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Hypospadias repair with the glanular-frenular collar (GFC) technique

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Summary

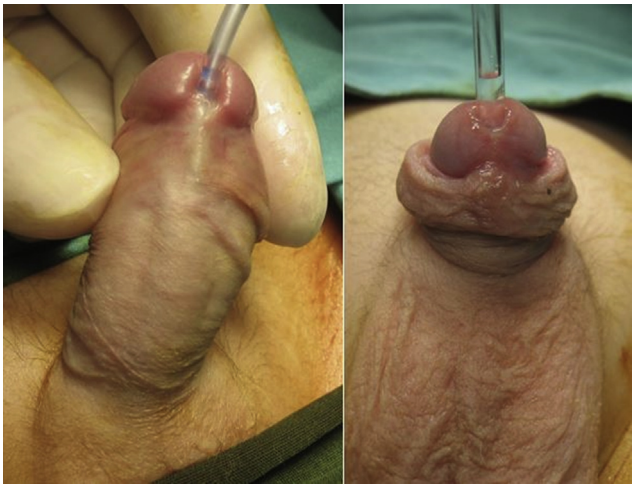
Background
In the normal human penis, the glans wings merge in the midline ventrally, but are separated by the 'septum glandis' in conjunction with the frenulum. The frenulum is also included in the formation of the distal (glanular and subcoronal) urethra, which has a special part known as the 'fossa navicularis'. This has inspired a hypospadias repair technique that simulates the development of the glanular and subcoronal urethra, which can be incorporated into the repair of all cases of hypospadias.

Material and method
A total of 121 patients with varying degrees of hypospadias underwent surgery with the described technique: a Y-V plasty was used to dissect the inner foreskin, in a fashion that allowed for its ventral mobilization as a frenular mucosal collar. After tubularization of the proximal urethra, a partial spongioplasty was performed that extended up to the subcoronal level. The glans wings were approximated only at their outermost convexities, with a couple of subepithelial sutures, leaving a slit for the meatus. The cleft-like area between the split wings of the glans penis was filled with the terminal ends of the spongiosum and the dartos of the mucosal collar, which converged to form a septum and a neo-frenulum (glanular-frenular collar, GFC). The midline skin closure of the ventral collar and the circumferential foreskin closure was completed as usual.

Results
At a mean follow-up of 10 months, two patients developed urethral fistula (2%), six had meatal stenosis (5%), and two had glans dehiscence (2%) that resulted in meatal retraction. Overall, patients had a cosmetically satisfying appearance (Figure). Forty-one received secondary circumcision; the parents of 80 (66%) patients were satisfied with the final foreskin appearance obtained with this method.

Discussion
The split wings of the glans penis or so-called ventral cleft between the glans wings that accommodate the frenulum is part of normal anatomy. Hence, in hypospadias surgery, the approximated glans wings should allow for ventral support of the glanular and subcoronal urethra through a reconstructed neo-frenulum. Neither glanular surface enhancement nor extensive dissection of the glans wings and their full-length approximation are necessary, and may in fact be counter-productive.

Conclusions
The employment of a GFC provided: 1) an anatomical restoration of the distal (glanular and subcoronal) urethra, supported by a frenulum; 2) a protective (undissected) dartos layer over the distal part of the tubularized neourethra; and 3) a space for the re-formation of the fossa navicularis.



Summary Fig Pre-operative and postoperative images of a patient operated with the GFC technique.1

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Introduction

In normal human penis anatomy, the glans wings are separated by a median partition (septum glandis) and a ventral cleft between the glans wings that accommodates the frenulum. The septum glandis is well-defined fibrous tissue that separates the two hemiglans and suspends the glanular urethra (fossa navicularis) between the sheath of the conical end of the corpora cavernosa and the frenulum of the prepuce [1—3]. In addition to a defective urethra and its corpus spongiosum, the frenulum is entirely missing in hypospadias. The foreskin is not fused ventrally; it appears as a hood over the glans penis. Recent studies have shown that masculinization of the urethral plate occurs in association with the growth and fusion of the preputial fold along the ventral midline of the genital tubercle, which also forms the frenulum of the proximal part of the glanular urethra [4—9]. Hence, it is clear that formation of a normal urethra, with its fossa navicularis, is an important indicator of an anatomical hypospadias reconstruction.

