Review Article

A scoping review on chordee correction in boys with ventral congenital penile curvature and hypospadias

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ABSTRACT

Introduction: Congenital penile curvature (PC), often concomitant with hypospadias, poses challenges in urology. Surgical correction techniques, including plication and corporotomy, lack standardized guidelines. This study aims to address the paucity of high-level evidence by comprehensively reviewing the outcomes of PC correction procedures in patients with and without hypospadias. This will inform clinical decision-making and provide insights for future research and meta-analyses.

Methods: We conducted this scoping review in accordance with the JBI Manual for Evidence Synthesis and PRISMA-ScR guidelines. An extensive literature search was performed and comparative studies published in English up to June 2023 were included. The studies were divided into three categories: PC without hypospadias, PC with hypospadias, and studies comparing two or more materials for covering the ventral corporotomy. Data extraction comprised author details, patient characteristics, study design, interventions, outcomes, and complications. Methodological quality was assessed using the Newcastle–Ottawa Scale.

Results: Forty-two studies were included in the review, which collectively comprised 3180 patients. Thirteen comparative studies reported the outcomes of surgery for congenital PC without hypospadias, 22 studies compared different techniques of PC correction in patients with hypospadias and 7 studies compared the type of materials for coverage following ventral corporotomy. In cases of PC without hypospadias, the most commonly reported surgery was the Nesbit's plication. For PC with hypospadias correction, the results of ventral corporotomy were superior to that of dorsal plication in most of the studies. The two-stage repair had better results when compared to the one-stage repair for patients with perineo-scrotal hypospadias. In studies comparing materials for coverage of ventral corporotomy, the tunica vaginalis flap or graft was utilized most commonly. The majority of the studies reported a success rate ranging from 85% to 100%. The methodological quality was high in all but four studies.

Conclusion: Plication procedures are generally preferred for PC without hypospadias, but they result in penile shortening. For those with hypospadias, corporotomy is associated with superior outcomes than plication, especially for those with severe curvature and redo procedures. For ventral corporotomy coverage, the tunica vaginalis flap or graft is the most commonly reported tissue in the literature.

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INTRODUCTION

Congenital penile curvature (PC) is a condition most frequently associated with hypospadias, although it can also be seen in those with an orthotopic meatus. Approximately 3%–5% of the general population has varying degrees of PC without any functional limitation in the majority of the cases.[1] When associated with hypospadias, PC is invariably associated with the maldevelopment of the urethra, which lacks a tubular conformation distal to the meatus and is known as the urethral plate. On the other hand, PC without hypospadias may result from a corporeal disproportion or a nonpliable urethral tube that opens in an orthotopic location.[2] If the urethra is otherwise lax, such a curvature is typically managed by shortening the longer or the convex side to account for the corporeal disproportion. This may be achieved by excision and closure of a part of dorsal tunica albuginea, plication of the tunica albuginea, or by the transverse closure of a longitudinal incision. Currently, there are no randomized, head-to-head trials comparing these surgical techniques to help the surgeons in selecting the most appropriate procedure for a specific indication. A recent meta-analysis tried to address the question whether the dorsal plication or a ventral lengthening carries a higher risk of recurrent curvature in those undergoing a proximal hypospadias repair.[3] A closer look at their published data reveals that only five studies (among the 17 included) had 2 or more comparative groups. Among these, there were only two studies that compared plication with ventral corporotomy/corporoplasty. Unless the patients in the plication and the corporotomy groups belonged to the same study and were operated upon by the same surgeon or team, a comparison of their success rates may not be accurate as there will be an operator bias.

Given the lack of high-level literature on this topic, the objective of this scoping review was to develop a better understanding of the outcomes of congenital PC correction in patients with and without hypospadias. This review can also act as a springboard for the future studies, reviews, and meta-analyses.[4]

METHODS

We conducted a scoping review using the methodological approach outlined in the JBI Manual for Evidence Synthesis and the reporting followed the PRISMA Protocols Extension for Scoping Reviews (PRISMA-ScR) checklist.[5,6]

Inclusion criteria

Participants

We included all studies on hypospadias with symptomatic chordee and those on the correction of PC in patients younger than 18 years. We also included studies evaluating male participants with congenital PC without hypospadias where the age range extended beyond 18 years. Studies that reported correction of non-congenital PC (e.g., Peyronie's disease) were excluded.

Concept

The concept of interest for this scoping review was the correction of congenital PC with or without hypospadias. Intervention was defined as "any technique that corrected PC either alone or in combination with another surgical technique." Further, studies assessing symptomatic PC were also included.

Context

This review included studies published up to June 2023. We did not limit our criteria to exclude any specific type of repair. Comparisons of interest included assessments of two or more different techniques or materials for covering the corporotomy defect. The primary outcome was treatment success, defined as curvature resolution, which was described in all the studies. The secondary outcome was to assess the procedure-related complications.

Search strategy

An initial limited search on MEDLINE was undertaken to identify articles on the topic. The text words contained in the titles and abstracts of relevant articles, and the index terms used to describe the articles were used to develop a full search strategy for MEDLINE, EMBASE, and Scopus. The reference list of all the included studies were screened for additional studies and only those which were published in the English language were included. The search strategy is summarized in Supplementary Figure 1.

Type of sources

Randomized and non-randomized controlled trials, before-and-after studies, and interrupted time-series studies, as well as analytical observational studies, were considered for inclusion.

Study/source of evidence selection

All identified citations were collated and uploaded into Covidence systematic review software (Veritas Health Innovation, Melbourne, Australia. Available at www.covidence.org). Studies were screened for relevance by two independent reviewers. Following this, full-text publications were retrieved and examined. Any disagreements that arose between the reviewers at each stage of the selection process were resolved through discussion and consultation with a third reviewer. The results of the search and inclusion process are illustrated in Figure 1.[5]

Data extraction and synthesis

Data extraction

Extracted data included author names, journal, year of publication, patient characteristics (including the age, diagnosis, and severity of PC), distribution of the study groups, follow-up, effectiveness of the intervention and complications such as edema and/or decreased penile

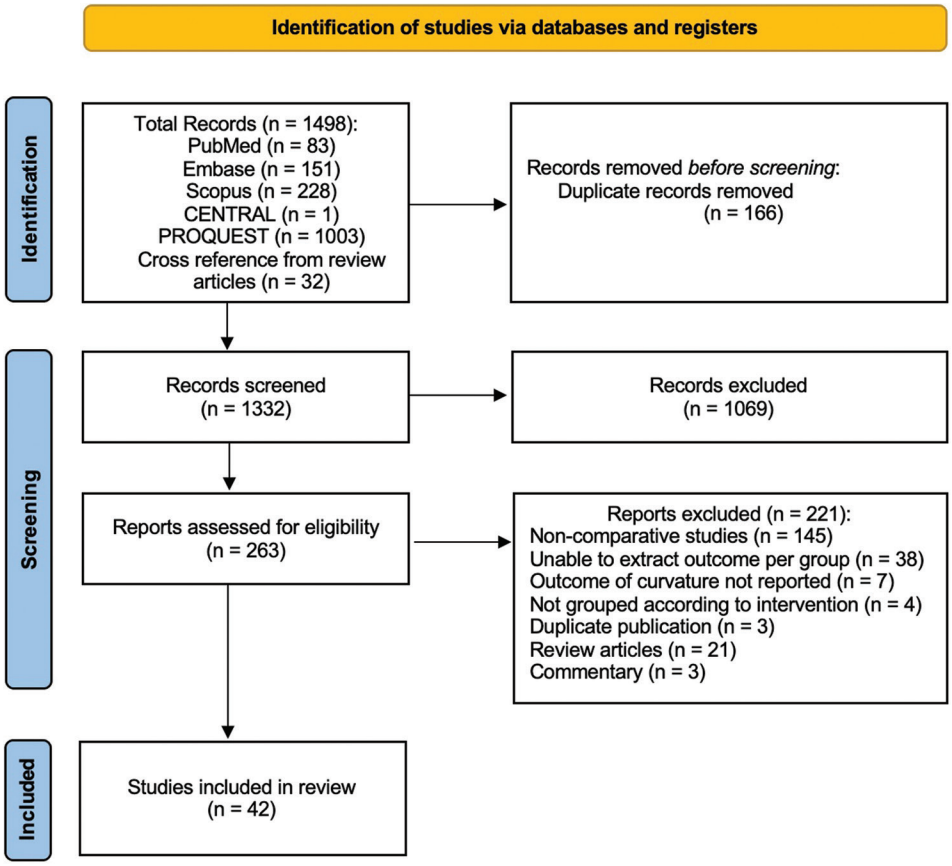

Figure 1: PRISMA compliant flow diagram of search strategy and included studies

sensitivity, hematoma, penile shortening, urethrocutaneous fistula and meatal stenosis.

