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Distension methods of surgical correction of hypospadias in boys

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Abstract

Difficulties in the treatment of hypospadias in boys persist to this day. After surgical correction of hypospadias, fistulas, strictures, urethral diverticula, retraction of the meatus, glans dehiscence and other complications occur. At the same time, it is quite difficult to understand the whole variety of proposed methods for correcting hypospadias, which creates confusion for specialists and negatively affects the results of treatment. The literature describes more than 300 different methods of correcting hypospadias, but none of the methods is perfect, and there are no generally accepted treatment standards. Despite this, it is an established fact that the choice of the surgery procedure depends on the type of hypospadias. A successful technique of hypospadias repair should be completed with a good cosmetic and functional result. The article presents an overview of the distension techniques of urethroplasty. For the first time, the experience of urethral advancement was presented at the end of the XIX century, but the technique was unpopular and did not have significant success. However, by the end of the XX century, more effective distension techniques of urethroplasty began to be developed, which were widely used around the world (Koff S.A., Ti-Seng Chang, Belman A.B., MAGPI, LUM, etc.). According to scientific literature, urethral advancement is a safe and reliable way to correct distal hypospadias, and it is considered as an alternative to creating a "neourethra". This technique has many competitive advantages, such as the short operation time, the absence of urethral tubularization, excellent functional and cosmetic results, and a small number of complications. It, therefore, follows that distension techniques of urethroplasty are considered a good option for correcting distal hypospadias, which should be in the arsenal of every pediatric surgeon and urologist.

Keywords: hypospadias, boys, literature review, advancement urethroplasty.

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Hypospadias is a common congenital malformation of the genitourinary system [1, 2] and the most common congenital malformation of the penis [3, 4]. The diagnosis is established according to the results of a clinical examination, and it is determined by the presence of any of the following three elements of congenital malformation: dystopia of the meatus, ventral chordee, and the absence of foreskin on the ventral surface of the penis (Fig. 1) [5, 6].

Over the past decades, there has been a significant increase in the number of male newborns with hypospadias [7]. If the frequency was 1:300–500 newborns between the 1960s and 1970s, the frequency of births of children with various forms of hypospadias has now increased to 1:125–150 cases [8]. According to the latest numbers, the incidence of hypospadias in Europe is 18.6 (5.1–36.8) per 10,000 newborns [9–11].

Most often, hypospadias is classified according to the location of the urethral meatus. The classification proposed by Duckett in which he divided the hypospadias into anterior, medial, and posterior

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is popular [12]. However, modern classifications (Fig. 2) considered only the location of the meatus before surgery, which cannot serve as an accurate criterion for determining the severity of hypospadias. This approach does not consider factors such as the size of the penis, size of the glans and urethral site, presence of curvature, division level of spongy body pedicles, presence of urethral dysplasia, and scrotum malposition. All these factors directly determine the severity of hypospadias and affect the surgical approach and its outcome [11, 13, 14]. For this reason, the direct diagnosis and severity of hypospadias are often established during surgery [15].

Distal hypospadias including granular, subcoronal, and distal-penile are the most common and account for 73.4% of all forms. Proximal forms including penile, penoscrotal, scrotal, and perineal hypospadias account for not more than 17.5% [16–18].

Since Galenus first described and introduced the term "hypospadias," methods of its correction have evolved from creating a functional "neourethra" to achieving a good cosmetic result [19]. A successful surgical technique for hypospadias should be technically simple, with good cosmetic and functional results. And in distal hypospadias, an important component of the surgical treatment result is the improvement of penis appearance [20, 21].

Over the past 20–30 years, several methods for hypospadias correction have been developed to reduce the number of postoperative complications and achieve good cosmetic results [6, 22]. Modern surgical maneuvers and techniques allow the elimination of the curvature, creation of "neourethra" up to the apex of the glans, and then reconstruction of the penis skin [23–25]. The choice of method largely depends on the patient's subjective assessment of the penis structure and the experience and preferences of the surgeon [22, 26].

The restoration of the urethra in hypospadias is associated with several complications including urethral fistulas, meatostenosis, diverticula, and chordee even in the hands of the most experienced surgeons [27]. Most of the described methods for hypospadias correction can be accompanied by complications; therefore, they are regularly reviewed and modified to achieve better functional and cosmetic results [18, 28].

Currently, we can conditionally distinguish four following basic principles of hypospadias correction.

