Fundamentals and Principles of Tissue Transfer

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Genitourinary reconstructive surgery often requires transfer of tissue from a donor to a recipient site. Techniques of tissue transfer in reconstructive urologic surgery require knowledge of donor and recipient tissue composition and physical characteristics and principles of tissue transfer—topics that are addressed in this chapter.

4.1 Tissue Composition and Physical Characteristics

The three types of tissue frequently used for urethral reconstruction are skin, bladder epithelium, and buccal mucosa [1]. This chapter will focus on these transferred tissues; however, the basic principles apply to all donor and transfer situations.

4.1.1 Tissue Composition

The superficial layer of the skin, the epidermis, is 0.8–1.0 mm deep (Fig. 4.1). The deep layer of the skin, the dermis, is separated into two layers. The superficial dermal layer, the adventitial dermis, is also called the papillary dermis in areas without skin adnexal structures, and the periadnexal dermis in areas with adnexal structures. The deep dermal layer is called the reticular dermis.

The superficial layer of the bladder wall lining is the epithelial layer and the deep layer of the bladder wall lining is the lamina propria (Fig. 4.2). Similar to skin, the bladder lamina propria also has a superficial and deep layer. The contraction characteristics of a bladder epithelial graft appear to be similar to those of full-thickness skin, and although formation of diverticula in bladder epithelial grafts is a concern, proper graft tailoring can prevent this complication.
The superficial layer of the buccal tissue is the mucosal layer and the deep layer is referred to as the lamina propria (Fig. 4.3). As in the bladder, the buccal lamina propria has superficial and deep layers. Unlike split thickness skin, which contracts significantly in unsupported tissues, the contraction characteristics of the buccal mucosal graft appear to be similar to those of full-thickness skin, even with only a portion of the deep lamina included in the harvest.

4.1.2 Vascularity

The interface of the epidermal or epithelial layer with the superficial dermis or superficial lamina contains the superficial plexus (e.g., in skin, the intradermal plexus) and some lymphatics. The deep dermal layer, or lamina, contains most of the lymphatics and the majority of the collagen content, as compared with the superficial layers. The deep plexus (e.g., in skin, the subdermal plexus) is located at the interface of the deep dermal layer and underlying tissue and, in most cases, is connected via perforators to the superficial plexus (Fig. 4.1). The microvasculature of the bladder epithelium is similar to skin in that it consists of two plexuses: a deep laminar plexus and a superficial laminar plexus (Fig. 4.2). In contrast to the layered distribution found in the skin and bladder, the microvasculature of the lamina propria in the buccal mucosa is distributed uniformly, which allows it to be harvested at various levels without affecting the vascular characteristics of the graft (Fig. 4.3).

4.1.3 Tissue Characteristics

All tissue has inherent physical characteristics. Extensibility and innate tissue tension are primarily a function of the helical arrangement of collagen and elastin cross-links in the deep tissue layers. Extensibility relates to the tissue's ability to distend, while innate tissue tension relates to the static forces present in nondistended or distracted tissue. The vesicoelastic properties of stress relaxation and creep are influenced by the collagen-elastin architecture and the interaction with the mucopolysaccharide matrix in which it is suspended. The vesicoelastic property creep describes the ability of skin to gradually stretch when a constant unchanging load is applied (Fig. 4.4). Stress relaxation, in contrast, is the gradual decrease in tension occurring over time when skin is stretched at a constant distance (Fig. 4.5).

![Fig. 4.3. Cross-sectional anatomy of the buccal mucosa (histology above, microvascular anatomy below). Note the panlaminar vascular plexus. (From [13, 14])](image)

![Fig. 4.4. Example of the vesicoelastic property termed creep. (From [15])](image)

![Fig. 4.5. Example of stress relaxation, another skin property. (From [15])](image)
In cases where tissue transfer is required for urethral reconstruction, nonhirsute full-thickness skin or, recently, a buccal mucosa graft is preferred. Bladder epithelium may be used as a substitute when other tissue is unavai-

4.2 Tissue Transfer Techniques

Tissue can be transferred as a graft or a flap. Tissue that has been excised and transferred to a recipient (graft host) bed where a new blood supply develops is termed a graft. Tissue that is excised and transferred with its blood supply either preserved or surgically reestablished at the recipient site is termed a flap.

4.2.1 Grafts

Neovascularization is the development of a new blood supply and «take» is the term applied to the process whereby graft tissue undergoes neovascularization after excision and transfer to a recipient (graft host) bed. Take occurs in two phases that together require approximately 96 h. During the initial phase, called imbibition (approximately 48 h), the graft temperature is lower than the core body temperature and the graft survives by taking up nutrients from the adjacent graft host bed. During the second phase, termed inosculation (approximately 48 h), the graft temperature rises to core body temperature and true microcirculation is reestablished in the graft. The process of take is influenced by both the nature of the grafted tissue and the conditions of the graft host bed. Processes that interfere with the graft or host bed vascu-

larity (e.g., infection or a subgraft collection) can interfere with graft take.

4.2.1.1 Graft Classifications

Four grafts commonly used for genital reconstruction are the split thickness skin graft (STSG), full-thickness skin graft (FTSG), bladder epithelial graft, and buccal mucosal graft. A STSG carries the epidermis or covering and exposes the superficial dermal (intradermal) plexus (Fig. 4.1). Because the superficial plexus has numerous small vessels, a STSG has favorable vascular characteristics; however, because it «carries» few physical characteristics of the transferred tissue, it has a tendency to be brittle and less durable. However, because the STSG does not include most of the lymphatics, it is useful in cases of reconstruction for lymphedema.