Data synthesis

All studies were summarized in tables and descriptive text. The studies were then segregated into different categories of interest.

Risk of bias analysis

The quality of the studies included in this review was assessed using the Newcastle–Ottawa Scale (NOS) (http://www.ohri.ca/programs/clinical_epidemiology/oxford.asp). This validated instrument has three quality parameters (selection, comparability, and outcome) which are further divided into subcategories. For this review, we modified the scale by removing two items in the "Selection" category ("Ascertainment of exposure" and "Demonstration that outcome of interest was not present at the start of the study"). Thus, the maximum possible score on this modified NOS was 7. We considered a score of 5–7 as high quality and <5 as low quality.[7]

RESULTS

Descriptive information

Figure 1 illustrates the study selection process. Following a full-text review, 42 articles were deemed eligible for analysis. These studies collectively comprised 3180 patients. Nine studies assessing the management of patients with congenital PC without hypospadias and included adult patients, while the remaining studies exclusively included pediatric population. All the studies were published as original articles. No systematic reviews or scoping reviews were published prior to the search date.

Characteristics of included studies

The following categories of studies were identified as per the JBI methodological classification: retrospective case series (n = 27), retrospective cohort (n = 10), prospective case series (n = 4), and randomized control trials (n = 1). Three author groups accounted for 12 studies.[7-18] We observed an upward trend in the number of studies published over time, with 18 studies (42%) being published after 2015 [Figure 2].

The summarized data of the studies are presented in Supplementary Tables 1-3. The studies were grouped into three broad categories (*vide infra*).

Review findings

Studies on congenital penile curvature without hypospadias

Thirteen studies compared the outcomes of surgical approaches for the correction of congenital PC without

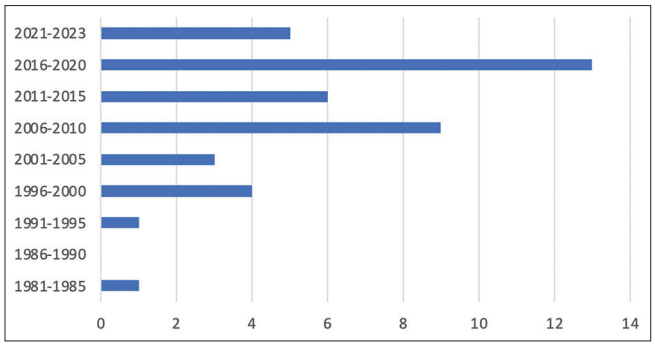

Figure 2: Number of studies on correction of penile curvature published over the years

hypospadias [Supplementary Table 1]. Five types of comparisons were observed.

Plication versus plication

Seven studies compared two or more forms of plication.[2,19-24] Overall, the success rate for curvature correction ranged from 84.2% to 100%. Popken *et al.*, Nyirády *et al.*, and Leonardo *et al.*, compared Nesbit's plication with other techniques such as tunica albuginea plication, Heineke-Mikulicz plication or plication without tunica albuginea incision/excision.[2,19,20]

Plication versus mobilization

Three studies compared plication with urethral mobilization.[12,25,26] The success rate of all the mobilization procedures was 100% while the plication procedures had a success rate ranging between 84.6% and 100%. One of the studies noted the possibility of hypercorrection following the plication.[25]

Plication versus plication and mobilization

Dipaola *et al.* compared Nesbit's plication alone with plication and urethral plate mobilization.[27] One patient with the most severe PC and three patients with intermediate PC had recurrent curvature and all these four patients underwent urethral plate mobilization.

Degloving versus plication versus mobilization

Kramer *et al.* compared the Nesbit's procedure with degloving (or Allen-Spence technique) and urethral mobilization for PC correction in 20 patients.[27] Only 2 patients who underwent Nesbit's plication had residual PC. Of note, both of these subjects belonged to the group with severe PC (type 1, $n = 9$).

Corporotomy versus corporotomy and plication

Simonato *et al.* compared corporotomy and dermal graft placement with a combination of corporotomy, dermal grafting, and plication in 15 patients with congenital PC.[28] The subjects were divided into four groups: one graft, one graft with plication, two grafts, and two grafts with plication. All groups had 100% success except the one graft with plication group which had a success rate of 85.7%.

Studies on penile curvature correction in patients with hypospadias

Twenty-two studies compared the different techniques of PC correction in patients with hypospadias [Supplementary Table 2]. Eight comparisons were observed.

Plication versus corporotomy

Seven studies compared plication with corporotomy.[9,29-34] Four of these publications described 1- or 2-stage hypospadias repair in patients without a history of prior surgical intervention. Braga *et al.* reported a significantly higher incidence of recurrent PC with dorsal plication compared to the ventral corporotomy with grafting in a single-stage surgery ($P = 0.029$).[9] Gershbaum *et al.* compared 1-stage repair (dorsal plication) with 2-stage repair (corporotomy with grafting) and found a similarly high rate of PC resolution with corporotomy.[29] Cheng *et al.* reported a 100% success rate for dorsal plication as well as corporotomy with grafting during the staged hypospadias repair.[30] Another study by Takeda *et al.* reported on 9 patients with recurrent PC following repair.[31] All patients with recurrent PC had undergone dorsal plication alone.

Urethral transection versus plication

Two studies compared urethral transection with plication.[35,36] Wang *et al.* performed a retrospective evaluation of 43 patients with proximal hypospadias who underwent transverse preputial island flap repair and 14 had recurrent curvature.[35] The overall success of the initial surgery was 50% for the urethral plate transection alone and 77.8% for urethral plate transection with dorsal plication. Zhang *et al.* compared dorsal plication alone against dorsal plication with urethral transection and reported a success rate of 100% and 97.5%, respectively.[36]

Degloving versus plication versus corporotomy

Three studies compared degloving, plication, and corporotomy against one another for the correction of PC.[11,14,37] Pippi Salle *et al.* reported the results of 140 boys with hypospadias and divided them into three groups based on the surgical procedure: (1) tubularized incised plate (TIP), (2) long dorsal inlay TIP technique (DIG), and (3) staged repair with ventral corporotomy.[11] Patients with TIP and DIG underwent degloving and dorsal plication depending on the degree of curvature and a recurrent curvature was noted in 14% of the patients with TIP, 17.3% of the patients with DIG, and 5% of the patients who underwent the staged repair. Seo *et al.* compared degloving and chordectomy ($n = 17$) with Nesbit's plication ($n = 16$) and ventral corporotomy with tunica vaginalis flap ($n = 10$) in 23 boys with glandular and subcoronal hypospadias and in 20 boys with PC without hypospadias with a curvature of >30°.[37] At a mean follow-up of 6.4 years, recurrent

curvature was noted in 3 patients who underwent dorsal plication as the primary surgery. Similarly, Snodgrass and Prieto reported a 97.1% success rate in their series of patients with proximal shaft to perineal hypospadias and all the recurrences were noted in the dorsal plication group.[14]

Degloving versus plication
Golomb *et al.* reported the long-term outcomes of ventral curvature correction in 27 boys who underwent hypospadias repair in infancy and were assessed in the postpubertal period after a mean follow-up of 15 years.[38] At the post-pubertal examination, 8 patients who underwent skin release had no PC whereas 3 of those who underwent dorsal plication had curvature. The authors hypothesized that the higher recurrence rate in the dorsal-plication group could have resulted from the continued asymmetric growth of the ventral dysplastic tissue during puberty.

Urethral mobilization versus no mobilization
Snodgrass *et al.* reviewed 76 patients with proximal hypospadias and a PC >30° who underwent TIP repair to evaluate whether the urethral plate and urethral mobilization leads to an increase in the incidence of neourethral strictures.[15] They found that 5 out of the 29 patients with urethral mobilization and 0 out of the 47 patients without urethral mobilization developed neourethral stricture.