1. Use of the ventral penis tissues
2. Use of the ventral and dorsal penis tissues
3. Use of extragenital tissues—the mucous membrane of the cheeks, lips, bladder, and forearm skin
4. Distention methods of urethroplasty—as an alternative to the creation of "neourethra."

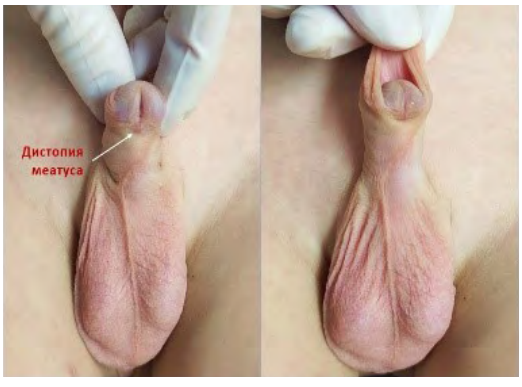

Fig. 1. Dystopia of the meatus

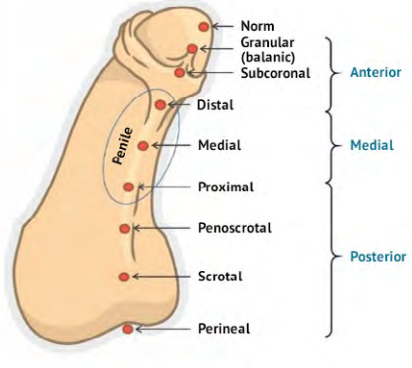

Fig. 2. Types of hypospadias

In this review, we would like to dwell on the distention methods of urethroplasty, that is, on the principles of hypospadias treatment including urethra isolation and displacement in more detail.

Displacing urethroplasty techniques are considered good one-stage techniques for treating distal forms of hypospadias, but their main disadvantage is the high frequency of meatostenosis [29, 30].

Anatomical and physiological features of the urethra in the form of its elasticity, extensibility, and proximal blood supply ensure physiological erection [31]. The fear of devascularization and necrosis due to urethra mobilization is not justified because of the presence of a vasculature formed by the branch of the internal pudendal artery and the terminal branch of the dorsal genital artery [32–34].

The morphology of the anterior part of the urethra is represented by a large amount of intercellular substance, which provides significant extensibility of the urethra and spongy body together with smooth muscles and elastic fibers [35, 36]. For this reason, the penis can double during erection [37]. The displaced urethra does not delay the further growth of the penis and does not lead to problems during puberty [38–40].

In recent decades, distension methods of treating hypospadias have not been very popular. However, publications from this period indicate good

functional and cosmetic results when using displacing urethroplasty for treating distal forms of hypospadias [41–43].

Modern authors recommend using various methods of displacing urethroplasty only for distal forms of hypospadias [44,45]. An exception is some publications considering the possibility of using displacing urethroplasty in combination with other techniques for the correction of proximal forms of hypospadias [33,46]. Also, some authors suggest using displacing urethroplasty for treating postoperative urethral fistulas [47,48].

Carl Beck was the first to propose the principle of urethral mobilization and meatal advancement. He published the results of his technique in 1898. The essence of the surgery includes mobilizing the distal segment of the urethra, after which a T-shaped incision of the glans is made along the midline on the ventral surface, and two quadrangular flaps are dissected out. The urethra is pulled out and placed in the formed bed. The edges of the urethra are sutured to the apex of the glans with the formation of the meatus, after which the balanoplasty is performed over the displaced urethra [49].

In the same year, the principle of urethra displacement was proposed by Austrian surgeon Viktor Ritter von Hacker and published his results in Germany. Unlike Beck's technique, he proposed to perforate the glans and pass the urethra through the formed tunnel without incising the glans along the midline [50].

Beck and von Hacker are deservedly considered the pioneers in modern surgery of distal hypospadias and the founders of displacing urethroplasty [19].

The absence of urethral sutures was guaranteed to reduce the number of urethral fistulas, but the number of meatal stenoses increased. As a rule, the distal part of the urethra in hypospadias is devoid of spongy tissue, thinned, and low elastic, and its distension increases the risk of complications. In addition, distension techniques were not used for severe chordee. This because the techniques proposed by Beck and von Hacker did not find proper recognition for a long time; they were rarely used.

Only by the end of the 20th century, publications based on the principles of distal urethroplasty began to appear. In 1977, Belman published the results of treating hypospadias using the principles proposed by Beck. Unlike the author's technique, he was one of the first to propose a wide mobilization of the urethra with its subsequent advancement. The principles proposed by Belman have become decisive for the further development of distal methods of treating hypospadias, and there were publications on the use of widespread urethral mobilization and its results [51].

