Management of residual penile curvature after penile prosthesis placement

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Residual penile curvature is a common situation following the implantation of a penile prosthesis in patients with Peyronie’s disease. Currently, there is a variety of options for the correction of residual curvature, including penile modeling, plication techniques, as well as tunical incision/excision with or without grafting. A literature search of PubMed and Medline databases was conducted from 1964 until 2020, using search terms for all articles in the English language. In this article, we provide a review of the techniques and the outcomes, according to the published literature.

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INTRODUCTION

Residual curvature of the penis is a well-known phenomenon after implantation of a penile prosthesis.¹-² This may occur in the preexisting context of Peyronie’s disease (PD) or following other causes of end-stage erectile dysfunction, such as after radical prostatectomy.³ While it may not be anticipated that there exists a penile curvature in the latter situation, residual curvatures may be so significant and they prevent penetrative intercourse and thus may require treatment at the time of the inflatable penile prosthesis (IPP) or semirigid penile prosthesis insertion.⁴ While some mild curvatures may not require any correction, options for more severe curvatures range from modeling, then plication, to grafting. In this article, we review different available management options for residual penile curvature after penile prosthesis placement.

A literature review was performed with PubMed and Medline, for all articles written in the English language, from 1964 to 2020. The search terms incorporated were PD, residual penile curvature, penile prosthesis, penile modeling, incision/excision with grafting, tunical plication, and sliding technique.

It is a common finding for surgeons to note penile curvature during the insertion of penile implants. Curvature deformities may become apparent in the context of penile prosthesis implantation primarily due to PD or may appear somewhat de novo.⁵

PD is a chronic inflammatory disease characterized by excessive accumulation of collagen fibers and other extracellular matrix (ECM) components within the tunica albuginea (TA) of the corpora cavernosa.⁶ The prevalence of PD ranges from 0.4% to 20%, mainly in men aged between 40 years and 70 years.⁷ PD in the chronic phase frequently results in erectile dysfunction (ED), occurring in from 22% to 37.5% of cases.⁸ The cause of ED in this context may be related to several factors including infiltration of the plaque into the neurovascular bundle,⁹ as well as veno-occlusive dysfunction from corporal scarring.¹⁰ However, it is not only the initial disease process that causes ED. Treatments such as intracavernosal injections are well known to cause fibrosis, with possible subsequent curvature in some men.¹¹ Curvature correction surgeries such as tunical plication or lengthening/grafting techniques may themselves lead to ED.¹² Radical prostatectomy has also been associated with the development of penile curvature, possibly due to cavernosal denervation with subsequent fibrotic changes.¹³⁻¹⁴

Preoperatively, surgeons should be prepared for the likelihood of a curvature. This may be obtained either from the patient history or from an artificial erection test. While many surgeons may not measure penile dimensions perioperatively,¹⁵ it is the authors’ opinion that performing this is vital to plan the appropriate surgery for the individual patient and manage their expectations. The penile dimensions (either stretched or erect length) should be measured and note taken of any complexity. Mild curvatures may sometimes not require any treatment, as the implant will self-correct subtle deformities over time.¹⁶ However, when there are curvatures exceeding 45° or 60°, the requirement for correction increases up to 75%–100%.¹⁷⁻¹⁸ The surgeon must also have an understanding of the various options to correct a curvature in this setting.

MODELING MANEUVER OVER A PENILE PROSTHESIS

Modeling is a well-described maneuver for the correction of residual curvature after penile prosthesis placement.¹⁹ This technique involves the following steps: (1) full inflation of the device; (2) clamping of the exit tubing of the device for protection of the pump; (3) steady forceful...
bending of the penile shaft in the opposite direction of curvature for 90 s, this may result in a partial or complete rupture of the plaque; and (4) compression of corporotomy sites for the prevention of cylinder blowout during bending. Successful modeling is defined as an angle of <10°–20°. Modeling may need to be repeated until adequate straightening results.22,31,32 This method of straightening was originally described by Wilson and Delk in 1994.23 In his series of 138 patients, he demonstrated success in 118 patients (86%). Eleven patients (8%) required tunical relaxing incisions. Further publications have revealed adequate penile straightening and satisfaction with sexual intercourse ranging from 54%–100% to 88%–100% of cases, respectively (Table 1).25–29 Despite the high success rate, it should be borne in mind that this maneuver can lead to complications such as urethral perforation or laceration, which occurs in 2.5%–4% of cases.30 If this occurs, the offending cylinder should be removed and a urethral catheter was placed with delayed replacement of the ipsilateral cylinder after an adequate period of urethral healing, usually 4 weeks–6 weeks. Others have proposed leaving both cylinders in place and simply repairing the urethra directly over a Foley catheter and diverting the urine with a suprapubic cystostomy for 4 weeks–8 weeks before the prosthesis is activated.31,32 It is the authors’ opinion that surgeons should have a high threshold to perform this maneuver as it is likely to increase the prosthesis infection rate.