Urethral transection versus urethral transection and/or corporotomy/corporoplasty
Five studies compared urethral transection alone or in combination with corporotomy with corporoplasty for the correction of PC in patients with hypospadias.[10,16,17,39,40] Snodgrass and Bush reviewed 43 patients with proximal hypospadias with a mean PC of 70° who underwent urethral plate transection alone (± dorsal plication) or in combination with ventral corporotomy.[16] None had a recurrence in curvature at a mean follow-up of 1.83 years. In another series, the same authors reviewed 73 patients with persistent ventral PC (mean 50°) following proximal hypospadias repair and found that the corporeal disproportion was least in the patients who underwent ventral corporotomy ± graft placement at the time of initial surgery.[17] Vandersteen *et al.* reviewed their surgical results for recurrent chordee at a minimum of 10 years after the repair of the proximal hypospadias.[39] None of the patients who underwent urethral transection had a recurrence while one patient, among those who underwent corporoplasty, had ventral glandular tilt without functional limitations. Bhat *et al.* reviewed 21 boys with proximal hypospadias who underwent modified Glassberg-Duckett urethroplasty.[10] None of the patients had recurrence of the curvature at a mean follow-up of 1.5 years. Finally, Badawy *et al.* followed boys with proximal hypospadias who underwent staged repair with an inner prepucial graft.[40] These boys underwent urethral plate transection alone or in combination with ventral corporotomy and over a mean follow-up of 3.2 years, the authors noted two recurrences, both in the corporotomy group.

Spongioplasty versus spongioplasty and plication
Hayashi *et al.* studied the role of spongioplasty with or without dorsal plication for the correction of PC in boys undergoing TIP repair for coronal to penoscrotal hypospadias who had a curvature ranging from 15° to 45°.[41] The plication group was associated with penile shortening which was limited to 5 mm only in 11 of the 13 patients.

Mobilization ± corporotomy versus plication ± corporotomy
Two studies compared urethral mobilization along with plication to variable degrees of corporotomy.[12,18] Bhat *et al.* compared urethral plate mobilization (n = 12) with dorsal plication to corporotomy (n = 2) in boys with perineal and penoscrotal hypospadias with a PC of >30° and managed with TIP.[12] They reported a 100% success at a mean follow-up of 1.25 years. Snodgrass and Bush studied 58 boys with recurrent ventral PC after TIP repair for proximal hypospadias.[18] The incidence of recurrent PC was greatest in those who underwent urethral plate mobilization and was the least in the combined mobilization and dorsal plication group.

Studies comparing materials for ventral corporotomy coverage

Seven studies compared the different types of tissues utilized to cover the defect created by the ventral corporotomy [Supplementary Table 3].[8,41-47] Tissues of interest included tunica vaginalis flap/graft, dermis, small intestinal submucosa (SIS), dura, and pericardium. Tunica vaginalis coverage, in the form of a flap or a graft, was the most commonly employed tissue. Almost all the groups had a success rate between 85% and 100%, except in one study where 3/5 of the tunica vaginalis graft recipients had a recurrence of the curvature and in another study where 4/9 of the dural graft recipients had a recurrence.[8,43] Conversely, Ritchey *et al.* reported a nearly 95% success rate with the tunica vaginalis graft.[42] Similar rate was noted by Wu *et al.* (35070828). Elmore *et al.* compared 1 ply SIS with 4 ply SIS and recommended for 1 ply SIS due to a lower incidence of complications.[44] However, no difference was noted between the 1 ply SIS and the 4 ply SIS by Hayn *et al.*[45] Leslie *et al.* compared the SIS, dermal grafts and tunica vaginalis flaps and found that the overall success rate was 95% or more and none of the patients who received tunica vaginalis flap had recurrent chordee.[46] The mean follow-up of all four studies ranged from 2 to 5 years and the cumulative complication rate was up to 23%.

Risk of bias analysis

Using the modified NOS, we reviewed the quality of the studies included in this review [Supplementary Table 4]. Four studies were identified as low quality[27,36,39,44] and the remaining were of high quality (Total score of 5–7).

DISCUSSION

This scoping review aimed to present a comprehensive summary of the existing evidence on the results of different surgical techniques utilized for the correction of congenital PC and that associated with hypospadias. Nearly all the studies identified in this review were retrospective reviews of institutional databases. Through this review, we hope to identify areas of future research by focusing on the available evidence and categorising the studies into 3 subsets.

Studies on congenital penile curvature without hypospadias

There are numerous procedures aimed at addressing PC without hypospadias. Plication techniques involve folding and suturing the tunica albuginea to rectify the curvature, with variations like Nesbit's plication and Heineke–Mikulicz plication. These methods are straightforward and are effective for those with less severe curvature, albeit potentially causing penile shortening and sensitivity reduction. Urethral mobilization involves liberating the urethra from its attachments with the corpora cavernosa and is suitable for those with mild curvatures and maintains the penile length while correcting the curvature. This technique can be combined with other methods for the complex cases. In specific instances, combined procedures harmonize techniques such as plication and urethral mobilization to optimize the outcomes, especially in the intricate scenarios. The intricacies and comparisons of these surgical methods revolve around their unique characteristics. Thirteen studies made five types of comparisons and a maximum number of studies compared two or more types of plication. Plication techniques, efficacious yet associated with potential shortening, underline the significance of patient selection. Urethral mobilization, sparing the penile length, is constrained in severe curvatures. The most common procedure overall appears to be the Nesbit's procedure. However, the most severe forms of chordee require urethral division and a staged urethroplasty.[25,48] Unlike hypospadias, where ventral corporotomy is very popular for the correction of PC, congenital PC without hypospadias is almost exclusively treated by various forms of plication due to the high risk of retraction of the scar and consequent ventral curvature in case of ventral corporotomy.[2] Combining different techniques caters to multifaceted cases, underscoring the importance of individualized solutions. Furthermore, absorbable sutures are not recommended for plication due to a high rate of relapse.

The overall success rate of surgery for PC without hypospadias is high, around 90%–100% in most of the series. However, most of the studies also reported shortening of the penis, and some of them reported decreased sensitivity of the penis, particularly with the Nesbit's excision. The sensitivity may be affected more with a medial rather than a lateral excision,[21] and larger excision may lead to hypercorrection.[25] Recurrence of the curvature remains a concern despite corrective procedures.

Studies on hypospadias chordee correction

Twenty-two studies addressing correction of hypospadias made eight broad comparisons and some of them had a mean follow-up as long as 15 years. The results of a 2-stage surgery were superior to that of a single-stage surgery for those with perineoscrotal hypospadias.[29] Within the single-stage repair, the results of ventral lengthening were superior to that of dorsal plication.[9] In properly selected patients, urethral plate transection alone (± dorsal plication) or in combination with ventral corporotomy has a success rate reaching 100%.[16]

Two studies reported the results of PC correction in patients with recurrent curvature following a previous surgery.[31,39] One of them showed that dorsal plication is inferior to corporotomy for a redo surgery,[31] and the other showed the opposite.[39]

Most studies highlight that the process of chordee correction is more sequential or algorithmic.[10,14,17,33,36,39] Most extensive procedures such as corporotomy and grafting best serve the cases that have the maximum curvature or have failed the prior repairs. One of the aspects which has not been assessed in the reported studies is the effect of the type of surgery on the sexual functions and this remains a topic for future research.

Studies comparing materials for ventral corporotomy coverage

In the present review, we found that tunica vaginalis is the only durable flap with acceptable success rates. Among the grafts, there are a variety of options such as dermis, dura, pericardium, and SIS. Dural grafts appear to have a low success rates and more than 50% of the patients end up with a recurrent chordee. Dermal grafts may perform better than the tunica vaginalis-free grafts,[43] but tunica vaginalis flaps achieve similar or even better results as compared to the dermal grafts.[46,47] Although the use of a buccal mucosal graft to cover the corporotomy has been reported,[49] a comparison of the same with other materials has not been performed and remains a topic for further research.

CONCLUSION

Correction of PC in patients with or without hypospadias is challenging. For congenital PC without hypospadias, plication is preferred; however, this technique is associated with varying degrees of penile shortening. For hypospadias, while degloving and urethral mobilization can be useful in patients with lower degrees of curvature, dorsal plication and ventral corporotomy with coverage are required for the more severe cases. Ventral coporotomy, in general, is

associated with superior outcomes, particularly for the most severe types of hypospadias and redo operations. As for covering the ventral corporotomy, tunica vaginalis flaps and grafts continue to be the most commonly reported tissues. This scoping review identified a lack of randomized studies evaluating curvature correction in those with hypospadias with regards to the techniques of curvature correction and the materials for ventral corporotomy coverage, which are the areas for future research.

