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Original Article

Penile Reconstruction with Radial Forearm Free Flap—Present State of the Art

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Abstract

Background Patients with congenital or acquired penile defects face significant psychological trauma. Various methods for penile reconstruction have been described of which the free radial artery forearm flap using the tube-within-tube design is found to be the most commonly used. We have assimilated the best practices described at different times in our bid to standardize the technique and have strived to make it reproducible. The reconstructed phalluses with this method can withstand the test of time, allowing the patients to lead a normal life.

Materials and Methods We conducted a retrospective review of the past 16 years and collected data for all radial forearm free flap phalloplasties. We have modified the design originally described by Biemer. The urethra is kept 1 cm longer than the shaft and the proximal 5 mm of the prospective urethra is not sutured to allow for spatulation of the urethral anastomosis.

Results A total of nine patients were included out of which six patients had congenital malformations, two had traumatic injuries, and one had penile carcinoma. Six out of the nine patients had implants placed which were wrapped in fascia lata graft. One of these patients experienced displacement of the implant which needed to be repositioned. Three patients faced postoperative complications. All patients had tactile and erogenous sensation at the tip of the glans at the end of 1 year and all patients could micturate while standing. One patient's esthetic and functional outcome was compromised. One of the married patients has fathered a child through normal sexual intercourse.

Conclusion Radial forearm phalloplasty done by this technique allows us to achieve consistently stable functional and esthetic outcomes. We firmly believe that this standardized protocol for penile reconstruction could be of great benefit to patients as well as to the treating reconstructive surgeon in their quest to achieve a completely rehabilitated patient.

Keywords
- phalloplasty
- penile reconstruction
- penile implant

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Introduction

Congenital or acquired anomalies of the penis can lead to significant physical and psychological problems in a patient. These may involve a wide spectrum of problems such as ambiguous genitalia, epispadias, hypospadias, micropenis, traumatic amputations, and malignancies. Some of the congenital problems could be addressed by using the available local tissue but in situations involving multiple failed operations, total reconstruction of the phallus is the only practical option to rehabilitate these patients.[1]

The first successful penile reconstruction was reported by Bogoras in 1936 where he used a tubed abdominal flap with a rib cartilage as the support.[2] The surgery has evolved with many myocutaneous and fasciocutaneous and even osteocutaneous flaps being used, which may be local pedicle flaps or free tissue transfers.

The goals to be considered while planning phalloplasty are:

1. Creation of an esthetic appearing phallus.
2. Ensuring tactile and erogenous sensation to the glans and shaft.
3. Achieving micturition in standing position.
4. Ability to perform penetrative sexual intercourse.[3]

There are many flap choices and designs described which vary as per the patient's requirement, but to achieve the above-mentioned goals, the recreation of both the urethra and the shaft is essential which can be achieved either with two separate flaps or by using the tube-within-tube (TWT) design.[4] To achieve a successful outcome from a TWT phalloplasty, a thin and pliable flap donor site with reliable vascular anatomy and long pedicle for anastomosis is preferable, and these reasons make the radial artery forearm free flap the most widely used option worldwide.[5]

Dependent edema with fibrosis over time is considered by a few to provide adequate stiffness to undergo penetrative sexual intercourse,[6] but in most patients, this does not suffice. In the past, radial bone or costal cartilage has been used to provide adequate stiffness during penetration. These autologous materials either get fractured, do not provide the right curvature, or undergo resorption over time.

The most frequently used method presently involves a two-stage phalloplasty, in which the implant is placed in a second stage when the glans region of the penis gets a protective sensation.[7]

Puckett and Montie reported the first inflatable prosthesis placement for a total phalloplasty patient in 1978.[8] There are two basic options available for penile implants which are inflatable implants and flexible rod implants. Implants are associated with their own set of complications of which the most common is extrusion.[9] The use of fascia lata wraparound for implants has been described to reduce the chances of extrusion.[10]

There are a few reported cases of penile vascularized composite allotransplantation but to date the functionality and erections have not been documented unequivocally in any of these patients; moreover, these patients have to face the adverse effects of lifelong immunosuppression and the spouses have to face the issues of psychological acceptance.[11–13]

We understand that if a standardized protocol for phalloplasty is followed for reconstruction, the need for transplantation can be greatly reduced.

