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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 **1. INTRODUCTION**

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

12 The use of buccal mucosa (BM) in urethral surgery was first described by Humby in
13 1941,¹ following which it was not reported again until the late 1980s. Since then, it has
14 gained favour as a versatile graft material well suited to repair of the urethra,²⁻⁵ and it is
15 thought to be especially suitable as it is a wet epithelium, it is readily harvested, it has
16 been shown to be resistant to recurrence of strictures (especially in the presence of
17 balanitis xerotica obliterans, BXO, and possibly due to its privileged immunity) and it is
18 amenable to surgical manipulation. Buccal mucosa also has a dense submucosa with a
19 dense capillary network, which facilitates the early imbibition of nutrients from the wound
20 bed as well as early inosculation of neovasculature.²⁻⁶ Recently, several groups have
21 published the outcomes for series of substitution urethroplasty using buccal mucosa.
22 In particular, controversy has surrounded whether it is most appropriate to insert this
23 tissue in a ventral or dorsal position, indeed a previous review suggested that contrary to

24 previous suggestions the two techniques might be more similar in terms of outcome than
25 previously thought.⁷ With this in mind the authors performed a literature review to
26 ascertain whether the updated literature was more indicative of which technique results in
27 the best outcomes for BM urethroplasty, and should therefore for preference be used
28 clinically.

29

30 **2. METHOD**

31

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

37

38 **3. RESULTS**

39 *3.1. Bulbar Urethra*

40 Most of the literature relates to bulbar urethroplasty. Traditionally urethroplasty is
41 performed as an ventral onlay , with the corpus spongiosum either excised and
42 reconstructed using a buccal mucosal patch applied to a dorsal native urethral roof strip
43 or incised in the midline over the stricture to perform a ventral stricturotomy,^{8,9} with the
44 free graft applied to augment the urethra. Ideally, the corpus spongiosum is then closed
45 over the graft to provide a well-vascularised bed, and the bulbocavernosus muscle and
46 soft tissues are then closed to complete the procedure.

47 The concept of dorsal onlay grafts for substitution bulbar urethroplasty, mobilising the
48 urethra intact, and performing the stricturotomy dorsally, was introduced by Barbagli *et*
49 *al* in 1996¹⁰⁻¹², and since has found widespread support. This has been suggested to
50 produce the following benefits; less bleeding from the thinner dorsal spongiosum,
51 application of the graft to the tunica albuginea of the corpora cavernosa providing a more
52 stable base allowing better fixation of the graft, facilitating the acquisition of a richer
53 blood supply and reducing contracture during healing. Also, theoretically there should be
54 less risk of sacculation of the graft under pressure of voiding, and hence a lower
55 incidence of diverticulum formation. In some cases, the degree of spongiofibrosis is such
56 that a lengthy segment of urethra has to be removed and hence incision and augmentation
57 of the onlay with corpus spongiosum is not possible. In these cases, the strictured urethra
58 needs to be excised and a modified onlay procedure can be performed (e.g. augmented
59 roof-strip procedure^{6, 12} or one-stage circumferential graft¹³).

60 Alternatively a tubularised graft can be placed, but this should be avoided because of the
61 higher failure rate.^{6, 14} In these cases two-stage surgery is more appropriate with the
62 formation of a temporary perineal urethrostomy prior to the second stage.

63 *3.1.1. Dorsal Onlay*

64 Although the technique of dorsal onlay grafts for substitution bulbar urethroplasty was
65 first described using penile skin as a graft material, subsequently BM has been used with
66 increasing favour. The results reported in the literature are summarised in Table 1.

67 Barbagli *et al* reported medium-term outcomes from the first 37 patients treated with
68 dorsal onlay grafts in 1998¹⁰, including six patients treated with BM. Of these patients, 34
69 operations (92%) were considered a success at an average of 21.5 months, including all

70 six BM patients, with no requirement for post-operative instrumentation or recurrence of
71 stricture. Longer term follow up¹⁵ of these patients (excepting the BM patients) showed
72 an increased failure rate over time, with a success rate of 85% in 40 patients over 43
73 months. Although these patients had preputial skin grafts rather than BM grafts, it
74 emphasises the long-term attrition rate for substitution urethroplasty, compared to
75 anastomotic repair.