REFERENCES

1. Ebbehøj J, Metz P. Congenital penile angulation. Br J Urol 1987;60:264-6.
2. Leonardo C, De Nunzio C, Michetti P, Tartaglia N, Tubaro A, De Dominicis C, *et al.* Plication corporoplasty versus Nesbit operation for the correction of congenital penile curvature. A long-term follow-up. Int Urol Nephrol 2012;44:55-60.
3. Babu R, Chandrasekharam VV. A meta-analysis comparing dorsal plication and ventral lengthening for chordee correction during primary proximal hypospadias repair. Pediatr Surg Int 2022;38:389-98.
4. Nyanchoka L, Tudur-Smith C, Thu VN, Iversen V, Tricco AC, Porcher R. A scoping review describes methods used to identify, prioritize and display gaps in health research. J Clin Epidemiol 2019;109:99-110.
5. Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, *et al.* PRISMA extension for scoping reviews (PRISMA-ScR): Checklist and explanation. Ann Intern Med 2018;169:467-73.
6. Peters M, Godfrey C, McInerney P, Munn Z, Tricco A, Khalil H, *et al*. Chapter 11: Scoping reviews. In: JBI Manual for Evidence Synthesis. Adelaide: JBI; 2020. Available from: https://synthesismanual.jbi.global. [Last accessed on 2021 Sep 15].
7. Braga LH, Pace K, DeMaria J, Lorenzo AJ. Systematic review and meta-analysis of robotic-assisted versus conventional laparoscopic pyeloplasty for patients with ureteropelvic junction obstruction: Effect on operative time, length of hospital stay, postoperative complications, and success rate. Eur Urol 2009;56:848-57.
8. Braga LH, Pippi Salle JL, Dave S, Bagli DJ, Lorenzo AJ, Khoury AE. Outcome analysis of severe chordee correction using tunica vaginalis as a flap in boys with proximal hypospadias. J Urol 2007;178:1693-7.
9. Braga LH, Lorenzo AJ, Bägli DJ, Dave S, Eeg K, Farhat WA, *et al.* Ventral penile lengthening versus dorsal plication for severe ventral curvature in children with proximal hypospadias. J Urol 2008;180:1743-7.
10. Bhat A, Bhat M, Sabharwal K, Bhat A, Kumar R. Bhat's modifications of Glassberg-Duckett repair to reduce complications in management severe hypospadias with curvature. Afr J Urol 2017;23:94-9.
11. Pippi Salle JL, Sayed S, Salle A, Bagli D, Farhat W, Koyle M, *et al.* Proximal hypospadias: A persistent challenge. Single institution outcome analysis of three surgical techniques over a 10-year period. J Pediatr Urol 2016;12:7.e1-7.
12. Bhat A, Sabharwal K, Bhat M, Singla M, Kumar V, Upadhyay R. Correction of penile torsion and chordee by mobilization of urethra with spongiosum in chordee without hypospadias. J Pediatr Urol 2014;10:1238-43.
13. Bhat A, Singla M, Bhat M, Sabharwal K, Upadhaya R, Kumar V. Incised plate urethroplasty in perineal and perineo-scrotal hypospadias. Afr J Urol 2015;21:105-10.
14. Snodgrass W, Prieto J. Straightening ventral curvature while preserving the urethral plate in proximal hypospadias repair. J Urol 2009;182:1720-5.
15. Snodgrass WT, Granberg C, Bush NC. Urethral strictures following urethral plate and proximal urethral elevation during proximal TIP hypospadias repair. J Pediatr Urol 2013;9:990-4.
16. Snodgrass W, Bush N. Staged tubularized autograft repair for primary proximal hypospadias with 30-degree or greater ventral curvature. J Urol 2017;198:680-6.
17. Snodgrass W, Bush NC. Persistent or recurrent ventral curvature after failed proximal hypospadias repair. J Pediatr Urol 2019;15:344.e1-6.
18. Snodgrass W, Bush N. Recurrent ventral curvature after proximal TIP hypospadias repair. J Pediatr Urol 2021;17:222.e1-5.
19. Popken G, Wetterauer U, Schultze-Seemann W, Deckart AB, Sommerkamp H. A modified corporoplasty for treating congenital penile curvature and reducing the incidence of palpable indurations. BJU Int 1999;83:71-5.
20. Nyirády P, Kelemen Z, Bánfi G, Rusz A, Majoros A, Romics I. Management of congenital penile curvature. J Urol 2008;179:1495-8.
21. Akbulut F, Akman T, Salabas E, Dincer M, Ortac M, Kadioglu A. Neurovascular bundle dissection for Nesbit procedure in congenital penile curvature patients: Medial or lateral? Asian J Androl 2014;16:442-5.
22. Shaeer O. Shaeer's double-eight plication technique for correction of penile curvature. J Genit Surg 2017;2017:1-6. doi: 10.21608/jgs.2017.4178.
23. Shaeer O, Shaeer K. Shaeer's corporal rotation IV: Length-preserving correction of congenital ventral penile curvature. J Sex Med 2023;20:699-703.
24. Kusin SB, Khouri RK Jr., Dropkin BM, Dietrich PN, Ward EE, Baumgarten AS, *et al.* Plication for correction of congenital penile curvature: With or without degloving? Sex Med 2021;9:100462.
25. Marrocco G, Calisti A, Palmiotto F, De Simone P, Di Meo L. Congenital penile curvature in children: A practical approach. Pediatr Surg Int 1995;10:40-3.
26. Tang YM, Chen SJ, Huang LG, Wang MH. Chordee without hypospadias: Report of 79 Chinese prepubertal patients. J Androl 2007;28:630-3.
27. Dipaola G, Spalletta M, Balducci T, Giacomello L, Camoglio FS, Bianchi S, *et al.* Surgical treatment of chordee without hypospadias. Eur Urol 2000;38:758-61.
28. Simonato A, Gregori A, Ambruosi C, Ruggiero G, Traverso P, Carmignani G. Congenital penile curvature: Dermal grafting procedure to prevent penile shortening in adults. Eur Urol 2007;51:1420-7.
29. Gershbaum MD, Stock JA, Hanna MK. A case for 2-stage repair of perineoscrotal hypospadias with severe chordee. J Urol 2002;168:1727-8.
30. Cheng EY, Kropp BP, Pope JC 4th, Brock JW 3rd. Proximal division of the urethral plate in staged hypospadias repair. J Urol 2003;170:1580-3.
31. Takeda M, Seo S, Sueyoshi R, Nakamura H, Suda K, Lane GJ, *et al.* Reconstructive surgery for recurrent penile curvature. Pediatr Surg Int 2018;34:245-8.
32. Bandini M, Sekulovic S, Spiridonescu B, Krishnappa P, Dangi AD, Slavkovic M, *et al.* Prevalence, assessment and surgical correction of penile curvature in hypospadias patients treated at one European referral center: Description of the technique and surgical outcomes. World J Urol 2020;38:2041-8.
33. Howe AS, Hanna MK. Management of 220 adolescents and adults with complications of hypospadias repair during childhood. Asian J Urol 2017;4:14-7.
34. Abosena W, Talab SS, Hanna MK. Recurrent chordee in 59 adolescents and young adults following childhood hypospadias repair. J Pediatr Urol 2020;16:162.e1-5.
35. Wang C, Zhang W, Song H. Recurrent ventral curvature with long-term follow-up after transverse preputial Island urethroplasty. Eur J Pediatr Surg 2020;30:429-33.
36. Zhang Y, Chao M, Zhang WP, Tang YM, Chen HC, Zhang KP, *et al.* Using buck's fascia as an integral covering in urethroplasty to restore the anatomical structure of the penis in one-stage hypospadias repair: A multicenter Chinese study comprising 1,386 surgeries. Front Pediatr 2021;9:695912.
37. Seo S, Ochi T, Yazaki Y, Murakami H, Okawada M, Doi T, *et al.* Correction of penile ventral curvature in patients with minor or no

