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**Published paper**
Surgical Techniques in Substitution Urethroplasty Using Buccal Mucosa

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ABSTRACT

Introduction
Since the resurgence in the use of buccal mucosa in substitution urethroplasty in the late 1980s and early 1990s, there has been controversy as to which surgical technique is the most appropriate for its application.

Method
The authors performed a literature review. Several centres have published widely on this topic, and the points considered include the use buccal mucosa (BM) in dorsal-onlay grafts, ventral-onlay grafts, tubularised grafts and the role of two-stage procedures.

Results
In experienced hands, the outcomes of both dorsal-onlay grafts and ventral-onlay grafts in bulbar urethroplasty are very similar. The dorsal-onlay technique is however possibly less dependent on surgical expertise and therefore more suitable for surgeons new to the practice of urethroplasty. The complications associated with ventral-onlay techniques can be minimised by meticulous surgical technique, but in series with longer follow-up still tend to be more prevalent.

In penile urethroplasty, two-stage dorsal onlay of BM (after complete excision of the scarred urethra) still provides the best results, although in certain circumstances a one-stage dorsal-onlay procedure is possible. In general, ventral-onlay of BM and tube graft procedures in the management of penile strictures are associated with much higher rates of recurrence and should therefore be avoided.

Conclusions
In experienced hands the results of the ventral and dorsal-onlay of BM for bulbar urethroplasty are equivalent. Two-stage procedures are preferable in the penile urethra, except under certain circumstances when one-stage dorsal-onlay is feasible.
1. INTRODUCTION

Where possible, it is best to perform anastomotic repair of the urethra as this has better success than any other type of repair. In some cases however, substitution procedures are necessary. Historically, various tissues have been used to repair the damaged urethra including genital (penile and scrotal) skin, extra-genital skin, bladder mucosa and buccal mucosa. These tissues have been used as either pedicled flaps with their own blood supply or as free tissue grafts. The most common graft materials in use today are buccal mucosa, preputial skin (when available) and penile and preputial skin flaps with their own blood supply. The most appropriate use of these materials has long been a subject of controversy, especially in terms of which type of tissue and whether as a graft or flap and at which site along the urethra.

The use of buccal mucosa (BM) in urethral surgery was first described by Humby in 1941, following which it was not reported again until the late 1980s. Since then, it has gained favour as a versatile graft material well suited to repair of the urethra, and it is thought to be especially suitable as it is a wet epithelium, it is readily harvested, it has been shown to be resistant to recurrence of strictures (especially in the presence of balanitis xerotica obliterans, BXO, and possibly due to its privileged immunity) and it is amenable to surgical manipulation. Buccal mucosa also has a dense submucosa with a dense capillary network, which facilitates the early imbibition of nutrients from the wound bed as well as early inosculation of neovasculature. Recently, several groups have published the outcomes for series of substitution urethroplasty using buccal mucosa. In particular, controversy has surrounded whether it is most appropriate to insert this tissue in a ventral or dorsal position, indeed a previous review suggested that contrary to
previous suggestions the two techniques might be more similar in terms of outcome than
previously thought. With this in mind the authors performed a literature review to
ascertain whether the updated literature was more indicative of which technique results in
the best outcomes for BM urethroplasty, and should therefore for preference be used
clinically.

2. METHOD

A search of Medline was carried out. Included were articles from 1985 onwards, searched
using the above keywords. Articles not discussing the specific technique of substitution
urethroplasty were discounted. Due to the nature of the surgery being performed, it is
usually carried out in specialist centres. These centres tend to have larger series, and
hence the majority of papers tend to come from few sources.

3. RESULTS

3.1. Bulbar Urethra

Most of the literature relates to bulbar urethroplasty. Traditionally urethroplasty is
performed as an ventral onlay, with the corpus spongiosum either excised and
reconstructed using a buccal mucosal patch applied to a dorsal native urethral roof strip
or incised in the midline over the stricture to perform a ventral stricturotomy, with the
free graft applied to augment the urethra. Ideally, the corpus spongiosum is then closed
over the graft to provide a well-vascularised bed, and the bulbocavernosus muscle and
soft tissues are then closed to complete the procedure.
The concept of dorsal onlay grafts for substitution bulbar urethroplasty, mobilising the urethra intact, and performing the stricturotomy dorsally, was introduced by Barbagli et al in 1996, and since has found widespread support. This has been suggested to produce the following benefits; less bleeding from the thinner dorsal spongiosum, application of the graft to the tunica albuginea of the corpora cavernosa providing a more stable base allowing better fixation of the graft, facilitating the acquisition of a richer blood supply and reducing contracture during healing. Also, theoretically there should be less risk of sacculation of the graft under pressure of voiding, and hence a lower incidence of diverticulum formation. In some cases, the degree of spongiofibrosis is such that a lengthy segment of urethra has to be removed and hence incision and augmentation of the onlay with corpus spongiosum is not possible. In these cases, the strictured urethra needs to be excised and a modified onlay procedure can be performed (e.g. augmented roof-strip procedure or one-stage circumferential graft).