Materials and Methods

We conducted a retrospective review of cases of phalloplasty from the year 2006 to 2023 and excluded all transgender cases from our series. After going through our medical records, a total of nine cases of penile reconstruction were noted. All the cases were done using a radial artery free forearm flap. The technique has been constantly refined over some time.

Our technique is a modification of the radial forearm flap phalloplasty technique with a TWT design described by Biemer.[14]

Surgical Technique

Patient preparation: In the consultation room, the first thing to establish is the nondominance of the radial circulation, which is checked by performing Allen's test. The patient is given six sessions of laser therapy for hair removal for 6 months; this prevents future blockage of the penile urethra due to excessive hair growth.

Preoperative investigations: A retrograde urethrogram is done to delineate and document the anatomy of the present urethra.

Local dissection: The rudimentary, previously operated or amputated penile shaft, as the case may be, is degloved. Skin, corpora cavernosa, and spongiosum containing the urethra are separated.

The dorsal nerve of the penis is dissected off and tagged, and one or two superficial veins are identified in the vicinity.

Recipient vessel preparation: Initially, we were using the deep inferior epigastric vessels as recipients but now we have started using the descending branch of the lateral circumflex femoral artery (LCFA). The descending branch of LCFA was dissected along its entire course and transferred on to the base of the penis by tunneling under the rectus femoris muscle and subcutaneously thereafter. Additionally, one of the superficial epigastric veins is also dissected and mobilized.

Flap design dissection and phallus creation: The radial forearm flap design consists of three components—the neourethra, the shaft of the phallus, and the glans.

The neourethra is 3 cm in circumference and 11 cm in length and is centered on the radial artery. On both sides of the prospective neourethra, a skin segment of approximately 1 cm is de-epithelialized. Lateral to this segment, we mark an area of approximately 5 cm width and 10 cm length which would form the outer surface of the neophallus. A distal oval-shaped marking of 4×8 cm is done to create the flap for the glans on both the sides of urethral marking; an almost triangular area of skin is de-epithelialized onto which the glans flap is turned over and sutured. As the circumference of the glans flap is more than the site to which it is sutured, it gives rise to puckering, giving the semblance of a glans ridge (►**Fig. 1A–C**).