76 Andrich and Mundy^{6, 14} described the results of 71 patients who underwent BM
77 substitution urethroplasty, 42 were performed as dorsal onlay grafts (33 Barbagli
78 procedures and 9 augmented roof strip procedures). After follow-up of 48 to 60 months,
79 success defined by a lack of recurrent stricture on urethrography was seen in 95%, in
80 contrast to ventral-onlay, which had worse outcomes in terms of post-operative
81 symptoms and recurrence rates (14%), and tube grafts which had even worse outcomes;
82 45% of these developed recurrent strictures during the follow-up period.

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

91 Pansadoro *et al*²³ reported a retrograde study of 56 patients receiving dorsal-onlay BM
92 grafts, with a median follow-up of 41 months which included regular uroflowmetry and

93 radiological investigation in the form of urethrocytography. They report a 98% success
94 rate, with only one patient having a recurrence found on post-operative urethrography.
95 They reported no graft sacculation with dorsal-onlay, and postulated that in the event of
96 the graft failing or perishing, there was a possibility that urothelium could regenerate
97 along the surface of the corpora cavernosa.

98 Dubey *et al*¹⁷ discussed their experience with a range of techniques, including 16 patients
99 undergoing dorsal-onlay BM grafting. They reported an 87% success rate in this group,
100 with success criteria similar to the above studies (i.e. no recurrent stricture seen on
101 follow-up urethrography), but with a short follow-up of a mean of 22 months. A second
102 paper from this group¹⁸ looked specifically at BM urethroplasty, identifying it as “a
103 versatile technique for all urethral segments”. The patients studied included 41
104 undergoing dorsal-onlay BM bulbar urethroplasty. Over a mean of 36.2 months follow-
105 up, they reported success in 90% of these patients.

106 Most recently, Barbagli and colleagues have presented two papers looking more closely
107 at the optimum techniques for the use of BM grafts in bulbar urethroplasty. The first was
108 designed to look specifically at a comparison of dorsal versus ventral application of the
109 BM graft.⁷ The study included 50 patients, of whom 17 had the graft applied ventrally,
110 27 dorsally, and 6 laterally within the urethra. They reported a similar success rate of 83-
111 85% in all groups. In the dorsal-onlay group, the success rate was 85% and included 4
112 failures. Across the whole series, eight patients developed urethral sacculation and these
113 abnormalities were only evident on voiding cysto-urethrography and not retrograde
114 studies. Of these, six were in the group undergoing ventral-onlay grafting.

115 The most recent paper in 6 patients addresses the modification to their technique,¹⁹ of
116 using fibrin glue to attach the BM graft to the underlying tissues *in lieu* of quilting the
117 graft with sutures. With a mean follow-up of 16 months they describe a 100% success
118 rate. Clearly a larger series with longer follow-up is mandatory before any meaningful
119 conclusions can be drawn as to whether this is a technical advance.

120

121 *3.1.2 Ventral Onlay*

122 The published outcomes of ventral-onlay BM grafting are summarised in Table 2.
123 Ventral-onlay of BM was initially introduced as an alternative to the use of tubularised
124 grafts used for the treatment of hypospadias and urethral strictures.³ As use of BM
125 became established, ventral-onlay procedures for the management of bulbar strictures
126 greater than 2-3cm in length became the norm, and only when Barbagli introduced the
127 concept of dorsal-onlay grafts¹¹ was the technique questioned.
128 Morey and McAninch (1996) published their initial series of ventral-onlay BM bulbar
129 urethroplasty.⁸ They described 13 patients with an average stricture length of 6.2cm who
130 had urethroplasty performed with either BM alone (n=5) or as an adjunct to other
131 procedures for more extensive strictures (n=8). At median follow-up of 18 months, they
132 reported success in all 13 patients, with none requiring further instrumentation or repeat
133 surgery. Interestingly, no patients developed sacculation or out-pouchings of the graft,
134 and there was no radiological evidence of graft contracture.

135 Andrich *et al* (2001)^{6, 14} compared their results of ventral-onlay as contrasted to dorsal-
136 onlay BM bulbar urethroplasty. 29 patients were followed up for 48 to 60 months with a
137 success rate of 86%. They noted that with both techniques, all patients had some post-

138 coital pooling of semen or post-micturition urine dribbling, reported as significant in 21%
139 of ventral-onlay versus 17% of dorsal onlay patients. They conclude that although the
140 rates of recurrent stricture are similar irrespective of technique or graft material used
141 (compared with published series²⁰), the post-surgical outcome in dorsally-applied BM
142 grafts seem to be the most favourable, and recommend this technique for bulbar
143 urethroplasty.