In 1982, Turkish surgeon Namik Baran proposed his method of treating distal hypospadias. In his modification, he proposed dissecting the triangular flap on the glans penis and forming a distal anastomosis between the flap and displaced urethra. The author noted that mobilizing the distal part of the urethra by 1.5–2 cm and pulling it to the tip of the penis through the tunneled glans do not cause ventral chordee, and the formation of the anastomosis with a triangular flap reduces the number of postoperative strictures. However, he was not a supporter of widespread mobilization of the urethra and believed that this can cause ventral chordee [37].

A popular modification of replacing urethroplasty is the "anterior urethral replacement" technique proposed by Ti-Seng Chang. He presented the results of his proposed technique in the British Journal of Plastic Surgery in 1984 [38].

Chang was one of the first to conduct basic research to substantiate the effectiveness of the proposed technique of performing surgical interventions on cadavers. He found that the degree of urethral advancement after mobilizing the urethra is up to 1.8–2.0 cm in children and about 4.5–5.0 cm in adults, which was more than enough to treat various forms of hypospadias according to the author. He used his technique quite successfully to treat both distal and medial penile hypospadias and recurrent hypospadias and fistulas of the urethra.

Nevertheless, some authors report possible complications when using the author's technique such as postoperative chordee and meatostenosis, which discouraged surgeons from using this surgery [30]. The limitation of indications for the use of this technique and some modifications proposed by modern authors made it possible to reduce the number of complications and expand the possibilities of its application [29, 30, 52, 53].

The work of Koff was a new jump in the development of distal hypospadias treatment methods. To eliminate the disadvantages of Beck's technique, he suggested isolating the urethra up to the penoscrotal angle and dissect away its distal pathologically developed part. At the same time, degloving of the penis was conducted, which made it possible to perform surgery in patients with chordee. According to the author's data, the technique allowed replacing the meatus distally by an average of 2–3 cm and up to a maximum of 3.5 cm after preliminary isolation and spatulating the urethra. This surgery was used to treat distal and proximal forms of hypospadias. In a large part, Koff's technique is considered a modern option for replacing urethroplasty, and most surgeons and authors refer to it [54].

Among the modern publications devoted to Koff's technique, the study performed by Thiry et al. in 2013 is the most interesting [55]. The presented publication included 158 patients with distal forms of hypospadias with diastasis from the apex of the glans to the meatus of not more than 1.5 cm. The overall complication rate was 8.5%, which is comparable with similar publications devoted to distal correction methods. In the group of primary correction, only three cases of meatal stenosis were reported among complications, which amounted to 3.5%. In the long term, secondary chordee developed only in one patient, which serves as a good prognostic criterion and confirms good long-term results.

Using Koff's technique, Paparel noted postoperative meatostenosis in 19.2% of cases [56]. In two other publications, Atan [57] and Hamdy [33] reported postoperative meatostenosis incidences of 23% and 7.1%, respectively, which may be due to the inclusion of more proximal forms of hypospadias in the study. Nevertheless, the authors noted good functional and cosmetic results of the surgery and recommended it for use [58].

In 1981, Waterhouse and Glassberg presented their method of hypospadias correction, which is similar to Koff's technique in many aspects concerning main technical principles. The authors transferred their many years of experience in treating urethral strictures to treating hypospadias. In particular, they found a similarity in the blood supply to the ureter and urethra, substantiating the anatomical prerequisites for its mobilization. Because of this similarity, the principles of ureteral surgery (ureterolysis) have been used to treat hypospadias and urethral strictures [59].

In 1994, Koff proposed a modification of the technique proposed by Barcat [60] and supplemented it with a stage of urethral mobilization, taking the techniques from the previously proposed method and replacing urethroplasty. For 5 years, 168 surgeries were performed using a modified technique. The number of complications requiring repeated surgery decreased to 3.5%, and good functional and cosmetic results were obtained [61].

The meatal advancement glanuloplasty inclusive (MAGPI) surgery, proposed by Duckett in 1981, is a popular method for correcting distal forms of hypospadias based on distension principles [62]. The MAGPI surgery was performed quite often in treating granular forms of hypospadias, and it is still used by some surgeons. The main aim of the surgery is to advance the meatus distally without tubularization of the urethra; it is based on the Heineke–Mikulicz principle [63, 64]. However, some authors such as Mouriquand noted that MAGPI surgery creates the illusion of urethral movement, although it does not [65].