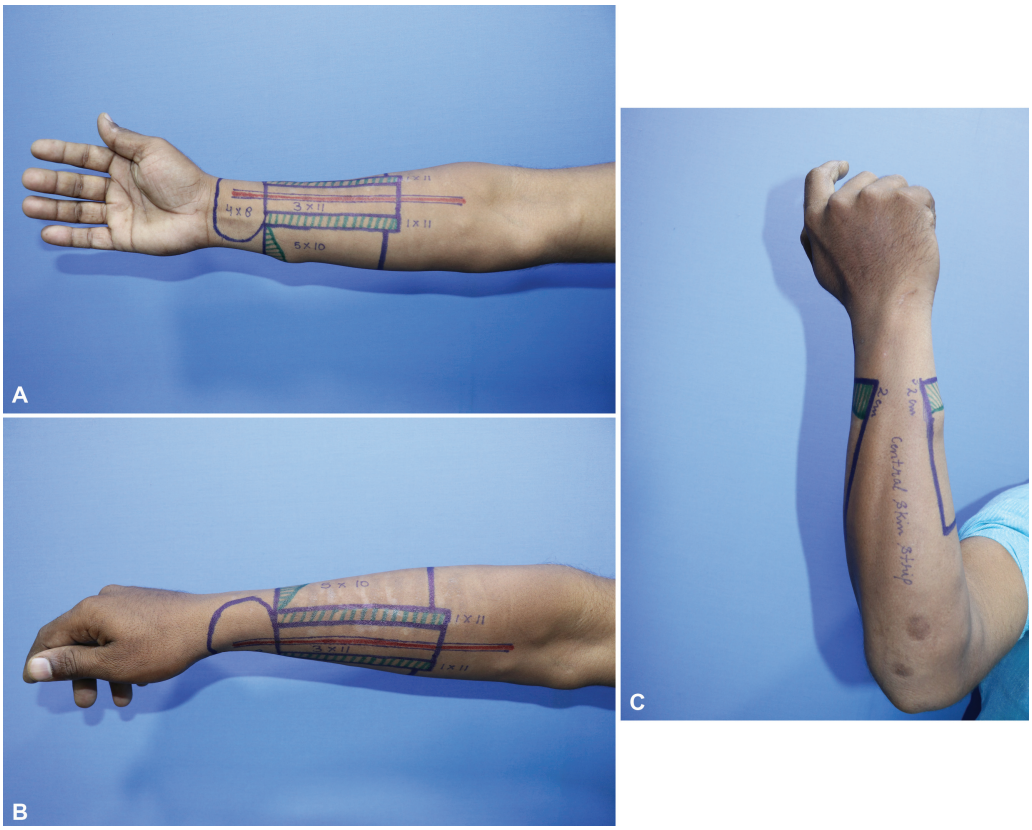

Fig. 1 (A) Marking for radial forearm phalloplasty donor site—volar aspect of forearm. Neourethra is 3 cm × 11 cm and is centered on the radial artery. On either side 1 cm de-epithelialized segment. Lateral to this segment we mark an area 5 cm × 10 cm length of the neophallus. A distal ovoid marking of 4 × 8 cm is done for the glans. (B) Marking for radial forearm phalloplasty donor site—radial aspect of forearm demonstrating the 1 × 11 cm area of de-epithelialized region and lateral to that 5 × 10 cm area of neophallus. (C) Marking for radial forearm phalloplasty donor site—dorsal aspect of forearm.

The flap is raised in the suprafascial plane except between the flexor carpi radialis and brachioradialis and the radial artery along with venae comitantes is dissected out. Both the basilic and cephalic veins are included in the flap. The medial and lateral antebrachial cutaneous nerves are included in the flap, and the superficial branch of the radial nerve is carefully preserved. All the veins and nerves were dissected as proximally as possible before the harvest. The urethral tube creation is done in three layers using 3–0 PDS. The urethra is planned 1 cm longer than the shaft of the penis and the proximal 0.5 cm of the prospective urethra is not sutured to create a spatulated end, to help in anastomosis with the native urethra and to reduce the chance of stenosis. Arterial anastomosis is done with 9/0 Nylon sutures and both the venae comitantes and at least one superficial vein are anastomosed to either the basilic or cephalic vein (►**Fig. 2A–D**).

Dorsal nerves of penis branches are coapted to the medial and lateral antebrachial cutaneous nerves.

The implant placement is done as a second-stage procedure after approximately 1 year; once the tactile sensation reaches the tip of the reconstructed penis. A flexible silicone rod implant is matched and tailored to the length of the reconstructed penis. Fascia lata is harvested and wrapped around the implant and sutured using continuous 3-0 PDS sutures and the implant is also fixed to the fascia lata using a transfixation stitch (►**Fig. 3A–C**).

The urethra is exposed through a scrotal incision; the remnant corpora cavernosa is exposed. Two 3–0 silk sutures are taken onto the corpora and an incision is given between the sutures on the corpora. With a tenotomy scissor, a tunnel is created from the corpora to the reconstructed penis distally. At the coronal region of the glans, an incision is given, and another subcutaneous tunnel is created through the shaft. The tunnel is then dilated using Hegar's dilator till it is adequate to accommodate the implant wrapped with tensor fascia lata. A 2–0 silk suture is taken 1 cm from the tip of the implant. The implant is lubricated with sterile lignocaine jelly and then the tip suture is passed through the subcutaneous tunnel and the implant is pulled into the tunnel distally, and in a retrograde fashion, the proximal portion of the implant is pushed into the newly created corporal tunnel proximally. Tunica albuginea of the corpora is closed with 3/0 PDS sutures. The skin incisions are closed in two layers (►**Fig. 4A, B**) (►**Videos 1A, B, 2, 3**).

Video 1

(**A, B**) Demonstrative video of phallus reconstruction. Online content including video sequences viewable at: https://www.thieme-connect.com/products/ejournals/html/10.1055/s-0044-1791195.

Fig. 2 (A) Intraoperative picture of donor site after de-epithelialization. The neourethra is 3 cm in circumference and 11 cm in length and is centered on the radial artery. On both sides of the prospective neourethra, a skin segment of approximately 1 cm is de-epithelialized. (B) Intraoperative picture of donor site after flap is raised. (C) Intraoperative picture demonstrating the phallus creation while the phallus is still attached to the radial artery pedicle. The phallus creation is done with the Foley inset. The urethral tube creation is done in three layers using 3–0 PDS. (D) Neophallus after detachment with radial artery forearm pedicle, cephalic vein, medial and lateral cutaneous nerves of forearm preserved. (E) Healed donor site of the patient which has been resurfaced with split-thickness skin graft.(F) End on view of the penis with the portion of the urethra.