144 Palminteri and colleagues described a two-stage technique using ventrally-applied BM
145 graft associated with marsupialisation of the urethra and formation of a temporary
146 proximal urethrostomy²¹ for complex bulbar strictures and reported a series of 24 patients
147 with a success rate of 95.8%. Post-operative urethrography demonstrated an irregular
148 appearance in 10 of 23 successful cases, but no recurrent strictures were seen on
149 urethroscopy and no obstruction was evident on voiding urethrography. No patients
150 developed sacculation or diverticula.

151 Kane *et al* reported a multicentre experience of ventral-onlay BM grafts⁹ in 53 patients
152 treated between 1996-8, and followed-up for an average of 25 months with an overall
153 success rate of 94.3%. Four patients (7.5%) had good post-operative urine flow rates and
154 minimal symptoms but sacculation in the region of the graft on urethrography, which
155 correlated poorly with symptomatic dribbling or pooling of urine.

156 Heinke *et al* (2003) published the results of their series of ventrally-applied BM²²
157 reporting on 38 patients, of whom 30 had bulbar urethral disease. They reported success
158 as an improved urine flow rate (>15ml/s) and no requirement for post-operative
159 instrumentation. At a mean follow-up of 22.8 months, 7 of 38 patients had recurrence of
160 their disease (18.4%).

161 Pansadoro and colleagues included nine patients treated with ventral-onlay BM grafts in
162 their paper from 2003.²³ Over a follow-up period of 41 months, they noted a recurrence in
163 one of nine patients (11%) giving a success rate of 89%. These patients were included as
164 a comparator for a much larger group undergoing dorsal-onlay of BM, and due partly to
165 the smaller group, the percentage of failures was higher in the ventral-onlay group (11%
166 versus 2%). However, a success rate of 89% is comparable with the wider literature. The
167 authors did observe a degree of ventral irregularity on urethroscopy in these patients, but
168 no patients reported untoward voiding symptoms or diminished flow rates.

169 Elliott and colleagues reported their longer-term outcomes of ventral-onlay BM grafting
170 in bulbar urethroplasty.²⁴ The series includes 60 patients at a mean follow-up of 47
171 months with a 90% success rate. They highlighted the importance of sufficient graft
172 coverage with vascularised tissue using the corpus spongiosum with careful closure of the
173 bulbospongiosus muscle to provide graft support and minimise sacculation and
174 diverticulum formation.

175 Dubey *et al*¹⁷ included 18 patients undergoing ventral-onlay grafting, of which seven
176 received BM grafts, in a series of >100 patients treated with various urethroplasty
177 techniques. Over follow-up of 45.7 months, they reported a success rate of 77.8% (in all
178 18 patients), but noted a significantly higher incidence of graft sacculation, diverticulum
179 formation, urethro-cutaneous fistula (most healed without intervention) and post-
180 micturition dribbling than with dorsal-onlay procedures, although these problems were
181 seen in all patients to some degree. This was also true for patients undergoing
182 vascularised flap ventral-onlay procedures when compared to dorsal-onlay. Stricture
183 recurrence was equivalent amongst all groups.

184 Fichtner and colleagues also reported on longer-term outcome of ventrally-applied BM
185 grafts²⁵ in over 60 patients, but only included the 32 in whom more than five years'
186 follow-up was available. 15 of these patients had BM grafts applied to treat bulbar
187 strictures. Of these, the success rate was 86.7% after a mean 6.9 years. On follow-up
188 imaging and questioning, none of the patients developed diverticulae, and although 2
189 patients developed urethro-cutaneous fistulae, these settled with supra-pubic
190 catheterisation within a two week period. They emphasise the importance of meticulous
191 coverage of the graft with two to three well vascularised tissue layers, and reported that
192 the outcomes of ventral-onlay BM urethroplasty are equivalent to those seen with dorsal-
193 onlay procedures, maintained over at least five years of follow-up.

194 Berger and colleagues published the outcomes of their management of post-traumatic
195 urethral strictures.²⁶ This included seven patients undergoing ventral-onlay BM grafting
196 for bulbar urethral strictures. At a mean follow-up of 70.7 months, they noted a high
197 failure rate of 57%, with four of seven patients requiring revision surgery within the first
198 12 months for recurrence.