Alternatively a tubularised graft can be placed, but this should be avoided because of the higher failure rate. In these cases two-stage surgery is more appropriate with the formation of a temporary perineal urethrostomy prior to the second stage.

3.1.1. Dorsal Onlay

Although the technique of dorsal onlay grafts for substitution bulbar urethroplasty was first described using penile skin as a graft material, subsequently BM has been used with increasing favour. The results reported in the literature are summarised in Table 1. Barbagli et al reported medium-term outcomes from the first 37 patients treated with dorsal onlay grafts in 1998, including six patients treated with BM. Of these patients, 34 operations (92%) were considered a success at an average of 21.5 months, including all
six BM patients, with no requirement for post-operative instrumentation or recurrence of
stricture. Longer term follow up\textsuperscript{15} of these patients (excepting the BM patients) showed
an increased failure rate over time, with a success rate of 85\% in 40 patients over 43
months. Although these patients had preputial skin grafts rather than BM grafts, it
emphasises the long-term attrition rate for substitution urethroplasty, compared to
anastomotic repair.

Andrich and Mundy\textsuperscript{6,14} described the results of 71 patients who underwent BM
substitution urethroplasty, 42 were performed as dorsal onlay grafts (33 Barbagli
procedures and 9 augmented roof strip procedures). After follow-up of 48 to 60 months,
success defined by a lack of recurrent stricture on urethrography was seen in 95\%, in
contrast to ventral-onlay, which had worse outcomes in terms of post-operative
symptoms and recurrence rates (14\%), and tube grafts which had even worse outcomes;
45\% of these developed recurrent strictures during the follow-up period.

Raber and colleagues (2003) presented the outcomes of 30 patients with a mean follow-
up of 51 months;\textsuperscript{16} 13 had dorsal-onlay BM grafts and 17 had penile skin grafts. Success
defined by not needing post-operative instrumentation (and an improved International
Prostate Symptom Score (IPSS) scores and uroflowmetry), was 80\%; 76\% in the penile
skin group and 85\% in the BM group. Of the six patients needing further instrumentation,
two were in the BM group and four in the penile skin group. There were no statistical
differences in outcomes between penile skin and BM dorsal-onlay urethroplasty, although
the long-term failure rate appeared higher with penile skin than BM.

Pansadoro et al\textsuperscript{23} reported a retrograde study of 56 patients receiving dorsal-onlay BM
grafts, with a median follow-up of 41 months which included regular uroflowmetry and
radiological investigation in the form of urethrocystography. They report a 98% success rate, with only one patient having a recurrence found on post-operative urethrography. They reported no graft sacculation with dorsal-onlay, and postulated that in the event of the graft failing or perishing, there was a possibility that urothelium could regenerate along the surface of the corpora cavernosa.

Dubey et al \(^{17}\) discussed their experience with a range of techniques, including 16 patients undergoing dorsal-onlay BM grafting. They reported an 87% success rate in this group, with success criteria similar to the above studies (i.e. no recurrent stricture seen on follow-up urethrography), but with a short follow-up of a mean of 22 months. A second paper from this group \(^{18}\) looked specifically at BM urethroplasty, identifying it as “a versatile technique for all urethral segments”. The patients studied included 41 undergoing dorsal-onlay BM bulbar urethroplasty. Over a mean of 36.2 months follow-up, they reported success in 90% of these patients.