The described operative technique based on a glanular-frenular collar (GFC) was designed with an understanding of the abnormal urethral and foreskin development in hypospadias. The terminal ends of the bifurcated spongiosum and the dartos of the laterally-hooded inner foreskin were used as a ventral collar, thus emulating normal anatomy by creating a septum glandis and frenulum with a space to accommodate the fossa navicularis, which in general is not specifically addressed in urethroplasties. The preliminary reports were previously presented [10].

Materials and methods

Between 2010 and 2015, 121 patients with hypospadias (84 distal-to-mid penile, 37 proximal penile/penoscrotal), without severe chordee (<45°) underwent the GFC technique by one surgeon (HÖ). In all patients, urethral plates and hooded foreskins were present at a sufficient level for a primary repair with tubularized incised plate (TIP) incorporated with GFC reconstruction.

Surgical technique

The operation routinely started by specifying the anatomical landmarks of the foreskin and penis. Two holding sutures were placed on the edges of the 'dog-ears'. By elevating these sutures, the angle of the inverted V-shaped foreskin was changed from downwards to upwards, forming the arms of a 'Y'. The initial incision was performed between these two holding sutures on the naturally occurring linear border between the inner and outer forekin, ending on both sides of the hypospadic meatus. The leg of the 'Y' was formed with a vertical midline incision on the inner foreskin, and a third holding suture was placed at its end (Fig. 1A and B). Extreme care was taken while dividing the dartos layer, in order to preserve it for both the inner and outer foreskin layers. The vertical midline incision facilitates subsequent ventral rotation and midline approximation of the inner foreskin as a ventral collar in the form of the frenulum.

A ventral 'U' incision around the hypospadic meatus was performed, and the arms of the incision were extended towards the glans wings along the urethral plate. The glans wings were incised up until their outermost prominent convexities (glans monticuli). Degloving below the meatal level was performed as required in order to find and release the diverted corpus spongiosum. A tubularized incised plate (TIP) repair and partial spongioplasty that extended up to the subcoronal level (using subepithelial 7/0 polydioxanone) were performed in all patients. The terminal ends of the displayed and bifurcated corpus spongiosum at the glanular and subcoronal level and the dartos of the ventral preputial collar were dissected carefully (Fig. 2).

The glans wings were approximated only at their outermost convexities, with a couple of subepithelial (6/0 polyglactin) sutures, which left a slit for the urethral meatus. At the mid-frenular level, the ventral collar was approximated in the midline with a full-thickness suture (6/0 polyglactin). By suspending this suture superiorly, a cleft-like area between the wings of the glans penis was exposed. This cleft-like area was filled with the terminal ends of the spongiosum and the dartos of the mucosal collar (using 7/0 polydioxanone sutures), which converged to form a septum and a

