with regard to outcomes and satisfaction with inflatable penile prostheses in men with PD and ED refractory to PDE5 inhibitors. Recently Levine *et al.*[78] reported on 90 consecutive men undergoing placement of an inflatable penile prosthesis, with 4% having satisfactory straightening with prosthesis placement alone, 79% having satisfactory curvature correction with prosthesis and modeling, 4% required tunical incision and 12% had incision and pericardial grafting for correction of curvature. It did not appear that the additional maneuvers increased the rate of mechanical failure or infection. In the non-validated questionnaire used in this study, overall patient satisfaction was 84%, whereas only 73% were satisfied with curvature correction. This may indicate a flaw in the design of the questionnaire, but may also reflect the general disappointment and frustration of patients with PD.[78] Thus, preoperative counseling and setting appropriate expectations as with any prosthesis placement is critical.[81]

It is recommended that preoperative discussion is also focused on the goal of obtaining 'functional straightness', in which a residual curvature of 20° or less in any direction would likely not compromise sexual activity.

By far, the most common postoperative complaint heard in men who undergo penile prosthesis placement is length loss.[82] The first to objectively evaluate penile length after penile implant was Wang *et al.*[83] who demonstrated decreases of 0.8, 0.75 and 0.74 cm at 6 weeks, 6 months and 1 year, respectively. This is of particular concern in the PD population in whom the majority report length loss at initial presentation. Any additional length loss due to the implant may be distressing to the patient and should be addressed preoperatively. For those men who cannot tolerate any further length loss, a recent small pilot study using traction therapy before penile prosthesis placement in men with PD as well as other disorders causing penile shortening (e.g. prosthesis explants, radical prostatectomy) did demonstrate that, after 3–4 months of daily traction for an average of 3 h or more per day, there was no further loss of length after prosthesis placement, and the majority had gained some length (0.5–2.0 cm) compared to their pre-traction stretched length.[84] See **Table 3** for a summary on the outcomes of penile straightening with penile prosthesis placement.

CONCLUSION

Surgical correction of PD with or without penile prosthesis placement remains the gold standard to correct deformity. These men need to undergo a detailed and comprehensive consent process so that the patient will be more understanding of the potential limitations of the surgery in order to set appropriate expectations thus improving postoperative satisfaction. For the man with satisfactory preoperative rigidity with curvature less than 60°–70° without significant indentation, then some form of tunica plication is indicated. There does not appear to be any one plication technique which has been demonstrated to be superior to others, as no head-to-head comparative trial has been published. In addition, for those men who have more severe, complex deformity, but who have strong preoperative erectile function and no evidence of venous insufficiency on duplex ultrasound image analysis, these men should be considered candidates for straightening with plaque incision or partial excision and grafting. The complications associated with these operations include incomplete straightening, recurrent curvature, shaft shortening, diminished penile sexual sensation and ED. Finally, for those men who have inadequate rigidity and PD, penile prosthesis placement with straightening maneuvers as necessary should be considered first-line surgery.

Table 3 Outcome of penile prosthesis implantation for Peyronie's disease

Reference number	Prosthesis type	Number of patients	Mean follow-up duration (months)	Additional straightening maneuvers (%)	Satisfaction rates (%)
120	Inflatable	129	NA	37	86
	Maleable	80	NA	16	72
78	Inflatable	90	49	96	84
121	Inflatable	79	20	11	NA
29	Inflatable	138	NA	8	NA
82	Inflatable	72	NA	8	67
122	Inflatable	46	12	61	93
79	Inflatable	5	22	100	100

Abbreviation: NA, not available.

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The authors declare no competing financial interests.

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