Most recently, Barbagli and colleagues have presented two papers looking more closely at the optimum techniques for the use of BM grafts in bulbar urethroplasty. The first was designed to look specifically at a comparison of dorsal versus ventral application of the BM graft. \(^{7}\) The study included 50 patients, of whom 17 had the graft applied ventrally, 27 dorsally, and 6 laterally within the urethra. They reported a similar success rate of 83-85% in all groups. In the dorsal-onlay group, the success rate was 85% and included 4 failures. Across the whole series, eight patients developed urethral sacculation and these abnormalities were only evident on voiding cysto-urethrography and not retrograde studies. Of these, six were in the group undergoing ventral-onlay grafting.
The most recent paper in 6 patients addresses the modification to their technique, of using fibrin glue to attach the BM graft to the underlying tissues in lieu of quilting the graft with sutures. With a mean follow-up of 16 months they describe a 100% success rate. Clearly a larger series with longer follow-up is mandatory before any meaningful conclusions can be drawn as to whether this is a technical advance.

3.1.2 Ventral Onlay

The published outcomes of ventral-onlay BM grafting are summarised in Table 2. Ventral-onlay of BM was initially introduced as an alternative to the use of tubularised grafts used for the treatment of hypospadias and urethral strictures. As use of BM became established, ventral-onlay procedures for the management of bulbar strictures greater than 2-3cm in length became the norm, and only when Barbagli introduced the concept of dorsal-onlay grafts was the technique questioned.

Morey and McAninch (1996) published their initial series of ventral-onlay BM bulbar urethroplasty. They described 13 patients with an average stricture length of 6.2cm who had urethroplasty performed with either BM alone (n=5) or as an adjunct to other procedures for more extensive strictures (n=8). At median follow-up of 18 months, they reported success in all 13 patients, with none requiring further instrumentation or repeat surgery. Interestingly, no patients developed sacculation or out-pouchings of the graft, and there was no radiological evidence of graft contracture.

Andrich et al (2001) compared their results of ventral-onlay as contrasted to dorsal-onlay BM bulbar urethroplasty. 29 patients were followed up for 48 to 60 months with a success rate of 86%. They noted that with both techniques, all patients had some post-
Coital pooling of semen or post-micturition urine dribbling, reported as significant in 21% of ventral-onlay versus 17% of dorsal onlay patients. They conclude that although the rates of recurrent stricture are similar irrespective of technique or graft material used (compared with published series\textsuperscript{20}), the post-surgical outcome in dorsally-applied BM grafts seem to be the most favourable, and recommend this technique for bulbar urethroplasty.

Palminteri and colleagues described a two-stage technique using ventrally-applied BM graft associated with marsupialisation of the urethra and formation of a temporary proximal urethrostomy\textsuperscript{21} for complex bulbar strictures and reported a series of 24 patients with a success rate of 95.8%. Post-operative urethrography demonstrated an irregular appearance in 10 of 23 successful cases, but no recurrent strictures were seen on urethroscopy and no obstruction was evident on voiding urethrography. No patients developed sacculation or diverticula.

Kane et al reported a multicentre experience of ventral-onlay BM grafts\textsuperscript{9} in 53 patients treated between 1996-8, and followed-up for an average of 25 months with an overall success rate of 94.3%. Four patients (7.5%) had good post-operative urine flow rates and minimal symptoms but sacculation in the region of the graft on urethrography, which correlated poorly with symptomatic dribbling or pooling of urine.

Heinke et al (2003) published the results of their series of ventrally-applied BM\textsuperscript{22} reporting on 38 patients, of whom 30 had bulbar urethral disease. They reported success as an improved urine flow rate (>15ml/s) and no requirement for post-operative instrumentation. At a mean follow-up of 22.8 months, 7 of 38 patients had recurrence of their disease (18.4%).
Pansadoro and colleagues included nine patients treated with ventral-onlay BM grafts in their paper from 2003. Over a follow-up period of 41 months, they noted a recurrence in one of nine patients (11%) giving a success rate of 89%. These patients were included as a comparator for a much larger group undergoing dorsal-onlay of BM, and due partly to the smaller group, the percentage of failures was higher in the ventral-onlay group (11% versus 2%). However, a success rate of 89% is comparable with the wider literature. The authors did observe a degree of ventral irregularity on urethroscopy in these patients, but no patients reported untoward voiding symptoms or diminished flow rates.

Elliott and colleagues reported their longer-term outcomes of ventral-onlay BM grafting in bulbar urethroplasty. The series includes 60 patients at a mean follow-up of 47 months with a 90% success rate. They highlighted the importance of sufficient graft coverage with vascularised tissue using the corpus spongiosum with careful closure of the bulbospongiosus muscle to provide graft support and minimise sacculation and diverticulum formation.