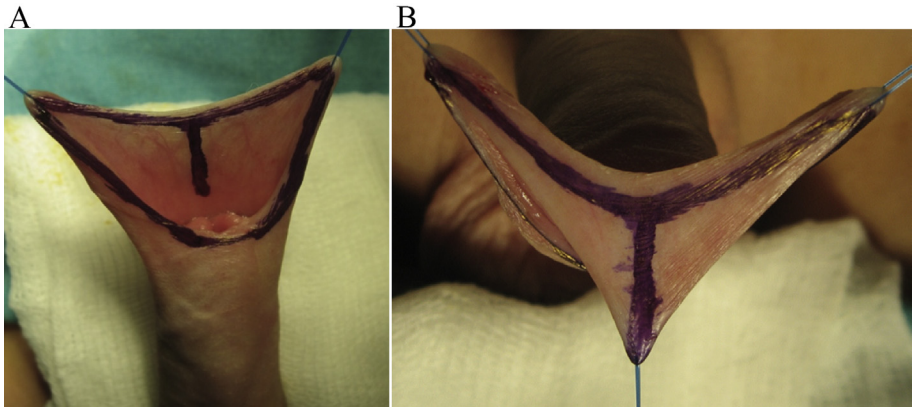

Figure 1 **A and B.** A 'Y' incision dividing the outer and inner foreskin, which facilitates ventral rotation of the latter as a ventral collar. The dartos layer is preserved for both the outer and inner foreskin layers.

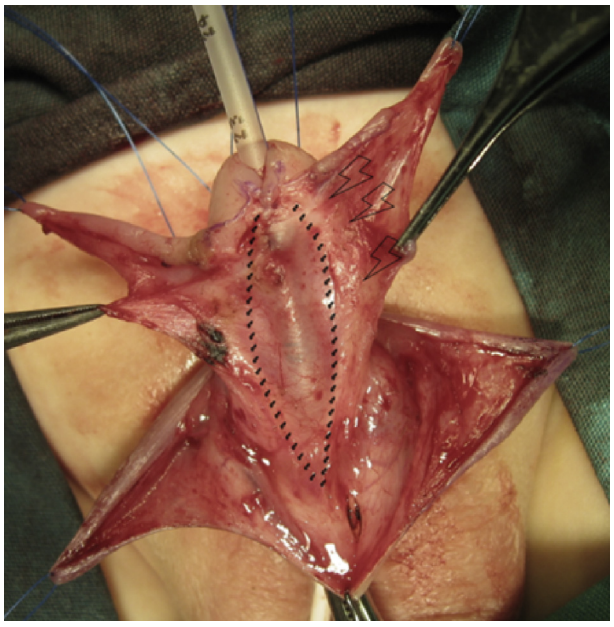

Figure 2 Completion of a tubularized incised plate repair and exposition of the laid open bifurcated corpus spongiosum (dotted lines) and the dartos of the ventral mucosal collar (arrows). Note their close relationship at the glandar and subcoronal level.

frenulum in the midline of the GFC. The midline skin closure of the ventral collar (with 6/0 polyglactin interrupted sutures) provided a normal glans anatomy with a neo-frenulum reinforced with spongiosal elements and dartos. Circumferential trimming of the outer foreskin (including the so called 'snake eyes') was performed, and the circumferential foreskin closure was completed with 6/0 polyglactin, as the Y-V plasty was developed circumferentially in the dorsum (Fig. 3A, B and C).

For dressing, the penis was lain backwards onto the pubis, loosely covered with a gauze and fixed with drape. The urethral dripping stent (8-FG feeding tube) was fixed with a glanular holding suture (4/0 Prolene) and kept for about 5—7 days.

Results

A slit meatus and a neo-frenulum between the split wings of the glans penis was obtained in all but two patients (Fig. 4B). At a mean follow-up of 10 months (range 3—46 months), two of the patients with proximal hypospadias (2%) developed urethral fistulas, six had meatal stenosis (5%), and two (2%) had glans dehiscence that resulted in coronal meatus. The fistulas were repaired, and the patients with meatal stenosis were successfully cured with dilation. Dilation was undertaken through calibration of the meatus with FG 6 and 8 feeding tubes, four times at the most, over a period of 3 months. Two patients with coronal meatus (without stenosis) remain as is. In compliance with parental preference, 41 patients received a delayed circumcision on a day surgery basis under general anesthesia, together with evaluation of the neo-meatus.