199 *3.2 Penile Urethra*

200 Due to the relative deficiency of the corpus spongiosum in the penile urethra there is
201 reduced potential for the survival of ventrally-applied free grafts.²⁰ Therefore, ventrally-
202 placed pedicled skin flaps have been advocated for the treatment of penile strictures.
203 Nevertheless, good results have been reported with using dorsally applied BM as both
204 one-stage and two-stage procedures. This is especially true when treating strictures
205 caused by BXO, as the risk of recurrence is reduced by using non-genital skin, including
206 BM.^{2, 6, 27, 28} Generally two-stage surgery is performed by quilting a 2-3cm wide strip of

207 BM onto the corpora cavernosa once the diseased segment of urethra has been excised. In
208 cases where the glans is involved, the urethra is also excised and the glans cleft widened
209 to allow a BM graft to be sutured in place. Urine is diverted proximally, via a proximal
210 urethrostomy. The graft is dressed for the initial post-operative period then left open prior
211 to second-stage, typically performed at six months if graft is healthy and not fibrotic. The
212 second-stage of the procedure is completed by mobilising the graft from the skin edges
213 and undermining to allow tubularisation of the neo-urethra over a catheter. This allows
214 adequate coverage, and over-closure with superficial tissues to reduce the risk of fistula
215 formation.

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

219 Mundy et al reported on 4 patients with BXO²⁷ causing penile urethral stricture disease
220 using BM as a two-stage procedure, in addition, there were four patients treated initially
221 with pedicled penile skin flap grafts, in which BXO recurred necessitating further
222 urethroplasty, performed with BM. At follow-up of up to 36 months, none of these
223 patients had developed recurrent stricturing, nor did they have symptoms of obstructive
224 or abnormal voiding. As part of the initial study, 12 further patients underwent pedicled
225 penile skin flap grafts, all of which failed due to recurrent BXO, illustrating the
226 importance of using extra-genital skin for treating BXO strictures.

227 A subsequent paper discussed the merits of BM free grafts,⁶ and included 41 patients
228 undergoing treatment for penile strictures followed-up for at least two years, and some up
229 to more than five years, although the average was not reported. 39 underwent two-stage

230 procedures. The success rate was 83%, (including a single patient undergoing two-stage
231 repair where a fistula developed which required surgical correction). Only one patient
232 required surgical treatment after second-stage, and nine required some small-scale
233 alterations to the graft prior to second-stage, (nearly a 25% revision rate- emphasising the
234 importance of a 2 stage approach), with a final overall success rate of 97.5%.

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

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

248 Dubey *et al* reported a series¹⁸ of 43 patients undergoing dorsal-onlay BM urethroplasty
249 for penile strictures. 28 of these were single-stage operations with 15 as two-stage
250 procedures. The follow-up was shorter for two-stage reconstruction compared to one-
251 stage, at 24.2 and 34 months respectively. For the purposes of this discussion, pan-
252 urethral strictures are included in this group. Two-stage procedures were only performed

253 if the urethral plate was non-viable, or the pre-operative calibre was less than 6Fr,
254 according to local practice. They report success rates of 85.7% for single-stage and
255 86.7% for two-stage procedures, with the majority of recurrences being managed
256 successfully with DIVU. In a further paper³⁰, the same authors report the outcomes of the
257 same procedures in a total of 39 patients with strictures due to BXO. At mean follow-up
258 of 32.5 months, 3 of 25 patients undergoing one-stage procedures had developed
259 recurrence, giving a success rate of 88%. In the group undergoing a 2 stage procedure
260 four patients needed graft modification or manipulation prior to the second-stage, and 3
261 of 14 developed recurrence after the second-stage, giving a success rate of 78.6%.

262

263 3.3. Other techniques

264 The other method of using BM in the literature is the use of tubularised grafts. These
265 remain popular in the management of hypospadias, but the majority of series using
266 tubularised BM grafts for the treatment of stricture disease have had poor outcomes.^{6, 31}
267 Andrich and Mundy described a 45% re-stricture rate with tubularised grafts using BM,
268 echoing previous findings by the same author using other graft materials.³² Caldamone *et*
269 *al* described the outcomes of 16 tubularised BM grafts predominantly after previous
270 failed hypospadias repair.³¹ At a mean follow-up of 20 months, 8 of 16 developed
271 complications, including four urethro-cutaneous fistulae and 3 recurrent strictures, all
272 requiring intervention, giving an overall success rate of 56.3%.