Dubey et al included 18 patients undergoing ventral-onlay grafting, of which seven received BM grafts, in a series of >100 patients treated with various urethroplasty techniques. Over follow-up of 45.7 months, they reported a success rate of 77.8% (in all 18 patients), but noted a significantly higher incidence of graft sacculation, diverticulum formation, urethro-cutaneous fistula (most healed without intervention) and post-micturition dribbling than with dorsal-onlay procedures, although these problems were seen in all patients to some degree. This was also true for patients undergoing vascularised flap ventral-onlay procedures when compared to dorsal-onlay. Stricture recurrence was equivalent amongst all groups.
Fichtner and colleagues also reported on longer-term outcome of ventrally-applied BM grafts\textsuperscript{25} in over 60 patients, but only included the 32 in whom more than five years’ follow-up was available. 15 of these patients had BM grafts applied to treat bulbar strictures. Of these, the success rate was 86.7% after a mean 6.9 years. On follow-up imaging and questioning, none of the patients developed diverticulae, and although 2 patients developed urethro-cutaneous fistulae, these settled with supra-pubic catheterisation within a two week period. They emphasise the importance of meticulous coverage of the graft with two to three well vascularised tissue layers, and reported that the outcomes of ventral-onlay BM urethroplasty are equivalent to those seen with dorsal-onlay procedures, maintained over at least five years of follow-up.

Berger and colleagues published the outcomes of their management of post-traumatic urethral strictures.\textsuperscript{26} This included seven patients undergoing ventral-onlay BM grafting for bulbar urethral strictures. At a mean follow-up of 70.7 months, they noted a high failure rate of 57%, with four of seven patients requiring revision surgery within the first 12 months for recurrence.

3.2 Penile Urethra

Due to the relative deficiency of the corpus spongiosum in the penile urethra there is reduced potential for the survival of ventrally-applied free grafts.\textsuperscript{20} Therefore, ventrally-placed pedicled skin flaps have been advocated for the treatment of penile strictures. Nevertheless, good results have been reported with using dorsally applied BM as both one-stage and two-stage procedures. This is especially true when treating strictures caused by BXO, as the risk of recurrence is reduced by using non-genital skin, including BM.\textsuperscript{2, 6, 27, 28} Generally two-stage surgery is performed by quilting a 2-3cm wide strip of
BM onto the corpora cavernosa once the diseased segment of urethra has been excised. In cases where the glans is involved, the urethra is also excised and the glans cleft widened to allow a BM graft to be sutured in place. Urine is diverted proximally, via a proximal urethrostomy. The graft is dressed for the initial post-operative period then left open prior to second-stage, typically performed at six months if graft is healthy and not fibrotic. The second-stage of the procedure is completed by mobilising the graft from the skin edges and undermining to allow tubularisation of the neo-urethra over a catheter. This allows adequate coverage, and over-closure with superficial tissues to reduce the risk of fistula formation.

One-stage dorsal-onlay BM urethroplasty is possible in the penile urethra, including the glans, as long as there is a sufficient and healthy urethral plate. The outcomes of penile urethroplasty using BM are summarised in table 3.

Mundy et al reported on 4 patients with BXO causing penile urethral stricture disease using BM as a two-stage procedure, in addition, there were four patients treated initially with pedicled penile skin flap grafts, in which BXO recurred necessitating further urethroplasty, performed with BM. At follow-up of up to 36 months, none of these patients had developed recurrent stricturing, nor did they have symptoms of obstructive or abnormal voiding. As part of the initial study, 12 further patients underwent pedicled penile skin flap grafts, all of which failed due to recurrent BXO, illustrating the importance of using extra-genital skin for treating BXO strictures.

A subsequent paper discussed the merits of BM free grafts, and included 41 patients undergoing treatment for penile strictures followed-up for at least two years, and some up to more than five years, although the average was not reported. 39 underwent two-stage
procedures. The success rate was 83%, (including a single patient undergoing two-stage repair where a fistula developed which required surgical correction). Only one patient required surgical treatment after second-stage, and nine required some small-scale alterations to the graft prior to second-stage, (nearly a 25% revision rate- emphasising the importance of a 2 stage approach), with a final overall success rate of 97.5%.