The retrospective review of 79 men (11 of whom had PD with intraoperative modeling) showed that the clamping of the tubing is required during modeling. Of the PD cohort, 3 of 11 (27%) patients had device failure, while 3 of 68 (4%) of the non-PD group exhibited device malfunction at an overall mean of 4.3 months.33 The exact nature of the mechanical failures was not reported. Another study comparing AMS 700 CX® versus Coloplast Titan® showed no difference in mechanical failure following modeling.34 There is limited and conflicting evidence when comparing semirigid and IPP devices. A prospective, nonrandomized cohort of patients who underwent either IPP (n = 30) or semirigid implants (n = 136) found no significant difference in the immediate end-of-procedure curvature correction. Satisfaction rates were similar with Likert satisfaction scores of 4.3 and 4.4, respectively.35 A retrospective review of 209 PD patients who underwent penile implant surgery concluded that modeling was more often successful (defined as curvature <10°–20°) with inflatable (84%) versus semirigid (54%) implants.36

**PLICATION TECHNIQUES**

Tunical plication is used in patients with residual curvature after implantation of a penile prosthesis after a failed attempt of modeling. It is possible when the patient has a persistent curve of 30°–60°. Ideally, these patients should not have a short penis nor complexities such as severe waisting. The principle of penile plication is shortening of the longer convex side. The tunica can be left untouched and sutures simply placed to plicate, or tunical excision or incision can occur, with subsequent closure of the defects.37 Several modifications of this concept have been published, including the original Nesbit’s procedure,38 Essed-Schroeder technique,39 16/24-dot,40 Heineke-Mikulicz-based repair (Yachia technique),41 as well as the Rolle et al.42 adaptation. The surgeon must consider the following nuances when correcting residual curvature over a penile prosthesis: incision, location of correction, and protection of the implant. If a penoscrotal incision is used, it is common to obtain good access and retraction to visualize most of the penile shaft tunica, if required. This obviously requires some further dissection. During an infrapubic approach, a second incision, either ventral, penoscrotal, or degloving, may need to occur to access the point of maximal curvature, depending on the location and direction of the curve. Once the site of curvature is identified by inflating the implant, the device should be deflated and pushed proximally or removed from the corpora.2,6,12,16,30,31,36–47 While it is possible to place sutures with an implant *in situ*, the possibility of puncture with subsequent mechanical failure exists.

This problem will clearly not occur when using a semirigid device. Plication sutures can then be placed opposite the angle of maximal curvature using the near-far-far-near technique.

One can consider replacing and inflating the IPP once the sutures are in place, but not tied. The sutures can then be tied and adjusted to optimize the degree of straightening. Outcomes of plication techniques after insertion of the penile prosthesis are summarized in Table 2.

**TUNICAL SCRATCH TECHNIQUE FOR CORRECTING RESIDUAL PENILE CURVATURE**

Perito and Wilson48 first described the scratch technique in 2013 as an effective complementary maneuver to modeling, performed