hypospadias: A single surgeon's experience of 43 cases. Pediatr Surg Int 2016;32:975-9.
38. Golomb D, Sivan B, Livne PM, Nevo A, Ben-Meir D. Long-term results of ventral penile curvature repair in childhood. Urology 2018;112:161-3.
39. Vandersteen DR, Husmann DA. Late onset recurrent penile chordee after successful correction at hypospadias repair. J Urol 1998;160:1131-3.
40. Badawy H, Dawood W, Soliman AS, Fahmy A, Mahfouz W, Moussa A, *et al.* Staged repair of proximal hypospadias: Reporting outcome of staged tubularized autograft repair (STAG). J Pediatr Surg 2020;55:2710-6.
41. Hayashi Y, Mizuno K, Moritoki Y, Nakane A, Kato T, Kurokawa S, *et al.* Can spongioplasty prevent fistula formation and correct penile curvature in TIP urethroplasty for hypospadias? Urology 2013;81:1330-5.
42. Ritchey ML, Ribbeck M. Successful use of tunica vaginalis grafts for treatment of severe penile chordee in children. J Urol 2003;170:1574-6.
43. Caesar RE, Caldamone AA. The use of free grafts for correcting penile chordee. J Urol 2000;164:1691-3.
44. Elmore JM, Kirsch AJ, Scherz HC, Smith EA. Small intestinal submucosa for corporeal body grafting in severe hypospadias requiring division of the urethral plate. J Urol 2007;178:1698-701.
45. Hayn MH, Bellinger MF, Schneck F×. Small intestine submucosa as a corporal body graft in the repair of severe chordee. Urology 2009;73:277-9.
46. Leslie JA, Cain MP, Kaefer M, Meldrum KK, Misseri R, Rink RC. Corporeal grafting for severe hypospadias: A single institution experience with 3 techniques. J Urol 2008;180:1749-52.
47. Wu S, He R, Sun J, Zhao H. Acellular dermal matrix graft for ventral corporal lengthening orthoplasty in 2-stage proximal hypospadias repair. Transl Pediatr 2021;10:3151-8.
48. Kramer SA, Aydin G, Kelalis PP. Chordee without hypospadias in children. J Urol 1982;128:559-61.
49. Mokhless IA, Youssif ME, Orabi SS, Ehnaish MM. Corporeal body grafting using buccal mucosa for posterior hypospadias with severe curvature. J Urol 2009;182:1726-9.

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Search Strategy

PUBMED
("hypospadias"[MeSH Terms] OR "hypospadias"[All Fields] OR "hypospadia"[All Fields] OR (("ventral"[All Fields] OR "ventrale"[All Fields] OR "ventrally"[All Fields] OR "ventrals"[All Fields]) AND ("curvature"[All Fields] OR "curvatures"[All Fields])) OR "chordee"[All Fields]) AND ("corporotomies"[All Fields] OR "corporotomy"[All Fields] OR ("corporotomies"[All Fields] OR "corporotomy"[All Fields]) OR (("ventral"[All Fields] OR "ventrale"[All Fields] OR "ventrally"[All Fields] OR "ventrals"[All Fields]) AND ("straighten"[All Fields] OR "straightened"[All Fields] OR "straightening"[All Fields] OR "straightens"[All Fields])))

EMBASE
1 exp hypospadias/
2 hypospadia*.ti,ab,kw9456
3 (hypospadias adj2 (correction* or repair* or procedure* or modif*)).ti,ab,kw.
4 exp chordee/
5 (chordee adj2 (correction* or repair* or procedure* or modfi*)).ti,ab,kw.
6 ventral curvature.mp.
7 ventral curvature.ti,ab,kw.
8 (ventral curvature adj2 (correction* or repair* or procedure*)).ti,ab,kw.
9 or/1-8
10 corporotomy.ti,ab,kw.
11 corporotomies.ti,ab,kw.
12 ventral lengthening.ti,ab,kw.
13 ventral straightening.ti,ab,kw.
14 dorsal plication.ti,ab,kw.
15 fairy cuts.ti,ab,kw.
16 or/10-15
17 9 and 16

SCOPUS
(Hypospadias OR ventral curvature OR chordee) AND (Corporotomy OR corporotomies OR Ventral straightening)

CENTRAL
#1 hypospadias Limits
#2 chordee Limits
#3 ventral curvature Limits
#4 corporotomy Limits
#5 corporotomies Limits
#6 ventral lengthening Limits
#7 ventral straightening Limits
#8 fairy cut Limits
#9 plication Limits
#10 (#4 OR #5 OR #6 OR #7 OR #8 OR #9) Limits
#11 (#1 OR #2 OR #3) AND #10 Limits

PROQUEST
(Hypospadias OR ventral curvature OR chordee) AND (Corporotomy OR corporotomies OR Ventral straightening OR Fairy cuts OR plication)

Supplementary Figure 1: Search strategy for the scoping review

Supplementary Table 1: Studies on congenital penile curvature without hypospadias

Study	Study Design	Sample size	Mean age (years)	Degree of chordee	Comparators of interest	Technique (*n*)
Shaeer and Shaeer, 2023	Randomized control trial	42	-	>30°–<60° ventral	Plication versus plication	i) Shaeer's corporal rotation IV (21) ii) Shaeer's corporal rotation III (21)
Popken *et al*., 1999	Retrospective cohort	105	i) 25 ii) 20	>30°	Plication versus plication	i) Nesbit-Kelami (55) ii) Modified corporoplasty with buried knots (50)
Nyiráidy *et al*., 2008	Retrospective cohort	87	24	>30° ventral Symptomatic >40° lateral	Plication versus plication	i) Nesbit (18) ii) Tunica albuginea plication (7) iii) Heineke-Mikulicz (62)
Leonardo *et al*., 2012	Retrospective cohort	62	19	>30°	Plication versus plication	i) Plication corporoplasty (19) ii) Nesbit (12)
Akbulut *et al*., 2014	Retrospective cohort	34	24.9	>30°	Plication versus plication	i) Nesbit: medial NVB (21) ii) Nesbit: Lateral NVB (13)
Kusin *et al*., 2021	Retrospective cohort	38	i) 28 ii) 23	>15°	Plication versus plication	i) Nondegloving incisionless plication (25) ii) Degloving incisionless plication (13)
Shaeer *et al*., 2017	Retrospective case series	60	26.5	i) Shaeer's Double-8 technique: 39.1°±8.4° ii) 16-dot technique: 34°±9°	Plication versus plication	i) Shaeer's Double-8 technique ii) 16-dot technique
Marrocco *et al*., 1995	Retrospective case series	16	9.7	Unspecified	Plication versus mobilization	i) Nesbit (13) ii) Urethral mobilization and division with tubularized preputial urethroplasty (2) iii) Heineke–Mikulicz (1)
Tang *et al*., 2007	Retrospective case series	29 (only Type III and IV included)	6.4	>30° Type III and IV chordee only	Plication versus mobilization	i) Plication±TIP/LIF (10) ii) LIF±DMP/Duplay (19)
Bhat *et al*., 2014	Retrospective case series	9	8	>30° Torsion >60	Plication versus mobilization	i) DP (1) ii) Mobilization of urethra and spongiosum (2) iii) Mobilization of urethra into glans (4) iv) Mobilization of proximal urethra (2)
Dipaola *et al*., 2000	Retrospective case series	22	6.81	Type I-III chordee	Plication versus plication and mobilization	i) Nesbit±Blair-Byars skin flap (9) ii) Nesbit and UP Mobilzation±Blair-Byars skin flap (10) iii) Vascular neourethra and reduction of dorsal TA (3)
Kramer *et al*., 1982	Retrospective case series	20	8	Type I–III chordee	Degloving versus plication versus mobilization	i) Nesbit (8) ii) Allen-Spence (8) iii) Urethral mobilization (2) iv) Urethral division with staged urethroplasty (2)
Simonato *et al*., 2007	Retrospective case series	15	26.6	>30°	Corporotomy versus corporotomy and plication	i) One dermal graft (1) ii) One graft and plication (7) iii) Two grafts (4) iv) Two grafts and plication (3)