Metro et al reported their eight-year experience of using BM to treat both hypospadias and urethral strictures.\textsuperscript{29} 30 patients were followed-up for median 5.3 years after surgery. Of the 30 patients, 16 underwent tube graft procedures and 14 had onlay procedures. Six of 14 patients had recurrent stricture requiring further intervention, giving a success rate of only 57.1%. This is most likely due to the grafts being performed as ventral-onlay in the distal penile urethra, where the corpus spongiosus is most deficient, often with the urethral strip anastomosed to an onlay segment that was too narrow or very scarred. The results of the patients treated with tubularised grafts are discussed later.

Fichtner and colleagues published their long-term outcomes with ventrally-applied BM grafts.\textsuperscript{25} They describe 17 patients undergoing urethroplasty, with a success rate of 88.2% to a mean 6.9 years follow-up. They noted that recurrences all occurred at the proximal end of the graft, similar to those in the bulbar urethra in the same paper, and were managed by DIVU with good results.

Dubey et al reported a series\textsuperscript{18} of 43 patients undergoing dorsal-onlay BM urethroplasty for penile strictures. 28 of these were single-stage operations with 15 as two-stage procedures. The follow-up was shorter for two-stage reconstruction compared to one-stage, at 24.2 and 34 months respectively. For the purposes of this discussion, pan-urethral strictures are included in this group. Two-stage procedures were only performed
if the urethral plate was non-viable, or the pre-operative calibre was less than 6Fr,

according to local practice. They report success rates of 85.7% for single-stage and

86.7% for two-stage procedures, with the majority of recurrences being managed

successfully with DIVU. In a further paper\textsuperscript{30}, the same authors report the outcomes of the

same procedures in a total of 39 patients with strictures due to BXO. At mean follow-up

of 32.5 months, 3 of 25 patients undergoing one-stage procedures had developed

recurrence, giving a success rate of 88%. In the group undergoing a 2 stage procedure

four patients needed graft modification or manipulation prior to the second-stage, and 3

of 14 developed recurrence after the second-stage, giving a success rate of 78.6%.

3.3. Other techniques

The other method of using BM in the literature is the use of tubularised grafts. These

remain popular in the management of hypospadias, but the majority of series using

tubularised BM grafts for the treatment of stricture disease have had poor outcomes.\textsuperscript{6,31} Andrich and Mundy described a 45% re-stricture rate with tubularised grafts using BM,

echoing previous findings by the same author using other graft materials.\textsuperscript{32} Caldamone \textit{et al} described the outcomes of 16 tubularised BM grafts predominantly after previous

failed hypospadias repair.\textsuperscript{31} At a mean follow-up of 20 months, 8 of 16 developed

complications, including four urethro-cutaneous fistulae and 3 recurrent strictures, all

requiring intervention, giving an overall success rate of 56.3%.

However, one group have reported better outcomes with tubularised grafts than with

onlay grafts in the penile urethra. Metro \textit{et al}\textsuperscript{29} had a success rate of 93.8% in their series

with respect to recurrent stricture (success rate for ventral-onlay BM grafts was only
57.1%), but they did report complications requiring intervention in both tube graft and ventral-onlay BM grafts, including meatal stenosis in five patients (out of a total of 30), glanuloplasty in one, meatal graft breakdown in another, and complete graft breakdown in another patient. In view of the above, the seemingly good results with tube grafts can be reduced to a success rate of 50% when the standards set out in previous papers (i.e. the need for intervention or instrumentation) are applied.

CONCLUSION

It is difficult to make recommendations for the best clinical practice using BM in substitution urethroplasty based on the current literature as clearly as in all reconstructive surgery, individualisation of therapy is essential. Most of the studies reported in the literature are retrospective, reflect surgery carried out by more than one surgeon and treat stricture arising due varied aetiologies. It is clear that in the presence of BXO, the rate of stricture recurrence is higher, but it is not clear from all of the papers reviewed precisely how many cases/failed cases were caused by this inflammatory condition. Another source of inconsistency is the way in which success and failure are reported; itself a direct consequence of the differing methodologies between the studies reviewed. The follow-up criteria and definitions of success and failure for each paper are summarised in table 4. Another point to raise is the differing types of failure. Recently, it has become increasingly evident that a large number of recurrent strictures seen after buccal mucosa urethroplasty occur in the area of the anastomosis of the graft to the native urethra, and often take the form of diaphragms or rings. These are more easily managed by
endoscopic incision (DIVU) than those recurrences resulting from graft failure, recurrent disease (especially BXO) or graft ischaemia, which more often require repeat surgery.\textsuperscript{33, 34}