273 However, one group have reported better outcomes with tubularised grafts than with
274 onlay grafts in the penile urethra. Metro *et al*²⁹ had a success rate of 93.8% in their series
275 with respect to recurrent stricture (success rate for ventral-onlay BM grafts was only

276 57.1%), but they did report complications requiring intervention in both tube graft and
277 ventral-onlay BM grafts, including meatal stenosis in five patients (out of a total of 30),
278 glanuloplasty in one, meatal graft breakdown in another, and complete graft breakdown
279 in another patient. In view of the above, the seemingly good results with tube grafts can
280 be reduced to a success rate of 50% when the standards set out in previous papers (i.e. the
281 need for intervention or instrumentation) are applied.

282

283 **CONCLUSION**

284 It is difficult to make recommendations for best clinical practice using BM in
285 substitution urethroplasty based on the current literature as clearly as in all reconstructive
286 surgery, individualisation of therapy is essential. Most of the studies reported in the
287 literature are retrospective, reflect surgery carried out by more than one surgeon and treat
288 stricture arising due varied aetiologies. It is clear that in the presence of BXO, the rate of
289 stricture recurrence is higher, but it is not clear from all of the papers reviewed precisely
290 how many cases/failed cases were caused by this inflammatory condition.

291 Another source of inconsistency is the way in which success and failure are reported;
292 itself a direct consequence of the differing methodologies between the studies reviewed.

293 The follow-up criteria and definitions of success and failure for each paper are
294 summarised in table 4.

295 Another point to raise is the differing types of failure. Recently, it has become
296 increasingly evident that a large number of recurrent strictures seen after buccal mucosa
297 urethroplasty occur in the area of the anastomosis of the graft to the native urethra, and
298 often take the form of diaphragms or rings. These are more easily managed by

299 endoscopic incision (DIVU) than those recurrences resulting from graft failure, recurrent
300 disease (especially BXO) or graft ischaemia, which more often require repeat surgery.^{33,}

301 ³⁴

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

319 In the management of penile strictures, the place of BM has been shown to not only be
320 limited to two-stage repair, with promising results for dorsal-onlay procedures when there
321 is a viable urethral plate. However, two-stage repair in some series has close to a 100%

322 success rate, including cases involving BXO, but again this is highly variable between
323 centres, and results can be assumed to be better if revision after first stage (which is not
324 uncommon) does not constitute a treatment failure. This first stage revision does not
325 however tend to affect longer-term outcomes of BM urethroplasty, however, and these
326 outcomes still tend to vary extensively between centres to the point where it is difficult to
327 make solid conclusions from the current literature.

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

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

335

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338

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459 Table 1.

Authors	Number treated (n)	Follow-up (months)	Success rate (%)
Barbagli <i>et al</i> 1998 ¹⁰	37 (6 BM)	21.5 (13.5)	92 (100 for BM)
Andrich <i>et al</i> 2001 ^{6, 14}	42	48-60	95
Raber <i>et al</i> 2005 ¹⁶	30 (13 BM)	51	80 (85 for BM)
Pansadoro <i>et al</i> 2003 ²³	56	41	98
Dubey <i>et al</i> 2003 ¹⁷	16	22	87
Dubey <i>et al</i> 2005 ¹⁸	41	36.2	90
Barbagli <i>et al</i> 2005 ⁷	27	42	85
Barbagli <i>et al</i> 2006 ¹⁹	6	16	100

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

461 Table 2.

Authors	Number treated (n)	Follow-up (months)	Success rate (%)
Morey + McAninch 1996 ⁸	13	18	100
Andrich <i>et al</i> 2001 ^{6, 14}	29	48-60	86
Palminteri <i>et al</i> 2002 ²¹	24	18	95.8
Kane <i>et al</i> 2002 ⁹	53	25	94
Heinke <i>et al</i> 2003 ²²	38 (30 bulbar)	22.8	81.6
Pansadoro <i>et al</i> 2003 ²³	9	41	89
Elliott <i>et al</i> 2003 ²⁴	60	47	90
Dubey <i>et al</i> 2003 ¹⁷	18 (7 BM)	45.7	77.8
Fichtner <i>et al</i> 2004 ²⁵	32 (15 bulbar)	6.9 years	87
Berger <i>et al</i> 2005 ²⁶	7	70.7	43
Barbagli <i>et al</i> 2005 ⁷	17	42	83

462 Table 2. Outcomes of ventral-onlay buccal mucosa (BM) bulbar urethroplasty

463 Table 3.

Authors	Number treated (n)	Follow-up (months)	Success rate (%)
Venn + Mundy 1998 ²⁷	4 (plus 4) _a	36	100 (8 of 8)
Andrich + Mundy 2001 ⁶	41	24-60+	100
Metro <i>et al</i> 2001 ²⁹	14	5.3 years	57.1
Fichtner <i>et al</i> 2004 ²⁵	17	6.9 years	88.2
Dubey <i>et al</i> 2005 ¹⁸	28/15 _b	34/24.2	85.7/86.7
Dubey <i>et al</i> 2005 ³⁰	25/14 _b	32.5	88/78.6

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

465 a- four patients previously having failed genital skin urethroplasty, re-operated with
 466 two-stage dorsal-onlay BM urethroplasty

467 b- one-stage / two-stage procedures

Table 4.