Study	Success rates (%)	Mean follow-up (years)	Residual curvature or recurrence, *n* (%)	Complications (%)
Shaeer and Shaeer, 2023	i) 100.0 ii) 100	5	i) SCR IV: 1 (4.8) ii) SCR III: 6 (26.6)	Palpable knot: 1 SCR IV (4.8), 6 SCR III (28.6) Decreased sensitivity: 2 SCR IV (9.5), 4 SCR II (19.0)
Popken *et al*., 1999	i) 95 ii) 96	i) 6 ii) 2.83	i) Nesbit-Kelami: 5 (9.0) ii) Modified corporoplasty: 2 (4.0)	Shortening: 6 Nesbit-Kelami (50.0), 14 Corporoplasty (73.6) Decreased sensitivity: 9 Nesbit-Kelami (75.0), 7 Corporoplasty (37.0) Induration: 54 Corporoplasty (21.0) Hematoma: 10 Nesbit-Kelami (18.2), 2 Corporoplasty (4.00)
Nyiráidy *et al*., 2008	93.10	7.4	i) Nesbit: 4 (33.3) ii) Plication: 3 (42.8) iii) Heineke-Mikulitz: 1 (1.60)	Shortening: 3 Nesbit (16.7), 2 Plication (28.6), 10 Heineke-Mikulitz (16.1) Decreased sensitivity: 1 Nesbit (5.56), 1 Heineke-Mikulitz (1.61)
Leonardo *et al*., 2012	i) 84.2 ii) 100.0	7.3	i) Plication corporoplasty: 3 (15.8) ii) Nesbit: 0 (0.00)	Shortening: 14 Plication (73.6), 6 Nesbit (50.0) Decreased sensitivity: 7 Plication (37.0), 9 Nesbit (75.0) Erection discomfort: 4 Plications (21.0)
Akbulut *et al*., 2014	i) 94.4 ii) 84.6	1.3	i) Lateral Nesbit: 1 (5.6) ii) Medial Nesbit: 2 (15.4)	Shortening: 3 Lateral Nesbit (23.1) Decreased Sensitivity: 1 Medial Nesbit (5.6)
Kusin *et al*., 2021	i) 100.0 ii) 92.0	4–6 weeks	i) NDIP: 0 (0.0) ii) DIP: 1 (8.3)	Lymphedema: 0 NDIP (0.0), 1 DIP (7.7) Erection discomfort: 2 NDIP (8.0), 2 DIP (15.0)
Shaeer *et al*., 2017	i) 100.0 ii) 89.50	3	i) Shaeer's: 0 (0.00) ii) 16-dot: 4 (10.50)	Shortening: All patients from both groups

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Supplementary Table 1: Contd...

Study	Success rates (%)	Mean follow-up (years)	Residual curvature or recurrence, *n* (%)	Complications (%)
Marrocco *et al*., 1995	i) 84.6 ii) 100.0 iii) 100.0	2.6	i) Nesbit: 1 (7.69) ii) Urethral Division: 0 (0.00) iii) Heineke-Mikulitz: 0 (0.00)	Hypercorrection: 1 Nesbit (7.69)
Tang *et al*., 2007	i) 90.0 ii) 100.0	1.2	i) Plication: 1 (10.0) ii) LIP: 0 (0.00)	Urethrocutaneous Fistula: 1 LIF (5.26). Urethral stricture: 1 LIF + Duplay (5.26)
Bhat *et al*., 2014	100	1.42	None	None
Dipaola *et al*., 2000	i) 100.0 ii) 60.0 iii) 100.0	11.2	Nesbit and UP Mobilzation: 4 (18.2)	Urethrocutaneous Fistula: 1 Nesbit and UP Mobilzation (10.0)
Kramer *et al*., 1982	i) 75.0 ii) 100.0 iii) 100.0 iv) 100.0	Minimum of 1	i) Nesbit: 2 (25.0) ii) Allen-Spence: 0 (0.00) iii) Urethral mobilization: 0 (0.00) iv) Urethral division: 0 (0.00)	None
Simonato *et al*., 2007	i) 100.0 ii) 85.7 iii) 100.0 iv) 100.0	1	One dermal graft: 1 (14.3)	None

DP=Dorsal plication, NVB=Neurovascular bundle, LIF=Longitudinal island flap, DMP=Dorsal midline plication, UP=Urethral plate, TIP=Tubularized incised plate, DIP=Degloving incisionless penile plication, NDIP=Non-degloving incisionless penile plication, SCR=Shaeer's corporal rotation

Supplementary Table 2: Studies on hypospadias chordee correction

Study	Study design	Sample size	Mean age (years)	Patient characteristics	Comparators of interest
Vandersteen *et al*., 1998	Retrospective case series	22	4 (initial surgery); 21 (re-presentation)	Recurrent chordae min. 10 years after penoscrotal and proximal shaft hypospadias repair	Transection versus corporoplasty versus both
Snodgrass *et al*., 2017	Prospective case series	43	1.15	Proximal/severe hypospadias, mean penile curvature 70°	Transection versus corporotomy
Wang *et al*., 2020	Retrospective case series	43	1.9 (surgery); 15.9 (re-presentation)	Postpubertal patients who underwent TPIF repair for proximal hypospadias in infancy	Transection versus plication and transection
Zhang *et al*., 2021	Retrospective cohort	1142	2.42	Distal, midshaft, proximal hypospadias managed with Buck's fascia integral-covering, penile curvature >10°	Plication versus plication and transection
Gershbaum *et al*., 2002	Retrospective case series	34	-	Underwent 1 or 2 stage perineoscrotal hypospadias and chordee repair	Plication versus corporotomy
Cheng *et al*., 2003	Retrospective case series	14	<1	Underwent staged hypospadias repair	Plication versus corporotomy
Braga *et al*., 2008	Retrospective cohort	100	i) 1.42 ii) 1.48	Patients with penoscrotal or more proximal hypospadias, penile curvature >45°	Plication versus corporotomy
Seo *et al*., 2016	Retrospective case series	43	3.2	Glanular and subcoronal hypospadias or orthotopic meatus, penile curvature >30°	Degloving versus plication versus corporotomy
Pippi Salle *et al*., 2016	Retrospective case series	140	i) TIP: 1.43 ii) DIG: 1.28 iii) Staged repair: 1.47	Patients with proximal hypospadias undergoing TIP, DIG or staged repair	Degloving versus plication (VC 30–50) versus corporotomy (VC >50)
Golomb *et al*., 2018	Retrospective cohort	27	1.5 (surgery); 16.5 (follow-up)	Patients with Tanner stage 5 who underwent TIP in infancy	Degloving versus plication
Snodgrass *et al*., 2019	Retrospective case series	60	2.7	Patients with persistent VC (mean 50°) following failed proximal hypospadias repair	Chordee excision versus plication versus corporotomy
Takeda *et al*., 2018	Retrospective case series	9	6.83	Recurrent >30° penile curvature	Plication versus corporotomy versus both
Bandini *et al*., 2020	Retrospective cohort	274	i) One stage: 1.83 ii). Two stage: 1.67	Distal, midshaft and proximal hypospadias included, penile curvature >10°	Plication versus corporotomy versus both
Hayashi *et al*., 2013	Retrospective case series	32	-	Patients undergoing TIP repair, penile curvature 15-45°	Spongioplasty versus spogioplasty and DP
Snodgrass *et al*., 2013	Retrospective cohort	76	i) 0.75 ii) 0.58	Proximal hypospadias patients undergoing TIP, penile curvature >30°	Mobilization versus no mobilization
Bhat *et al*., 2015	Retrospective case series	14	13	Perineal and periscrotal hypospadias managed with TIP, penile currvature >30°	Mobilization versus plication and corporotomy
Snodgrass *et al*., 2021	Prospective case series	58	1.83	Patients with recurrent VC after proximal TIP repair	Plication versus mobilization/corporotomy versus both
Bhat *et al*., 2017	Retrospective case series	16	11.5	Patients with scrotal, perineo-scrotal, penoscrotal, and proximal penile hypospadias treated with modified Glassberg-Duckett urethroplasty, penile curature "moderate-severe"	Mobilization versus transection versus corporotomy
Snodgrass *et al*., 2009	Prospective case series	70	-	Patients with proximal shaft to perineal hypospadias operated on at 2 periods of time	Degloving versus plication versus transection versus mobilization
Howe *et al*., 2017	Retrospective case series	45	Range: 15–39	Patients with previous hypospadias repair	Plication versus plication versus corporotomy
Abosena *et al*., 2019	Retrospective case series	59	Range: 14-21	Patients with recurrent penile curvature following hypospadias repair	Plication versus mobilization and corporotomy versus corporotomy
Badawy *et al*., 2020	Prospective case series	43	1	Primary proximal hypospadias	Transection versus corporotomy

Contd...