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**Table 1: Outcomes of manual modeling after insertion of penile prosthesis**

| Reference          | Year of publication | Patients (n) | Penile prosthesis               | Outcome (%)                     |
|--------------------|---------------------|--------------|---------------------------------|---------------------------------|
| Wilson et al.22     | 1994                | 138          | AMS 700 CX                      | Penile straightening (86)       |
| Montague et al.23   | 1996                | 34           | AMS 700 CX                      | Penile straightening (100)      |
| Carson24            | 2000                | 38           | AMS 700 Ultrex                  | Penile straightening (73.6)     |
| Usta et al.25       | 2003                | 31           | AMS 700 CX                      | Penile straightening (93)       |
| Chaudhary et al.2    | 2005                | 28           | AMS 700 CX                      | Penile straightening (93.5)     |
| Kadioglu et al.27   | 2008                | 60           | NA                              | Penile straightening (88)       |
| Levine et al.26     | 2010                | 90           | AMS 700 CX                      | Penile straightening (79)       |
| Garaffa et al.36    | 2011                | 129          | AMS 700 CX, Titan               | Penile straightening (84)       |
| Chung et al.28      | 2013                | 138          | AMS 600 Genesis                 | Penile straightening (54)       |
| Yafi et al.29       | 2016                | 19           | AMS 700 CX, Titan               | Penile straightening (92)       |

NA: not available
The sliding technique was first developed by Rolle et al. in 2012. This approach includes ventrodorsal incisions of the tunica albuginea, penile implant placement, and double dorsal-ventral patch grafting. Its aim is to address simultaneously ED, curvature, and length correction. In the initial series of three patients, none suffered major intraoperative or postoperative complications and resumed sexual activity. In a further cohort of 28 men, the same author published their results of IPP and semirigid devices using porcine small intestinal submucosa and acellular porcine dermal matrix and TachoSil, respectively. There were no differences regarding penile lengthening or curvature correction between the groups. However, the operative time was less in the semirigid prosthesis group. Egydio described a modification of the procedure, using Buck’s fascia alone for closure, without the need to graft material. The same author more recently describes the multiple-slit technique, whereby multiple small tunical defects replace one large tunical incision. These techniques have been shown to be effective in correcting penis length and girth in other studies. The sliding techniques have demonstrated high rates of penile straightening ranging from 80% to 100% after insertion of the penile prosthesis. A summary is shown in Table 4.

COLLAGENASE CLOSTRIDIUM HISTOLYTICUM (CCH)

CCH is an enzyme, produced by the bacterium Clostridium histolyticum, that hydrolyses collagen, and was first used in 1982 for the treatment of PD. While CCH is ideally used as a sole treatment, when failure occurs, some men may choose to proceed with curvature correction surgery. There is limited literature available in this context. De Lay et al. reported on ten patients who underwent curvature corrective surgery, three of whom underwent IPP, following a mean of 5 months after CCH injections. Increased surgical difficulty was encountered in three patients, all of whom had CCH < 6 months before curvature surgery. The authors therefore also suggest that curvature correction surgery should be deferred by at least six months following the last injection of CCH. Despite the small sample size, they concluded that surgery following CCH was safe and feasible. There are no studies investigating the use of CCH following penile implants. While Fischer et al. reported an animal study whereby CCH reduced fibrotic changes around a silicon implant, one would imagine that the financial implications as well as the risk of damage to IPP cylinders would prevent many surgeons from choosing such an option.
Table 3: Outcomes of grafting techniques after insertion of penile prosthesis

| Reference                | Year of publication | Patients (n) | Penile prosthesis | Graft                        | Outcome (%)                  |
|--------------------------|---------------------|--------------|-------------------|------------------------------|------------------------------|
| Austoni et al.76         | 2005                | 80           | Soft, axially rigid penile implants | Saphenous vein graft         | Penile straightening (100)   |
| Pathak et al.79          | 2005                | 15           | IPP               | Autologous rectus            | Penile straightening (100)   |
| Kadioglu et al.27        | 2008                | 20           | IPP               | Autologous rectus            | Penile straightening (100)   |
| Sansalone et al.75       | 2012                | 20           | AMS 700 CX        | InteXen                      | Penile straightening (90)    |
| Silvani et al.77         | 2012                | 58           | 7F Virilis I, 7F Virilis II | Bovine pericardium graft     | Penile straightening (100)   |
| Zucchi et al.78          | 2013                | 60           | 7F Virilis prostheses | Bovine pericardium graft     | Penile straightening (100)   |
| Hatzichristodoulou4      | 2018                | 15           | Coloplast Titan   | TachoSil                     | Penile straightening (80)    |
| Fernández-Pascual et al.61| 2019              | 43           | Semi-rigid MPP Genesis | TachoSil                     | Penile straightening (82.1)  |
| Farrell et al.62         | 2019                | 18           | Coloplast Titan   | Hemostatic patches           | Penile straightening (83.3)  |
|                          |                     |              |                   | (Evarrest, Tachosil, Nu-Knit) | Satisfaction with sex (94.4) |
|                          |                     |              |                   | Coloplast, AMS 700 CX        | Satisfaction with sex (94.9) |
|                          |                     |              |                   | AMS 700LGX IPP               |                              |
|                          |                     |              |                   | Coloplast Titan              | Penile straightening (86.7)  |
|                          |                     |              |                   | InteXen                      | Satisfaction with sex (93.3) |