A mesh graft is a STSG with systematic slits placed in it after harvest and before application. The slits can expand the graft by various ratios, allowing subgraft collections to escape and allowing better conformation to irregular graft host beds. It has also been proposed that the slits increase growth factors, causing a mesh graft to take more readily. Although FTSGs can be meshed, they rarely are; exceptions are preputial or penile skin. Expanded buccal mucosa grafts have been evaluated in the animal model but no clinical application has been undertaken to date.

A FTSG carries the covering (epidermis), the superficial dermis and the deep dermis. Its vascular characteristics are more fastidious than that of a STSG because the deeper plexus is composed of larger, more sparsely distributed vessels (Fig. 4.1). However, because a FTSG «carries» most of the physical characteristics of the trans-

ferred tissue, it is typically more durable at maturity and does not contract as much as a STSG. Because the lymphatics are usually associated with the deep layer, they are included with a FTSG. On the other hand, although these are general characteristics of FTSGs, because FTSGs carry characteristics of the transferred tissue, each graft has distinctive characteristics that are dependent on the donor site. For example, extragenital FTSGs have increased mass, which generally makes them more fastidious than genital FTSGs (i.e., penile and preputial skin grafts). However, an exception is found in the extrage-

nital skin of the posterior auricular area, which has thin skin overlying the temporalis fascia. The full-thickness postauricular graft (Wolfe graft) is carried on numerous perforators. The subdermal plexus of the Wolfe graft therefore appears to mimic the characteristics of the intradermal plexus, while its total mass is more like that of a STSG.

A bladder epithelial graft has superficial and deep plexuses that are connected by many perforators, and therefore it tends to have favorable vascular characteristics (Fig. 4.2). A buccal mucosal graft has a panlaminar plexus (Fig. 4.3), which is reputed to provide optimal vascular characteristics; when sufficient deep lamina is carried with the graft to preserve the physical characteristics of the buccal mucosa, it can be thinned without seemingly adversely affecting the graft’s vascular characteristics. Moreover, in recent times, the wet epithelial surface of the buccal mucosal graft is considered to be favorable for urethral reconstruction; therefore a buccal mucosal graft may often be preferred.

4.2.1.2 Use of Grafts for Excision and Tissue Transfer in Urethral Reconstruction

There has been a recent resurgence of interest in graft reconstruction of the urethra, especially using buccal mucosal grafts. The most successful use of grafts has been in the area of the bulbous urethra, where the urethra is invested by the ischial cavernosus musculature. Although the graft can be applied to the urethral ventrum,
A ventral urethrotomy only appears to be advantageous when spongioplasty is also used (Fig. 4.6A). However, spongioplasty requires that the corpus spongiosum be relatively normal and free of fibrosis adjacent to the stricture. A lateral urethrostomy or dorsal graft onlay, in our opinion, are preferred. Placing the urethrostomy laterally allows exposure of the urethra while cutting through the corpus spongiosum where it is relatively thinner, limiting bleeding and maximizing exposure (Fig. 4.6B). This can be quite useful with flaps, but with the recent experience with dorsal graft onlay, probably provides little advantage to dorsal graft onlay.

The Monseur urethral reconstruction technique, alternately used in a few centers, creates the urethrostomy through the dorsal wall of the stricture, with the edges of the stricture sutured open to the underlying triangular ligament and/or corpora cavernosa [2]. Barbagli described a modification of this technique in which the urethrostomy is created through the stricture on the dorsal wall with a graft then applied as an onlay [3]. The graft is fixed to the area of the urethrostomy at the triangular ligament and/or corpora cavernosa and the edges of the stricture are sutured to the edges of the graft and adjacent structures (Fig. 4.6C). Series with relatively short follow-up have yielded excellent results with this modification [4–6]. The dorsal graft onlay technique can also be used in combination with partial stricture excision and floor-strip anastomosis (i.e., augmented anastomotic procedure).

Two-staged application of a mesh STSG, buccal muco-sa graft, or posterior auricular FTSG is another option. A medium split thickness skin graft or other full thickness graft as indicated above are placed over the dartos fascia in the first stage of the mesh graft procedure (Fig. 4.7); however, when placed immediately onto the tunica albuginea or corpora cavernosa, the graft cannot be mobilized and second-stage tubularization is difficult. Having at least a midline strip of the graft adhered to the corpora cavernosa, though, supports the urethra. The graft is tubularized in second-stage surgery performed at a later date (Fig. 4.8). When the STSG procedure was first introduced, second-stage surgery was performed within 3–4 months of the first stage [7]; we now wait 6–12 months between first- and second-stage surgeries. It appears advantageous to wait at least 1 year with a STSG while the buccal mucosa grafts and postauricular grafts seem to mature at 6 months. This procedure has been useful for select cases in the United States and Europe; however, it has only been used for the most difficult cases in the United States, with single-stage reconstruction applied to most.

The staged buccal mucosa is a relatively new concept. The graft does very well when used in staged fashion, and the staged buccal graft technique may be the salvation for reconstruction of urethral strictures associated with

![Diagram of various techniques of graft onlay. A Ventral onlay with spongioplasty. B Lateral onlay with quilting to the ischial cavernous muscle. C Dorsal onlay with spread fixation of the graft. (From [13])](image-url)