Supplementary Table 2: Contd...

Study	Technique (number of patients)	Success rates (%)	Mean follow-up (years)	Residual curvature, *n* (%)	Complications (%)
Vandersteen *et al*., 1998	i) Urethral transection (7) ii) Corporoplasty (longitudinal incision with horizontal closure) (8) iii) Urethral transection, corporoplasty, and urethroplasty (7)	i) Transection: 100 ii) Corporoplasty: 93.3	1	i) Transection: 0 (0.00) ii) Corporoplatsy: 1 (6.67)	Urethrocutaneous fistula: 1 (7.14) transection
Snodgrass *et al*., 2017	i) UP transection (15) ii) Ventral corporotomy (28)	i) 100 ii) 100	1.83	None	Urethrocutaneous fistula: 2 (4.65) Glans dehiscence: 7 (16.3) Diverticulum: 1 (2.32)
Wang *et al*., 2020	i) UP transection (16) ii) UP transection+DP (27)	i) 50.0 ii) 77.8	1.23	i) Transection: 8 ii) Transection+DP: 6	Urethrocutaneous fistula: 12 (27.9) Stricture: 11 (25.6) Diverticulum: 3 (6.98)
Zhang *et al*., 2021	i) DP (705) ii) Plication and transection (437)	i) 100.0 ii) 97.5	2.25	11 (1.2, all in primary proximal hypospadias repairs)	Urethrocutaneous fistula: 73 (5.2) Dehiscence: 10 (0.6) Meatal stenosis: 22 (1.6) Stricture: 21 (1.5) Diverticulum: 6 (0.7)
Gershbaum *et al*., 2002	i) 1 stage - Plication (Nesbit or TA) (23) ii) 2 stage - TA or dermal graft (11)	i) 76.0 ii) 100.0	15	i) Plication: 5 (24.0) ii) TA or dermal graft: 0 (0.00)	One stage: i) Diverticulum: 3 (14.0) ii) Distal breakdown: 3 (14.0) iii) Anastomsis stricture: 1 (1.0) Two stage: i) Diverticulum: 1 (9.0)
Cheng *et al*., 2003	i) DP ii) Dermal corporal body grafting iii) SIS corporal body grafting	100	Range: 0.5–3	None	Of entire cohort: i) Meatal stenosis: 1 (7.14) ii) Urethrocutaneous fistula: 1 (7.14) iii) Diverticulum: 1 (7.14)
Braga *et al*., 2008	i) Ventral lengthening (32) ii) DP (68)	i) 90.63 ii) 72.06	i) 5.42 ii) 5.17	i) Ventral lengthening: 3 (9.4) ii) DP: 19 (27.9)	Urethrocutaneous fistula: 8 Ventral lengthening (25.0), 20 DP (29.4)
Seo *et al*., 2016	i) Deglove + chordectomy (17) ii) Nesbit and UP Mobilzation (16) iii) Deglove + chordectomy + TAI and TVF (10)	i) 100.0 ii) 97.7 iii) 100.0	6.4	i) Deglove and chordectomy: 0 (0.00) ii) Nesbit and UP Mobilzation: 3 (18.8) iii) Deglove, chordectomy, TAI and TVF: 0 (0.00)	Urethrocutaneous fistula: 1 deglove, chordectomy, TAI and TVF (10.0) Stenosis: 1 deglove, chordectomy, TAI and TVF (10.0)
Pippi Salle *et al*., 2016	i) TIP: DP (27) ii) DIG: DP (20) iii) Staged repair: UP division and TAIs (59)	i) TIP: 86.0 ii) DIG: 82.7 iii) Staged repair: 95.0	i) TIP: 4.03 ii) DIG: 2.98 iii) Staged repair: 2.47	i) TIP: 8 (14.0) ii) DIG: 4 (17.3) iii) Staged repair: 3 (5.00)	Urethrocutaneous fistula: 18 TIP (31.5), 3 DIG (13.0), 7 SR (11.6) Glans dehiscence: 3 TIP (5.21), 7 SR (11.6) Complete dehiscence: 4 TIP (7.00), 4 DIG (17.3), 3 SR (5.00) Meatal stenosis: 6 TIP (10.5), 3 DIG (13.0) Urethral stenosis: TIP 3 (5.20)/DIG 1 (4.30)/SR 1 (4.60) Diverticulum: TIP 1 (1.70)/SR 1 (1.60)
Golomb *et al*., 2018	i) Degloving (14) ii) DP (Baskin) (13)	i) 57.1 ii) 23.1	15	i) Degloving: 6 (42.9) ii) DP: 10 (76.9)	Unspecified
Snodgrass *et al*., 2019	i) Chordee excision (18) ii) DP (Baskin, Nesbit, uncharacterized) (23) iii) Ventral corporotomy +/− graft (15)	i) 17.0 ii) 30.0 iii) 66.0	1.83	i) Chordee excision: 15 (83.0) ii) DP: 16 (70.0) iii) Ventral corporotomy +/− graft: 5 (33.0)	Urethrocutaneous fistula: 14 (23.3) Glans dehiscence: 12 (20.0) Wound dehiscence: 18 (30.0) Stricture: 7 (11.7) Meatal stenosis: 3 (5.00)
Takeda *et al*., 2018	i) DP +/− UP (3) ii) TAI (3) iii) DP and TAI (1) iv) Scar removal (1) v) Unknown+UP (1)	i) 0 ii) 100 iii) 100 iv) 100 v) 0	2.6	i) DP +/− UP: 3 (100.0) ii) TAI: 0 (0.00) iii) DP and TAI: 0 (0.00) iv) Scar removal: 0 (0.00) v) Unknown+UP: 1 (100.0)	Unspecified
Bandini *et al*., 2020	i) One stage: DP (211) ii) Two stage: Tunical incisions (17) iii) Two stage: Both (46)	i) One stage: 100 ii) Two stage: 27.0 after tunical incisions alone	2.34	13 (4.74)	Urethrocutaneous fistula: 56 (18.5)

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Supplementary Table 2: Contd...

Study	Technique (number of patients)	Success rates (%)	Mean follow-up (years)	Residual curvature, *n* (%)	Complications (%)
Hayashi *et al*., 2013	i) Spongioplasty (19) ii) Spongioplasty and DP (13)	100	2.58	None	Shortening: 13 Spongioplasty and DP (100.0) Urethrocutaneous fistula: 3 (6.38) Glans dehisence: 1 (2.13)
Snodgrass *et al*., 2013	i) UP elevation and mobilization (29) ii) No UP elevation and mobilization (47)	i) 97.0 ii) 94.0	i) 1.0 ii) 2.25	i) Mobilization: 1 (3) ii) No mobilization: 3 (6)	Urethrocutaneous fistula: 8 (17.0) no UP mobilization Glans dehiscence: 4 (8.0) no UP mobilization; 3 (10.0) UP mobilization Diverticulum: 1 (2.00) no UP mobilization Meatal stenosis: 1 (2.00) no UP mobilization
Bhat *et al*., 2015	i) UP mobilization (12) ii) DP and corporotomy (2)	100	1.25	None	Urethrocutaneous fistula: 2 (14.28) Meatal stenosis: 1 (7.14)
Snodgrass *et al*., 2021	i) DP (31) ii) UP elevation +/− corporotomy (7) iii) DP and UP elevation +/− corportomy (20)	74	3.7	i) DP: 7 (22.6) ii) UP elevation: 5 (71.4) iii) DP and UP elevation: 3 (15.0)	Urethrocutaneous fistula: 2 (17.0) Glans dehiscence: 1 (8.33) Diverticulum: 1 (8.33) Stricture: 1 (8.33)
Bhat *et al*., 2017	i) Degloving with Mobilization (6) ii) UP transection (2) iii) Latereal dissection of Buck's Fascia (3) iv) Corporeal body dissection and superficial corporotomies (5)	100	1.5	None	Urethrocutaneous fistula: 2 (9.52) Mild preputial edema: 2 (9.52) Meatal stenosis: 1 (4.76) Dilated distal urethra: 1 (4.76)
Snodgrass *et al*., 2009	i) Degloving (13) ii) DP (22; done if VC <30 after degloving) iii) UP transection +/− plication +/− ventral corporotomy +/− grafting (20, done between 2000-2005 if VC >30 after degloving) iv) Mobilization +/- Plication +/− Ventral Corporotomy +/− Grafting (15, done between 2006-2008 if VC >30 after degloving)	97.10	i) Group 1: 2.25 ii) Group 2: 0.783	i) Degloving: 0 (0.00) ii) DP: 2 (9.09) iii) UP transection: 0 (0.00) iv) Mobilization: 0 (0.00)	None
Howe *et al*., 2017	i) Nesbit (16) ii) Baskin (14) iii) Corporal body grafting (15)	95.1	1.17	i) Nesbit: 1 (6.25) ii) Baskin: 1 (7.14)	i) Urethrocutaneous fistula: 2 (4.44) ii) Stricture: 3 (6.67)
Abosena *et al*., 2019	i) One-stage dorsal replication and skin detethering (32) ii) One-stage urethral mobilization and corporal/dermal grafts (12) iii) Staged corporal/dermal and grafted TIP (15)	96.4	1.25	2 (3.63)	i) Wound dehiscence: 2 (3.63)
Badawy *et al*., 2020	i) UP transection (27) ii) Ventral corporotomy (16)	i) 100 ii) 87.5	3.2	i) UP transection: 0 (0.00) ii) Ventral corporotomy: 2 (12.5)	Urethrocutaneous fistula: 8 (21.6) Glans dehiscence: 9 (24.3)