Video 2

Demonstrative video of implant placement. Online content including video sequences viewable at: https://www.thieme-connect.com/products/ejournals/html/10.1055/s-0044-1791195.

Video 3

Postoperative video scope. Online content including video sequences viewable at: https://www.thieme-connect.com/products/ejournals/html/10.1055/s-0044-1791195.

Results

A total of nine patients were included. The first case was done in 2006. The etiology was variable with the most common cause being congenital deformity in six patients, two patients had traumatic injury (one due to electric burns and one due to traumatic amputation), and one patient had undergone a penile amputation for squamous cell carcinoma. The mean age of the patients was 30.5 years. The dimensions for the reconstructed urethra and penile shaft were 11×3 cm.

The pedicle used for anastomosis was the femoral artery using a vein graft with the flipped saphenous vein only for the first case, in the next four cases, the deep inferior epigastric pedicle with its venae comitantes and saphenous vein was used, and in the last four cases, the descending branch of the lateral circumflex femoral vessels was used for anastomosis and is presently the vessel of choice.

The saphenous vein was used for anastomosis after clipping it distally and tunneling it to the penile base.

For reinnervation, the dorsal nerve of the penis was found and used in all cases except two, for whom the ilioinguinal nerve was used.

One out of the three patients developed partial necrosis of the dorsal skin flap of neophallus which needed excision and secondary suturing.

Four out of the nine patients had urinary fistulae. All four patients underwent secondary corrective procedures for closure of the fistulas. All fistulae have healed after the

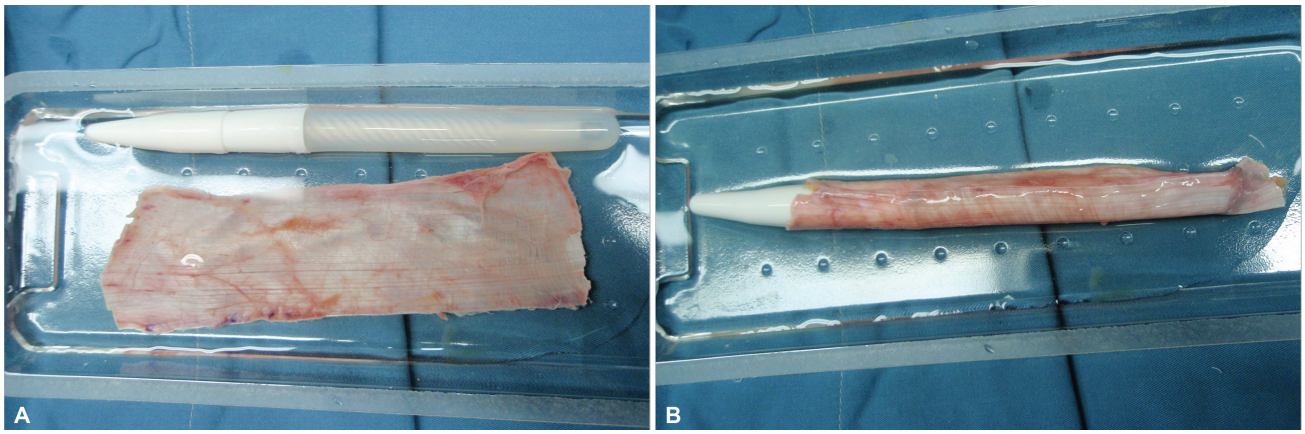

Fig. 3 (A) In the second stage, penile implant placement is done. The implant is wrapped in fascia lata—15 × 15 cm facia is harvested from the thigh. (B) Fascia lata is harvested and wrapped around the implant and sutured using continuous 3–0 PDS sutures and the implant is also fixed to the fascia lata using a transfixation stitch.