Discussion

A clear understanding of the normal anatomy of the penis and the origin of the penile urethra is essential for an anatomical reconstruction in hypospadias surgery. In the normal human penis, the glans wings merge in the ventral midline, but are separated by the frenulum at the same instance, and not attached to each in the deeper layers. The septum of the glans penis (septum glandis) is a median partition within the glans that extends between the conical end of the corpora cavernosa and the frenulum, and surrounds the glanular urethra. Hynes and Fraher proposed that the formation of the entire urethra occurs with the fusion of the paramedian folds, which entails a distally moving wave of medially directed mesodermal growth [9]. The frenular fold at the proximal glans is formed by the preputial fold, which is continuous with the mesoderm of the urethral fold. It was shown that subsequent fusion of the frenular folds form the proximal glanular urethra and the preputial frenulum. The mesodermal continuity of the caudal extremities of the preputial folds in the midline is thought to require fusion of the urethral folds, progressing at least as far as the base of the glans. The lacunar folds, which are continuous with the frenular folds, fuse and separate the lacunar groove from the surface, thereby

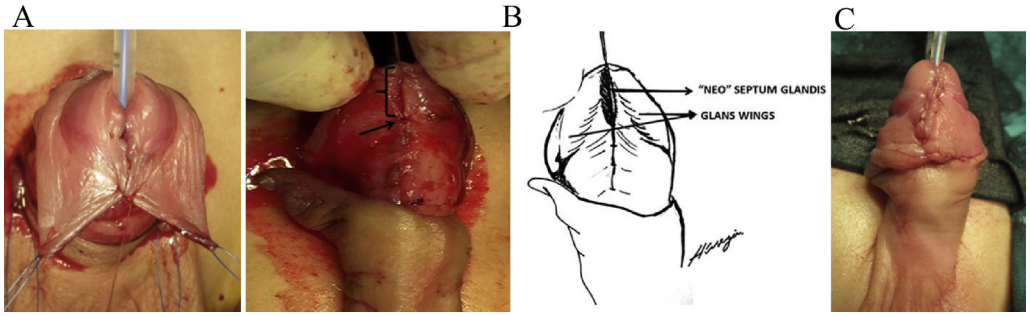

Figure 3 **A**. Subepithelial approximation of the glans wings and a holding suture at mid-frenular level of the ventral mucosal collar. **B**. Holding the suture superiorly exposes a cleft-like area between the glans wings (curly bracket) and the last stitch of the partial spongioplasty extending up to the subcoronal level (arrow), filling the cleft-like area between the glans wings (septum glandis) with the terminal ends of the spongiosum and dartos of the mucosal collar. **C**. Midline skin closure of the ventral collar providing a neo-frenulum reinforced with spongiosum and dartos: the glanular-frenular collar (GFC).

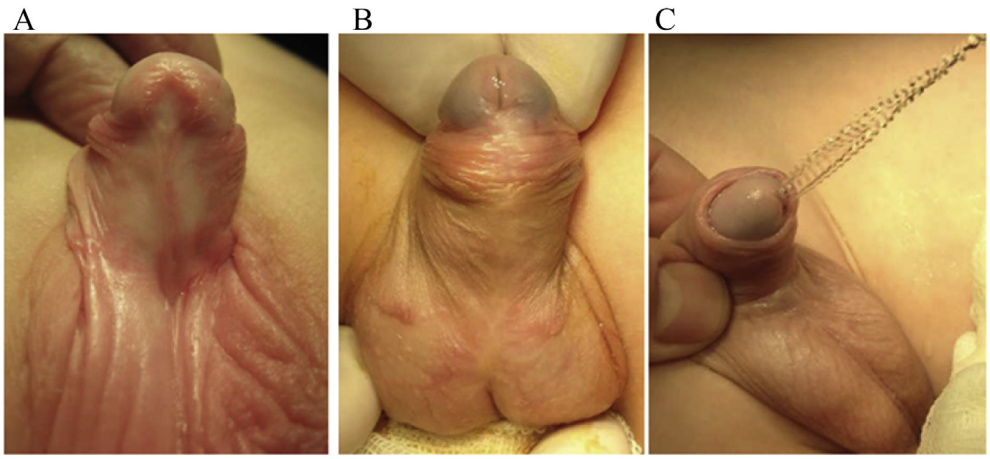

Figure 4 **A, B and C**. Pre-operative and postoperative views of a patient with penoscrotal hypospadias repaired with the GFC technique. Note the wave pattern of the urine stream.

forming the distal one third of the glandar urethra. Hynes and Frahe concluded that a hooded prepuce was the result of a failure in fusion of the caudal extremities of the preputial folds.

