

REVIEW ARTICLE

Reconstructive Urology: A Comprehensive Review of Flap and Graft Techniques – A review article

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Abstract: **Introduction:** Flap-based reconstruction plays a pivotal role in modern urologic surgery, especially in the management of complex urethral, genital, and perineal defects. **Methods:** This review provides an integrated analysis of flap types, their indications, surgical techniques, and clinical outcomes, with primary emphasis on regional and free flaps. Buccal mucosa grafts and inguinal flaps are discussed as complementary options, particularly in challenging or salvage cases. **Results and Conclusion:** A thorough understanding of tissue selection, flap design, and complication management is crucial for optimal functional and aesthetic results.

Keywords: Reconstructive urology, Flap, Urethral reconstruction, Buccal mucosal graft

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1. Introduction

Reconstructive urology encompasses a broad spectrum of surgical techniques aimed at restoring the function and anatomy of the urinary tract and genital organs. Urethral strictures, trauma, infections, and malignancies often necessitate complex reconstructive procedures. Over the decades, advancements in graft and flap techniques have significantly improved patient outcomes. When primary closure or grafting is insufficient, flaps—defined as vascularized tissue units offer reliable coverage and blood supply, especially in irradiated, ischemic, or infected fields. [1,2] This review highlights the classification, surgical principles, and clinical outcomes of flap-based techniques, with special reference to buccal mucosa and inguinal flaps as adjuncts in urethral and genital reconstruction.

1.1. Overview of Urethral Reconstruction Techniques

Urethral reconstruction can be broadly classified into graft-based and flap-based techniques. Grafts involve the trans-

plantation of tissue without its own blood supply, relying on the recipient site for revascularization. Flaps, conversely, maintain their intrinsic vascularity through a pedicle or microsurgical anastomosis, providing a robust option for complex or scarred tissues. [3]

2. Methods

This review article was conducted through a comprehensive search of published literature from PubMed, Scopus, and Google Scholar. The search terms used included “Reconstructive urology”, “flap”, “urethral reconstruction”, and “buccal mucosal graft”. Relevant peer-reviewed articles published in English between 1995 and 2025 were included (inclusion criteria). Preference was given to systematic reviews, meta-analyses, and clinical studies related to pathophysiology and clinical outcomes associated with Reconstructive urology. Reference lists of selected articles were also reviewed to identify additional relevant studies. 63 articles were reviewed, of which 44 were ultimately used in the text of this review article. The PRISMA flowchart was not used. Articles without full text availability were excluded (exclusion criteria).

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3. Flap Techniques in Reconstructive Urology

Flaps are essential for reconstruction when local tissue is insufficient, scarred, or irradiated. Common flap techniques include penile skin flaps, inguinal flaps, and free flaps such as radial forearm or anterolateral thigh flaps. These methods provide well-vascularized tissue, improving healing and reducing stricture recurrence. While buccal mucosa grafts are popular for urethroplasty, flaps are preferred in ischemic fields or when graft failure risk is high. [1,2,3]. Flaps are categorized by anatomical location and vascular dependence (Table 1).

Indications for Flap-Based Reconstruction

- Long or recurrent urethral strictures [1,2,3,4,5]
- Hypospadias and epispadias & Failed hypospadias repair and urethrocutaneous fistulae [6,7]
- Penile or scrotal skin loss (e.g., Fournier's gangrene) [8,9,10]
- Gender-affirming or trauma phalloplasty [11,12,13,14]
- Bladder and ureteric reconstruction (rare) [15,16]

3.1. Penile Skin Flaps

Penile skin flaps are pedicled fasciocutaneous flaps harvested from the penile shaft or foreskin. Their robust blood supply and tissue characteristics make them suitable for long segment urethral strictures, especially in patients with scarred or irradiated urethras. However, donor site morbidity and the complexity of surgery are notable considerations.

3.2. Inguinal Flaps

Inguinal flaps provide a large, well-vascularized tissue source for complex reconstructions, including genital and urethral defects. These flaps are useful in cases of extensive tissue loss or prior failed repairs but require careful planning and expertise. A regional fasciocutaneous flap based on the superficial circumflex iliac artery.[24] Highly effective in penile and scrotal resurfacing, urethral coverage in staged repairs, and salvage of hypospadias. [24,25] May require thinning due to bulk; hair-bearing skin can be a limitation. In urethral reconstruction, the flap can be tubed or used as a cover for staged repairs [26].