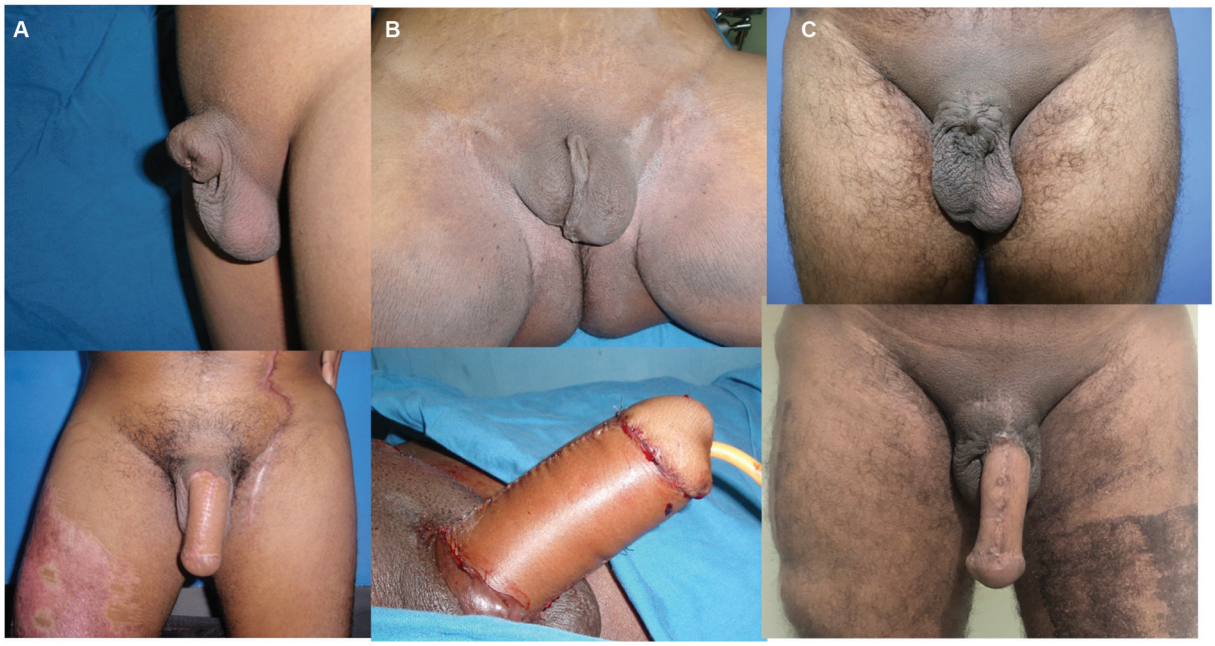

Fig. 4 (A, B) Preoperative and postoperative pictures.

procedure and the patients can micturate in the standing position without any further issues.

All patients at the end of 1 year developed tactile and erogenous sensations. Implants were used in six out of the nine patients. A flexible silicone rod implant was used in all six cases which was wrapped in tensor fascia lata to reduce the chance of extrusion. One patient experienced abnormal projection of the implant from the ventral surface which needed to be repositioned.

All patients could micturate while standing. One patient got married and fathered a child through normal sexual intercourse. Our technique and recipient-site preparation have been modified over time which has reduced the complication rates and has led to a more satisfactory result for the patient (►**Tables 1** and **2**).

Discussion

There has been a great improvement in the outcomes of penile reconstruction since its inception and the technique have moved on from tube pedicle flaps and regional flaps to free tissue transfers.[15]

Among the free flap reconstructions also, there are many design options and flap choices, but worldwide the radial artery forearm flap is the most commonly performed procedure with the best esthetic outcomes and the least number of complications as it has pliable skin, reliable anatomy, and long vascular pedicle and possibility to make it a sensate flap.[16]

The quest for esthetic reconstruction by radial forearm flap has a cost in the form of the donor-site scar on the

Table 1 Etiology, choice of vessel anastomosis, and implant placement

S. no.	Etiology	Recipient artery	Recipient vein	Nerve coaptation	Implant
1	Squamous cell carcinoma	Femoral artery with vein graft	Saphenous vein	Dorsal nerve of penis	Lost to follow-up
2	Traumatic amputation	DIEP artery	Saphenous vein	Dorsal nerve of penis	Secondary
3	Ambiguous genitalia	DIEP artery	Saphenous vein	Dorsal nerve of penis	Primary
4	Micropenis with epispadias	DIEP artery	Saphenous vein	Ilioinguinal nerve	To be placed
5	Hypospadias with micropenis	DIEP artery	Saphenous vein	Dorsal nerve of penis	Secondary
6	Electric injury	LCFA	LCFA VC	Dorsal nerve of penis	Secondary
7	Hypospadias with micropenis	LCFA	LCFA VC	Dorsal nerve of penis	Secondary
8	Hypospadias with micropenis	LCFA	LCFA VC	Dorsal nerve of penis	Secondary
9	Hypospadias cripple	LCFA	LCFA VC	Ilioinguinal nerve	To be placed

Abbreviations: DIEP, deep inferior epigastric pedicle; LCFA, lateral circumflex femoral artery; VC, venae comitantes.