Van der Putte proposed a similar hypothesis, suggesting that the shape and position of the urethral orifice was determined by the growth of primordial fascial tissues (mantle elements) and distal corpus spongiosum proximal to the terminal part of the urethra. The author also propounded that the urethral meatus was covered with ventral prepuce and frenulum, a concurrent distalward growth process of the median primordial fascial tissues [11,12]. Previously, a similar proposal was made by Kurzrock and Baskin, that the fusion of the urethral fold in the glandar urethra was associated with preputial folding. The end product of this association was described as an epidermally lined bar of mesenchymal tissue that connected the prepuce and glans ventrally — the frenulum [6]. This finding was confirmed by Shapiro et al. by staining 16—22 week human fetal glans with antibodies to cytokeratin (CK)14. The authors concluded that the ventral aspect of the meatus appeared to form the surrounding CK14-positive epithelium of the cellular lamella, which was explained with sufficient distal extension of the frenulum [13]. Hadidi et al. suggested that the floor of the glanular canal seemed to form through the distal migration of the glanulopreputial lamella, which formed the prepuce and fused the edges of the glanular groove to build the floor of the glanular urethra [14].

According to the above-mentioned recent concepts of urethral development, an anatomical correction of hypospadias should include tubularization of the urethral plate, reunion of the diverted corpus spongiosum, and construction of septum and frenulum to form the glanular and the subcoronal urethra. With magnetic resonance imaging (MRI) studies of the hypospadic penis, Kureel et al. recently demonstrated a close connection between the dartos and bifurcated spongiosum of the laid-open urethra, which were continuous with glans tissue and the adjacent preputium [15]. By using the terminal ends of the diverted corpus spongiosum and the dartos tissue of the mucosal collar approximated at the midline, the GFC technique involves formation of a septum and a frenulum between the glans wings, similar to the embryologic development of the terminal urethra. If, as suggested by Van der Putte, the primordial fascial tissues, which bifurcate at some distance from the hypospadic orifice, terminate in dorsolateral 'dog-ears', the GFC technique can provide for these tissues to be brought symmetrically into the midline, thus restoring normal anatomy [8]. It can also be proposed that the glanular urethra (fossa navicularis) should be supported by loose connective tissue (septum and frenulum) ventrally, and should not be covered (compounded) by the glans wings over its full length. The concept of the GFC technique is compatible with histologic and MRI findings of the hypospadic penis.

In the present series, patients with severe chordee were excluded from the study for a two-stage repair. However, there is also experience of successful application of the GFC technique on patients in the second stage of their repair by harvesting the mucosal collar and attaching it to the lateral aspects of the future frenulum. In the present series, it was not necessary to augment the urethral plate with inlay grafting, and this was attributed to the tension-free tubularization afforded by the limited spongioplasty and the position of the ventral aspects of the glans wings separated by the septum and the neo-frenulum.

In 1987, Firlit introduced the 'mucosal collar' technique, in which the inner 'mucosal-like' surface of the foreskin was transposed to the ventral aspect of the penile shaft [16,17]. The incision and mucosal flaps in the GFC technique are essentially distinct from the Firlit mucosal collar technique (Fig. 5). The Firlit incision was described as a 'chevron' incision within the inner surface of the foreskin. In the GFC technique, the initial incision (i.e., the arms of the Y) follow the border between the inner and outer foreskin, and the leg of the Y-incision is on the midline of the inner foreskin. The Y-incision protects the vascular supply of the inner mucosal collar, which can be jeopardized with the chevron incision, and allows for complete dissection to include all other subepithelial elements. In most of the current surgical repair techniques, the fine