The inguinal flap is especially useful in the following urologic contexts:

- Penile Skin Loss
- Trauma (e.g., burns, degloving injuries) [8,9,10,23]
- Fournier's gangrene
- Penectomy reconstruction [19]
- Scrotal Reconstruction
- Extensive tissue loss due to necrotizing fasciitis or tumor excision [20]
- Urethral Reconstruction
- Complex urethrocutaneous fistulas

- Salvage hypospadias repair
- Urethral cutaneous substitution in failed perineal urethroplasty [25]
- Gender Affirmation Surgery
- Neophallus creation using pre-fabricated or pedicled flaps [27]

3.3. Free Flaps

Free flaps such as the radial forearm free flap (RFFF) or anterolateral thigh flap (ALT) offer versatility for extensive urethral and genital reconstruction, especially in cases with irradiated or scarred fields where local tissue options are limited. [23,24] Radial Forearm Free Flap (RFFF) Gold standard in phalloplasty; provides pliable tissue, acceptable aesthetic, and tactile qualities [11,13,28]. Anterolateral Thigh (ALT) Flap Increasingly used for phalloplasty due to less donor site morbidity [12,13]. It is used increasingly in neophallus construction due to lower donor morbidity. These flaps require microsurgical expertise and longer operative times.

3.4. Dartos and Tunica Vaginalis Flaps

Used to cover the neourethra in hypospadias repair, reducing fistula risk significantly. [17,18,19]

3.5. Gracilis Muscle Flap

Utilized in rectourethral or perineal fistula repairs, offering robust vascularity but potential donor site morbidity. [20,21,22]

3.6. Supporting tissues (flaps)

Use the diverticulum wall as a supporting tissue for this technique. One of the key points of urethral diverticula surgical repair is assembling a good supporting tissue on the surgical site to minimize recurrence and complication rate. A vascularized tissue is the first choice for this purpose, but sometimes it is difficult to find a proper tissue, for example, in large diverticula, so in this situation, using a vascularized graft, such as the buccal mucosal graft, warranted good results because, after a while, this tissue was vascularized. A supporting flap layer for covering the urethroplasty site has the advantage of minimal dissection during surgery and good postoperative outcomes. [44]

4. Graft Techniques in Reconstructive Urology

Initially introduced in the early 1990s [27], BMG urethroplasty has revolutionized the management of anterior urethral strictures and continues to gain popularity in reconstructive urology. Grafts, particularly buccal mucosa grafts, have become the gold standard for many anterior urethral reconstructions because of their favorable histological prop-

erties and ease of harvest. Though BMGs are technically a graft and not a flap, it complements flap procedures in urethral reconstruction due to their compatibility with moist environments and high graft take rates. [29] Other graft sources include penile skin, bladder mucosa, and lingual mucosa. Grafts require a healthy vascularized recipient bed to survive and integrate successfully.

Histological and Physiological Advantages of Buccal Mucosa
Buccal mucosa is composed of a thick, non-keratinized stratified squamous epithelium with a rich capillary network in the lamina propria. Its advantages include:

- Resilience to moist environment (similar to urethral tissue) [30]

- Ease of harvest with low donor site morbidity [31]

- Rapid neovascularization and integration [32]

- Resistance to infection and trauma [32]

The primary indications for BMG in urology include:

- Anterior Urethral Strictures – Especially in long or recurrent strictures of the bulbar urethra [2].

- Panurethral Strictures: As part of staged or single-stage procedures [33].

- Hypospadias Repair: In salvage and redo surgeries. [34]

- Lichen Sclerosus associated Strictures: Where genital skin is contraindicated [35].

- Pediatric Urology: Complex urethral reconstructions and redo hypospadias repairs [2].

4.1. Surgical Techniques

Several techniques have been developed for the application of BMG in urethral reconstruction:

5.1.1. Dorsal Onlay Urethroplasty (Barbagli Technique)

Involves dorsal urethrotomy and placement of the graft on the tunica albuginea of the corpora cavernosa [27].

5.1.2. Ventral Onlay Technique

Graft is placed ventrally; technically easier but possibly with higher complication rates in some cases [36].

5.1.3. Lateral Onlay

Modified approach providing a compromise between dorsal and ventral techniques [33].

5.1.4. Two-Stage Urethroplasty

For complex or obliterated strictures, especially those associated with lichen sclerosus [35].

5.1.5. Augmented Anastomotic Urethroplasty

Combines excision of the fibrotic segment with dorsal BMG to bridge longer gaps [2].

4.2. Artificial graft (such as amniotic membrane)

Dry human AM is a safe, efficient, and applicable option to accelerate the process of secondary healing of surgical wounds. Moreover, it can reduce wound complications, duration of hospitalization, and treatment costs. [42] Amniotic membrane graft provides an applicable, low-cost, feasible,

biodegradable, and safe second cover in redo-hypospadias repairs by tabularized incised plate technique. Its use is technically easy; it has satisfactory cosmetic outcomes and might decrease urethrocutaneous fistula formation. [43]

5. Hybrid and Staged Approaches

Complex or long-segment strictures may require combined or staged reconstruction using both grafts and flaps. Staged urethroplasty allows for tissue optimization and healing before definitive reconstruction. Hybrid approaches maximize the advantages of each technique while minimizing limitations.