Table 2 Complications and secondary corrective procedures

Patient	Complications	Secondary procedures
1	Urethral fistula	Urethroplasty
2	Nil	Nil
3	Proximal urethral fistula	Secondary closure of fistula
4	Nil	Nil
5	Neophallus skin necrosis; perineal urinary leak	Urethral tube creation with scrotal flap
6	Nil	Nil
7	Urethral fistula	Fistula closure and reinforcement with tunica vaginalis flap
8	Imminent implant exposure	Repositioning of implant
9	Nil	Nil

forearm, which makes it quite conspicuous, but the hand functionality is not affected.[17]

In our series of nine patients, we have continuously tried to incorporate different ideas into our reconstruction algorithm to give stable long-term outcomes:

1. Keeping the urethra at the most vascularized part of the flap to avoid the vascularity issues associated with the most important aspect of the reconstruction, namely, the inner tube of this TWT design.
2. Once the patient confirms that he wants to go ahead with the reconstruction, we mark the prospective urethra and start giving laser therapy for hair removal—Nd: YAG laser of 1,064 nm.
   We have observed that the newer lasers are efficient in controlling hair growth and long-term uretheroscopy documentation shows no significant hair growth and no signs of urinary flow obstruction in the urodynamic studies.
3. *Suprafascial dissection*: In most of the published reports, the flap has been raised including the deep fascia of the forearm, although it makes the flap robust, it increases the circumference of the penile shaft at the same time and makes it difficult to close the donor site, with an increase in the risk of complications.
   In our series, we have consistently raised the radial forearm flap in a suprafascial fashion, totally avoiding any donor-site problem and at the same time have not experienced any major issue related to the vascularity of the flap.
4. *Choice of recipient vessels*: In our understanding, this is the most important aspect of penile reconstruction and regarding this, there is a lot of variation in the choice in literature.
   The femoral vessels which are still used commonly need end-to-side anastomosis, necessitating handling the major vessel of lower limb with its inherent risks and in most of the cases a vein graft is required, further complicating an already complex procedure.
   The deep inferior epigastric vessels harvest needs an abdominal incision, with an unsightly scar, and as the vessels have to be tunneled through the deep inguinal ring, which cannot be closed tightly, moreover, there is a rent in the anterior rectus sheath, significantly increasing the chances of incisional hernia.[18]
   We have started using the descending branch of LCFA as a vessel of choice for radial forearm flap phalloplasties, as it has reliable anatomy, long length, and excellent caliber match with the radial artery. It is fairly easy to dissect and once tunneled under the rectus femoris and thereafter into the pubic region subcutaneously, it can easily reach beyond the midline of pubic symphysis, making the complex phallic reconstruction a relatively simple procedure.

5. *Reinnervation*: The dorsal nerve of penis is our choice for reinnervation of the reconstructed penis as it provides both erogenous and tactile sensation.[19,20]
6. *Implant placement*: We wrap the penile implant with tensor fascia lata because in the reconstructed penis, the implant is placed in the subcutaneous plane only, and natural tunica albuginea is absent; there is a high probability of implant extrusion because of the lack of any supportive structural layer.

To create a semblance of the tunica albuginea, the tensor fascia lata is wrapped around the implant. The healing process generates more fibrous tissue around the implant, restricting the implant movement and reducing the chances of implant extrusion.

We realize that the space available in the penile shaft could easily accommodate one implant and the single malleable implant is effective in maintaining enough rigidity for penetrative sexual intercourse; therefore, in our clinical practice, we have always placed a single malleable implant.

In some situations, we could encounter a forearm, in which the superficial venous system is dominant; therefore, great care always must be taken to anastomose at least one superficial vein along with the venae comitantes.

Conclusion

In our series of phalloplasty, we have attempted to standardize the steps, with great emphasis on simplifying the technique. The use of the descending branch of LCFA makes the procedure simpler, greatly reducing the surgeon's stress and donor-site morbidity. To the best of our knowledge, the use of LCFA as a recipient vessel for penile reconstruction has not been described in the literature. Numerous flaps and phalloplasty design techniques are available,[21] but the radial forearm flap is still the first choice for its predictable anatomy and reliability.

Conflict of Interest
None declared.

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