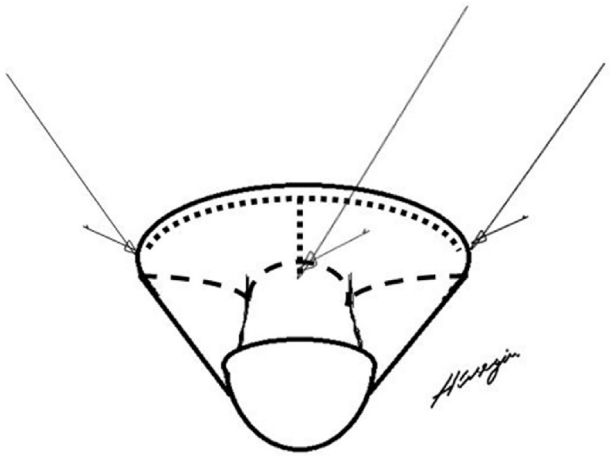

Figure 5 The schematic description of the Firlit incision (broken line) and the incision in GFC technique (dotted line), with stay sutures.

mucosalized foreskin around the ventral surfaces of the split glans wings are excised in order to accomplish glans-to-glans approximation. However, in the GFC technique, it is used as a component of the collar in order to create a ventral suspension of the glanular urethra, which is described as a 'neo-frenulum' — unlike the Firlit mucosal collar fashioned below the complete glans approximation.

Glans dehiscence, also described as meatal regression or retraction, is defined as loss of glans wings approximation after hypospadias repair [18]. The split wings of the glans penis or ventral cleft between the glans wings that accommodate the frenulum is part of normal anatomy. The contention is that approximation of the glans wings in full length and depth is not in entire compliance with normal anatomy. One important point of GFC repair is to provide connective tissue (spongiosum and dartos) between the glans wings, which has an adhesive function and limits glans dehiscence with tension-free approximation. Although it may seem that the slit-like meatus extends downwards further than it should, this extension is limited by the septum glandis and the neo-frenulum surgically created by the GFC technique. The resultant glans penis with the GFC technique is in concordance with many descriptions and depictions of the 'frenular triangle' and septum glandis in the anatomical literature. In the present series, there were two patients with frenular support failure in the midline, which resulted in meatal regression. The other eight patients who developed meatal stenosis and urethral fistulas were among the early cases. It was observed that, in order to prevent the common complications of urethroplasty, neither glandar surface enhancement nor extended dissection of the glans wings are necessary, and may in fact be counterproductive.

The GFC technique provides a frenular cushion between the glans wings, and the loose ventral support of the glanular urethra may possibly provide for a re-forming of the navicular fossa. A normal wave-like flow pattern of micturition was observed in 76 of 88 patients (86%), as formulated by Wheeler et al. [19]. The characteristic shape or wave pattern made by the urine stream as it exits the urethral meatus is related to the meatal (elliptic) shape and its surface tension. It was postulated that the fossa navicularis, which the GFC technique is able to provide, is another component of the observed physiologic stream pattern (Fig. 4).

In spite of the fact that a normal/natural penis is one with a complete foreskin, and the foreskin in the GFC repair is closer to normality (avoiding secondary phimosis in preputioplasty), there are occasional requests by parents to perform a secondary circumcision. Ritual male circumcision is common in society, and for those families who opt for complete excision of the prepuce in a second sitting, the impression is given that they see the hypospadias surgery as a restoration of normality, after which circumcision fulfils the ritual and social expectations. The outcome of GFC technique leaving a generous amount of mucosa (resembling subtotal posthectomy) has been welcomed by the majority of parents, which is encouraging.

Conclusion

The formation of the penile and distal (glanular and subcoronal) urethra are distinct. Therefore, a combined surgical approach to the two parts of the urethra is feasible, and tubularization of the urethra can be complemented with the described GFC technique to create an anatomical configuration of the distal urethra.

Conflict of interest/Funding

None.

Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.jpurol.2016.09.016.

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