DIG=Dorsal inlay graft, DP=Dorsal plication, UP=Urethral plate, TVF=Tunica vaginalis flap, TIP=Tubularized incised plate, TAIs=Tunica albuginea incisions, TPIF=Transverse preputial island flap, VC=Ventral curvature, TA=Tunica albuginea, SR=Staged repair

Supplementary Table 3: Studies comparing materials for ventral corporotomy coverage

Study	Study design	Sample size	Mean age (yeara)	Patient characteristics	Comparators of interest	Technique (number of patients)
Caesar *et al*., 2000	Retrospective case series	28	0.5	Primary hypospadias repair or secondary repair for recurrent chordee, mean penile curvature unspecified	TVFG versus dermis	i) TVFG (5; 2 primary repair and 3 secondary repair) ii) Dermis (23; 6 primary repair and 17 secondary repair)
Ritchey *et al*., 2003	Retrospective case series	25	0.67	Patients with scrotal and perineal hypospadias, mean penile curvature unspecified	TVFG versus dermis versus SIS	i) TVFG (19) ii) Dermis (3) iii) SIS (3)
Braga *et al*., 2007	Retrospective case series	38	1.25	Patients with perineal and periscrotal hypospadias, penile curvature >45°	TVF versus TVF and graft versus graft	i) TVF alone (23) ii) TVF and Dura (8) iii) TVF and Pericardium (2) iv) TVF and SIS (1) v) Dermis (1) vi) Dura (1) vii) Pericardium (1)
Elmore *et al*., 2007	Retrospective case series	28	1.33	Patients with perineal, scrotal, and penoscrotal hypospadias, penile curvature >30°	4 ply SIS versus 1 ply SIS	i) 4-ply SIS graft (21) ii) 1-ply SIS graft (7)
Leslie *et al*., 2008	Retrospective case series	71	0.83	Proximal hypospadias undergoing primary staged repair	SIS versus TVFG versus dermal graft	i) Dermal graft (29) ii) TVFG (21) iii) SIS (20) iv) TVFG+SIS (1)
Hayn *et al*., 2009	Retrospective case series	15	1	Proximal hypospadias with severe chordee	4 ply SIS versus 1 ply SIS	i) 4 ply SIS graft (9) ii) 1 ply SIS graft (6)
Wu *et al*., 2021	Retrospective case series	78	i) 1.21 ii) 1.35	Proximal hypospadias with >30° curvature undergoing primary staged repair	ADM graft versus TVF	i) ADM graft (43) ii) TVF (35)

Study	Success rates (%)	Mean follow-up	Residual curvature, *n* (%)	Complications, *n* (%)
Caesar *et al*., 2000	i) 40.0 ii) 100.0	2 years	i) TVFG: 3 (60.0)	i) Urethrocutaneous fistula: 1 (7.14) ii) Urethral stricture: 1 (2.80)
Ritchey *et al*., 2003	96.0	1 year minimum, 5 years maximum	i) TVFG: 1 (5.26)	i) Hematoma: 1 (5.26) TVFG ii) UTI: 1 TVFG (5.26)
Braga *et al*., 2007	85.7	5.3 years	i) TVF alone: 1 (4.35) ii) Dural graft: 4 (44.4)	i) Urethrocutaneous fistula: 5 (14.2) ii) Meatal stenosis: 2 (5.70) iii) Urethral stricture: 1 (2.80)
Elmore *et al*., 2007	i) 100 ii) 100	3.17 years	None	No complications related to SIS grafts
Leslie *et al*., 2008	i) 96 ii) 100 iii) 95 iv) 100	7.6 months	i) Dermal graft: 1 (4) ii) SIS: 1 (5)	None
Hayn *et al*., 2009	i) 100 ii) 100	Range: 2–75 months	None	No complications related to SIS graft
Wu *et al*., 2021	i) 88 ii) 94	i) 46.8 months ii) 45.3 months	i) ADM graft: 1 (2.3) ii) TVF: 1 (2.9)	i) Urethrocutaneous fistula: 9 (21) ADM graft, 7 (20) TVF ii) Meatal stenosis: 3 (7) ADM graft, 3 (8.6) TVF iii) Hematoma: 2 (4.7) ADM graft, 7 (20) TVF

ADM=Acellular dermal matrix, TVF=Tunica vaginalis flap, SIS=Small intestinal submucosa, UTI=Urinary tract infection, TVFG=Tunica vaginalis-free graft

Supplementary Table 4: Modified Newcastle–Ottawa Scale to assess the methodological quality of the studies

Authors	Year	Selection	Comparability	Outcome	Total score (maximum 7)
Kramer *et al*.	1982	2	1	2	5
Marrocco *et al*.	1995	2	1	2	5
Vandersteen *et al*.	1998	1	1	2	4
Popken *et al*.	1999	2	2	3	7
Dipaola *et al*.	2000	2	1	1	4
Caesar *et al*.	2000	2	1	2	5
Gershbaum *et al*.	2002	2	1	2	5
Cheng *et al*.	2003	1	2	2	5
Ritchey *et al*.	2003	2	1	2	5
Tang *et al*.	2007	2	1	2	5
Simonato *et al*.	2007	2	1	2	5
Braga *et al*.	2007	2	1	3	6
Elmore *et al*.	2007	1	1	2	4
NyirÃ¡dy *et al*.	2008	2	2	3	7
Braga *et al*.	2008	2	2	3	7
Leslie *et al*.	2008	2	1	2	5
Snodgrass *et al*.	2009	2	1	2	5
Hayn *et al*.	2009	2	2	2	6
Leonardo *et al*.	2012	2	1	3	6
Hayashi *et al*.	2013	2	1	3	6
Snodgrass *et al*.	2013	2	1	2	5
Bhat *et al*.	2014	2	1	2	5
Akbulut *et al*.	2014	2	2	3	7
Bhat *et al*.	2015	2	1	3	6
Seo *et al*.	2016	2	1	3	6
Pippi Salle *et al*.	2016	2	1	3	6
Shaeer *et al*.	2016	2	2	3	7
Howe *et al*.	2017	2	1	2	5
Bhat *et al*.	2017	2	1	2	5
Snodgrass *et al*.	2017	2	2	1	5
Golomb *et al*.	2018	2	2	2	6
Takeda *et al*.	2018	2	2	2	6
Snodgrass *et al*.	2019	2	1	2	5
Abosena *et al*.	2019	2	1	2	5
Bandini *et al*.	2020	2	1	3	6
Wang *et al*.	2020	2	2	2	6
Badawy *et al*.	2020	2	1	2	5
Snodgrass *et al*.	2021	2	1	3	6
Zhang *et al*.	2021	1	1	2	4
Kusin *et al*.	2021	2	2	3	7
Wu *et al*.	2021	2	2	2	6
Shaeer and Shaeer	2023	2	2	3	7