6. Key considerations

Grafts are preferred in healthy, well-vascularized recipient beds.

Harvesting Flaps must be meticulously dissected with preservation of vascular pedicles. [38,21]

In setting Proper orientation and tension-free suturing are critical. [39]

Flaps are advantageous in scarred, irradiated, or previously failed repairs.

Combined approaches maximize outcomes in complex scenarios but require advanced expertise.

Patient factors, surgeon experience, and resource availability influence technique choice.

Surgical Considerations

- Harvesting: Preservation of the vascular pedicle is essential.
- In setting: Tension-free, properly oriented suturing is critical for survival.
- Microvascular Anastomosis: Required for free flaps; technically demanding.
- Combination Techniques: Buccal mucosa + inguinal flap in multistage urethroplasty shows promise in complex cases.

7. Outcomes

BMG urethroplasty shows excellent long-term outcomes:

- Success rates: 80–90% for bulbar urethral strictures [2,34]
- Durability: Maintained over 5–10 years in most studies [34]
- Reoperation rates: Low with proper surgical technique and patient selection [31] Success Rates: Generally high (>80%) when flap selection is appropriate.

Dartos flaps reduce fistula rates from 30% to <10% in hypospadias [6,18].

Gracilis flap repairs achieve >80% fistula closure. [22]

RFFF phalloplasty shows high satisfaction, but donor site dissatisfaction in 30%. [11,13]



8. Conclusion

Selective arterial embolization (SAE) is a safe and effective palliative treatment for persistent hematuria refractory to conventional therapies. It offers significant symptom relief with a low complication rate and can reduce the need for more invasive surgical procedures, such as cystectomy. While additional interventions may be necessary in some cases, SAE represents a valuable option for managing intractable hematuria in patients with advanced urological malignancies and radiation cystitis, especially those not suitable for major surgery. This study emphasizes the importance of careful patient selection, individualized treatment planning, and ongoing monitoring to optimize patient outcomes. SAE provides meaningful clinical benefits and should be considered a viable alternative in managing refractory hematuria in high-risk populations.

9. Complications

- Flap necrosis (poor perfusion)
- Fistula formation (infection/tension)
- Donor site morbidity (e.g., sensory loss, scarring, Rare salivary duct injury, or oral stenosis [26])
- Donor site morbidity is minimal, with most patients healing within 1–2 weeks [26,27].
- Buccal mucosa grafts exhibit long-term durability with minimal morbidity.
- Inguinal flaps offer good aesthetics and healing in compromised fields but may require secondary revisions.

10. Future Directions

Use of perforator-based flap variants for thinner, more aesthetic outcomes

Tissue engineering approaches are under development to reduce the need for donor sites

Robotic-assisted flap harvesting and vascular mapping to improve precision and less morbidity. [12,15,40]

Microsurgical applications are emerging for total phallic reconstruction [37]

11. Conclusion

Reconstructive urology continues to evolve, offering patients effective solutions for complex urethral and genital defects. Flaps play a critical role in reconstructive urology. Their judicious use enables restoration of form and function in challenging cases. Surgical expertise and careful planning are essential for optimal results. [10,41] The choice of reconstructive technique should be individualized, considering defect characteristics, patient factors, and surgeon expertise.

Flap-based techniques, with their intrinsic vascularity and versatility, play a pivotal role, especially in challenging and

recurrent cases where grafts alone may be insufficient. Buccal mucosa graft remains the gold standard for many anterior urethral reconstructions due to its favorable histological and clinical properties.

Hybrid and staged approaches have expanded the reconstructive armamentarium, improving outcomes in complex scenarios. Future advances in tissue engineering hold promise but require further clinical validation.

Ultimately, successful reconstruction relies on meticulous surgical planning, appropriate technique selection, and multidisciplinary patient care to optimize functional and cosmetic results.

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Table 1: Category of flaps by anatomical location and vascular dependence

Type	Source	Application
Local flaps	Adjacent tissue	Hypospadias repair, small defects
Regional flaps	Nearby pedicled tissue	Urethral, penile, scrotal coverage
Free flaps	Distant tissue, microvascular	Total phallic reconstruction

Table 2: Comparative Table of Grafts and Flaps in Reconstructive Urology

Technique	Indications	Advantages	Limitations
BMG	Anterior urethral strictures, health recipient bed	Easy harvest, good histology, high success rate	Not suitable for scarred or irradiated tissue
Penile skin flap	Long segment strictures, scarred urethra	Vascularized, versatile, suitable for poor bed	Donor site morbidity, more complex surgery
Free flaps	Extensive tissue loss, irradiated/scarred fields	Versatile, well-vascularized	Requires microsurgery, high complexity