**Table 4: Outcomes of sliding techniques for correction residual penile curvature during insertion penile prosthesis**

| Reference                | Year of publication | Patients (n) | Penile prosthesis | Outcome (%)                  |
|--------------------------|---------------------|--------------|-------------------|------------------------------|
| Rolle et al.66           | 2012                | 3            | MPP, IPP          | Penile straightening (100)   |
| Egydio et al.69          | 2015                | 77           | Promedon Tube     | Penile straightening (100)   |
|                          |                     |              | Coloplast Genesis | Satisfaction with sex (100)  |
|                          |                     |              | Coloplast Titan   | Penile straightening (100)   |
|                          |                     |              | AMS 700 CX        | Satisfaction with sex (96)   |
| Rolle et al.67           | 2016                | 28           | Coloplast Genesis | Penile straightening (100)   |
|                          |                     |              | AMS 700 CX        | Satisfaction with sex (96)   |
|                          |                     |              | Coloplast Titan   |                              |
|                          |                     |              | AMS Spectra       |                              |
| Fang et al.71            | 2018                | 5            | Coloplast Titan   | Penile straightening (80)    |
| Egydio et al.70          | 2018                | 83           | Coloplast Titan   | Penile straightening (100)   |
| Clavell-Hernández et al.72| 2018               | 12           | Coloplast Titan   | Penile straightening (100)   |
|                          |                     |              | Coloplast Genesis |                              |

**Table 5: Summary of techniques used for correction of residual penile curvature**

| Adjunct Maneuver       | Residual Curvature indication | Comment                                           |
|------------------------|-------------------------------|---------------------------------------------------|
| Nil                    | Minor: <10°–20°               | Minor curves unlikely to be problematic and may straighten over time |
| Modeling               | 20°–60°                       | Small risk of urethral injury                     |
| Scratch technique      | 20°–60°                       | Can be performed with modeling                    |
| Plication              | 20°–60°, after failed modeling| Will lead to shortened length                     |
| Tunical incision       |                               | Can be used for waist or hourglass deformity, with or without grafting |
| Sliding technique      | >60°                          | For severe penile shortening. Higher risk of tissue ischemia |

**TREATMENT ALGORITHM**

Despite a variety of treatment options, there are no specific guidelines thus far for the management of residual curvature in penile prosthesis surgery. That said, we propose a fairly logical algorithm, which assumes that curvatures <20° will either not pose a functional issue or will self-correct over time. Modeling or scratch techniques should be employed for residual curvatures between 20° and 60°. Tunical plication should be performed for residual curvatures between 20° and 60° after failed
modeling/scratch. Tunical incisions with or without grafting is reserved for curvature >60°, complex changes such as waisting or hourglass deformities and in case when penile length is a significant concern. Summary and comments of techniques used for correction of residual penile curvature are shown in Table 5.

CONCLUSIONS
Following penile implant, a residual curvature is a common finding. While conservative options exist, the surgeon should be aware of the variety of treatment options at their disposal, with an understanding of their place and disadvantages.

AUTHOR CONTRIBUTIONS
DVK, RAB, and VAC performed literature searching and data collection. DVK prepared and designed the manuscript. RJD and GAB contributed to critically revising the manuscript. FG and EEB reviewed and edited the manuscript. All authors read and approved the final manuscript.

COMPETING INTERESTS
All authors declared no competing interests.

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Residual penile curvature after PP

DV Krakhotkin et al

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