There are valid arguments for the dorsal approach for the management of bulbar urethral strictures, namely the better support of the graft leading to lesser incidence of graft sacculation (although symptomatic sacculation is uncommon) and associated post-micturition dribble (most patients get some degree of PMD). Dorsal-onlay may also theoretically better facilitate graft fixation and take. However several authors have suggested that with appropriate tailoring of the graft and meticulous technique, to ensure adequate coverage of the graft with well-vascularised tissue layers, that these risks are minimised. Certainly in the posterior part of the bulbar urethra, a ventral onlay is easier to perform and more appropriate because of the difficulty of onlaying mucosa onto the corpora cavernosa if the midline septum has been divided to facilitate access. In experienced hands, the outcomes of both dorsal- and ventral-onlay BM grafts appear to be very similar. However there is a lack of long-term follow-up data looking at the outcome of BM grafting at follow-up greater than five or six years. Clearly longer-term follow-up is needed to assess whether the attrition rate of BM grafts is similar to that of skin grafts, which deteriorate with time; from the current literature it is not possible to give an “average attrition rate” for BM grafts due to the variety of methods and stricture aetiologies studied.

In the management of penile strictures, the place of BM has been shown to not only be limited to two-stage repair, with promising results for dorsal-onlay procedures when there is a viable urethral plate. However, two-stage repair in some series has close to a 100%
success rate, including cases involving BXO, but again this is highly variable between centres, and results can be assumed to be better if revision after first stage (which is not uncommon) does not constitute a treatment failure. This first stage revision does not however tend to affect longer-term outcomes of BM urethroplasty, however, and these outcomes still tend to vary extensively between centres to the point where it is difficult to make solid conclusions from the current literature.

Ventral-onlay of BM in the distal anterior urethra should be avoided however, as these types of graft are associated with poor outcomes. Also, the majority of the reported literature relating to tubularised grafts of BM shows poor outcomes, and these have largely gone out of favour except in very select cases.

In summary, BM grafting is a versatile and effective treatment for strictures throughout the anterior urethra, and in experienced hands, the outcomes are favourable whether a dorsal or ventral approach is taken.

ACKNOWLEDGMENT

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REFERENCES


16. Raber, M., Naspro, R., Scapaticci, E. et al.: Dorsal onlay graft


Table 1. Outcomes of dorsal-onlay buccal mucosa (BM) bulbar urethroplasty

<table>
<thead>
<tr>
<th>Authors</th>
<th>Number treated (n)</th>
<th>Follow-up (months)</th>
<th>Success rate (%)</th>
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Table 2. Outcomes of ventral-onlay buccal mucosa (BM) bulbar urethroplasty
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<td>Fichtner &lt;i&gt;et al&lt;/i&gt; 2004&lt;sup&gt;25&lt;/sup&gt;</td>
<td>17</td>
<td>6.9 years</td>
<td>88.2</td>
</tr>
<tr>
<td>Dubey &lt;i&gt;et al&lt;/i&gt; 2005&lt;sup&gt;18&lt;/sup&gt;</td>
<td>28/15&lt;sup&gt;b&lt;/sup&gt;</td>
<td>34/24.2</td>
<td>85.7/86.7</td>
</tr>
<tr>
<td>Dubey &lt;i&gt;et al&lt;/i&gt; 2005&lt;sup&gt;30&lt;/sup&gt;</td>
<td>25/14&lt;sup&gt;b&lt;/sup&gt;</td>
<td>32.5</td>
<td>88/78.6</td>
</tr>
</tbody>
</table>