Authors	Uroflowmetry +/- symptom score	Urethrography	Urethroscopy	Definition of failure
Barbagli <i>et al</i> 1998 ¹⁰	4,8 and 12 months, then annually	Voiding study at 3 weeks, repeated if $Q_{max} < 14\text{ml/s}$		Any instrumentation including dilatation
Andrich and Mundy 2001 ^{6, 14}	3,6 and 12 months, then annually	Retrograde and voiding studies at 6 and 18 months	Last 45 cases of series in addition to radiology	Development of symptoms leading to urethrogram or urethroscopy to confirm recurrence
Raber <i>et al</i> 2005 ¹⁶	6,12 and 18 months, with IPSS and IIEF scores	Voiding study at 3 weeks, repeated if required	As required	$Q_{max} < 20\text{ ml/s}$, voiding symptoms requiring intervention. (DIVU or ISD)
Pansadoro <i>et al</i> 2003 ²³	Periodic	Voiding study at 2 weeks, 6 and 12 months, then annually		Recurrence of symptoms
Dubey <i>et al</i> 2003 ¹⁷	6 months All patients performed ISD with 16Ch catheter to 6 months	6,12 and 18 months, then as required		Need for urethral calibration/dilatation +/- DIVU after 18 months
Metro <i>et al</i> 2001 ²⁹	6 and 12 months with symptom scoring			Need for ISD >6 months. ?other criteria
Dubey <i>et al</i> 2005 ¹⁸	3,6,9 and 12 months with ongoing urethral calibration (16Ch)	Voiding study at 3 months, then as required		Symptom recurrence or inability to pass 16Ch catheter
Barbagli <i>et al</i> 2005 ⁷	4,8 and 12 months then annually	Voiding study at 3 weeks, then as required (when $Q_{max} < 14\text{ml/s}$)	As required ($Q_{max} < 14\text{ml/s}$)	Any instrumentation including dilatation
Barbagli <i>et al</i> 2006 ¹⁹	6 and 12 monthly, then annually with PVRU estimation	Voiding study at 2 weeks, 6 and 12 months, then annually		Any instrumentation including dilatation
Berger <i>et al</i> 2005 ²⁶	3,6 and 12 months then annually	3 week voiding study		If stream or symptoms deteriorate
Morey and McAninch 1996 ⁸	Regular (?timing) with AUA symptom scores	Retrograde study at 3 and 12 months		Need for dilatation or instrumentation
Palminteri <i>et al</i> 2002 ²¹	4,8 and 12 months then annually	Voiding study at 3 weeks, then 12 months	At 12 months	Any instrumentation including dilatation
Kane <i>et al</i> 2002 ⁹	3,6 and 12 months then annually with symptom scores	Retrograde study at 3 weeks and 3 months		Recurrent narrowing on radiological studies requiring intervention. If no intervention performed (despite recurrence) quoted as successful outcome
Heinke <i>et al</i> 2003 ²²	6 and 12 months with PVRU estimation and symptom scores	Voiding study at 3 weeks, then only if Q_{max} deteriorated		Intervention only classed as a failure if outcome still poor- 4 patients underwent DIVU and had good outcomes, therefore

				counted as success. Also, patients perform regular ISD for first 6 weeks- ? numbers in this cohort
Elliott <i>et al</i> 2003 ²⁴		Voiding study at 3 weeks, then 3,6 and 12 months, then as required		If stream reduced or symptoms recurred
Fichtner <i>et al</i> 2004 ²⁵	6 and 12 months, with symptom questionnaire and PVRU estimation	Voiding study at 3 weeks		Any recurrence
Dubey <i>et al</i> 2005 ³⁰	3,6,9 and 12 months, then every 6 months, with ongoing urethral calibration (16Ch)	Voiding study at 3 weeks		Symptomatic recurrence

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Table 4. Follow-up and failure criteria for studies
Qmax = Peak flow rate (millilitres per second)
ISD = Intermittent self dilatation of urethra
DIVU = Direct inline visual urethrotomy