Table 3. Outcomes of buccal mucosa (BM) penile urethroplasty

- <sup>a</sup> four patients previously having failed genital skin urethroplasty, re-operated with two-stage dorsal-onlay BM urethroplasty
- <sup>b</sup> one-stage / two-stage procedures
<table>
<thead>
<tr>
<th>Authors</th>
<th>Uroflowmetry +/- symptom score</th>
<th>Urethrography</th>
<th>Urethroscopy</th>
<th>Definition of failure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barbagli et al 1998</td>
<td>4,8 and 12 months, then annually</td>
<td>Voiding study at 3 weeks, repeated if Q&lt;sub&gt;max&lt;/sub&gt; &lt;14ml/s</td>
<td>Any instrumentation including dilatation</td>
<td></td>
</tr>
<tr>
<td>Andrich and Mundy 2001</td>
<td>3,6 and 12 months, then annually</td>
<td>Retrograde and voiding studies at 6 and 18 months</td>
<td>Last 45 cases of series in addition to radiology</td>
<td></td>
</tr>
<tr>
<td>Raber et al 2005</td>
<td>6,12 and 18 months, with IPSS and IIEF scores</td>
<td>Voiding study at 3 weeks, repeated if required</td>
<td>Q&lt;sub&gt;max&lt;/sub&gt; &lt;20 ml/s, voiding symptoms requiring intervention. (DIVU or ISD)</td>
<td></td>
</tr>
<tr>
<td>Pansadoro et al 2003</td>
<td>Periodic</td>
<td>Voiding study at 2 weeks, 6 and 12 months, then annually</td>
<td>Recurrence of symptoms</td>
<td></td>
</tr>
<tr>
<td>Dubey et al 2003</td>
<td>6 months All patients performed ISD with 16Ch catheter to 6 months</td>
<td>6,12 and 18 months, then as required</td>
<td>Need for urethral calibration/dilatation +/- DIVU after 18 months</td>
<td></td>
</tr>
<tr>
<td>Metro et al 2001</td>
<td>6 and 12 months with symptom scoring</td>
<td>6,12 and 18 months, then as required</td>
<td>Need for ISD &gt;6 months. ?other criteria</td>
<td></td>
</tr>
<tr>
<td>Dubey et al 2005</td>
<td>3,6,9 and 12 months with ongoing urethral calibration (16Ch)</td>
<td>Voiding study at 3 months, then as required</td>
<td>Symptom recurrence or inability to pass 16Ch catheter</td>
<td></td>
</tr>
<tr>
<td>Barbagli et al 2005</td>
<td>4,8 and 12 months then annually</td>
<td>Voiding study at 3 weeks, then as required (when Q&lt;sub&gt;max&lt;/sub&gt; &lt;14ml/s)</td>
<td>Any instrumentation including dilatation</td>
<td></td>
</tr>
<tr>
<td>Barbagli et al 2006</td>
<td>6 and 12 monthly, then annually with PVRU estimation</td>
<td>Voiding study at 2 weeks, 6 and 12 months, then annually</td>
<td>Any instrumentation including dilatation</td>
<td></td>
</tr>
<tr>
<td>Berger et al 2005</td>
<td>3,6 and 12 months then annually</td>
<td>3 week voiding study</td>
<td>If stream or symptoms deteriorate</td>
<td></td>
</tr>
<tr>
<td>Morey and McAninch 1996</td>
<td>Regular (?timing) with AUA symptom scores</td>
<td>Retrograde study at 3 and 12 months</td>
<td>Need for dilatation or instrumentation</td>
<td></td>
</tr>
<tr>
<td>Palminteri et al 2002</td>
<td>4,8 and 12 months then annually</td>
<td>Voiding study at 3 weeks, then 12 months</td>
<td>At 12 months</td>
<td>Any instrumentation including dilatation</td>
</tr>
<tr>
<td>Kane et al 2002</td>
<td>3,6 and 12 months then annually with symptom scores</td>
<td>Retrograde study at 3 weeks and 3 months</td>
<td>Recurrent narrowing on radiological studies requiring intervention. If no intervention performed (despite recurrence) quoted as successful outcome</td>
<td></td>
</tr>
<tr>
<td>Heinke et al 2003</td>
<td>6 and 12 months with PVRU estimation and symptom scores</td>
<td>Voiding study at 3 weeks, then only if Q&lt;sub&gt;max&lt;/sub&gt; deteriorated</td>
<td>Intervention only classed as a failure if outcome still poor- 4 patients underwent DIVU and had good outcomes, therefore</td>
<td></td>
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<tr>
<td>Study</td>
<td>Follow-up and failure criteria</td>
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</tr>
<tr>
<td>Elliott et al 2003</td>
<td>Voiding study at 3 weeks, then 3, 6 and 12 months, then as required. If stream reduced or symptoms recurred.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fichtner et al 2004</td>
<td>6 and 12 months, with symptom questionnaire and PVRU estimation. Voiding study at 3 weeks. Any recurrence.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dubey et al 2005</td>
<td>3, 6, 9 and 12 months, then every 6 months, with ongoing urethral calibration (16Ch). Voiding study at 3 weeks. Symptomatic recurrence.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Qmax = Peak flow rate (millilitres per second)

ISD = Intermittent self dilatation of urethra

DIVU = Direct inline visual urethrotomy