Modern publications devoted to the MAGPI technique and its modifications generally show positive results of their use [66] if certain criteria and indications (hypospadias shape, penis size, presence or absence of chordee, glans size and shape, etc.) are met. A retrospective analysis of treating children using the MAGPI method showed good results and found positive feedback from patients and their parents [67–69].

It is quite difficult to reproduce the author's method of surgery that was also noted by Duckett. It is necessary to consider a sufficiently large number of factors to determine the indications for it [22, 70]. Also, the MAGPI surgery is applicable only in limited cases and in the absence of chordee [71].

Today, the MAGPI surgery is rarely used [72, 73]. However, there is no denying that the technique has not lost its relevance and has passed the test of time.

Like all previously proposed methods, the MAGPI surgery was not devoid of disadvantages and was accompanied by complications. In the postoperative period, many authors noted meatal retraction and stenosis and deformation in the form of a "fish mouth," which did not satisfy surgeons from a cosmetic point of view [67, 74, 75]. Hastie et al. evaluated the long-term results after the MAGPI surgery and noted that it did not maintain the terminal position of the formed meatus in the long-term period [71]. Also, after using the MAGPI technique, postoperative ventral chordee often occurred, which limited its use in more proximal forms of hypospadias [76, 77].

In 1994, Harrison and Grobbelaar proposed their modification of the MAGPI surgery and called it "urethral advancement and glanuloplasty" (UGPI). The authors supplemented the original MAGPI technique with a stage of urethral mobilization. In total, they performed 47 surgical interventions according to their own technique supplementing MAGPI with urethra mobilization but did not separate it by more than 1–1.5 cm. Because of this, the total number of postoperative complications decreased. The frequency of meatus retractions was reduced to 6.4%. Urethral fistula developed only in one patient, which required repeated surgery. In general, the UGPI surgery can be attributed to the "true" distension methods for treating hypospadias, which distinguishes it from the MAGPI surgery [78].

In 1990, Wishahi et al. proposed their own modification of the surgery of Beck. According to the proposed technique, the urethra was isolated beyond the penoscrotal angle, and a Y-shaped inci-

sion was made on the glans. The author's technique of glanuloplasty with a Y-shaped incision on the glans allowed freely replacing the urethra onto the glans and forming a wide meatus. In total, 80 patients underwent surgery. Repeated surgery due to urethral fistula was required in two patients, and meatostenosis requiring periodic urethra dilation developed in four patients. The authors obtained good cosmetic results and believed that the proposed technique has a competitive advantage over the MAGPI surgery [79].

Also, in 1991, a team of authors led by Paolo Caione proposed Y-shaped glanuloplasty with the stage of isolation and displacement of the urethra for treating distal forms of hypospadias. However, unlike Koff's technique, the urethra was isolated only for 0.5–1.5 cm. According to the author's technique, the distal urethra is isolated, a deep Y-shaped incision of the glans penis is made, a longitudinal incision of the meatus along its posterior surface is sutured to a wedge-shaped flap dissected on the glans, and glanuloplasty is performed. Meatoplasty and skin restoration are performed. In the postoperative period, the authors received three cases of meatostenosis requiring a meatotomy, and a fistula of the urethra developed in two cases. They noted that the technique has good cosmetic and functional results, allowed to perform surgery in children even with a chordee, and made it possible to abandon techniques using skin grafts and urethra tubularization [80].

In 1994, long-term results were presented by de Sy and Hoebeke. The functional and cosmetic results of observation for 5–14 years after the surgery of urethral mobilization were evaluated in 76 patients. The authors concluded that fear of ischemia and retraction and secondary chordee after extensive mobilization of the urethra is not justified [45].

Haberlik et al. in 1997 proposed their modification of Beck's technique. They supplemented the surgery with Z-shaped dermatoplasty and replaced the tunnelization of the glans with its dissection along the midline where the mobilized and displaced urethra was placed. During the surgical procedure, the urethra was exposed to the penoscrotal angle, and degloving of the penis was performed. After uroflow control in the postoperative period, the authors found meatostenosis in 3% of patients, which required bougienage of the urethra, and urethral stricture was found in 1 of 59 patients. The use of degloving and Z-shaped dermatoplasty allowed performing surgeries for chordee and prevented secondary ventral curvature [39].

In 1997, Warwick et al. proposed to isolate the urethra along its entire length including its bulbar part—the bulbar elongation anastomotic meatoplasty surgery. Such surgeries are widely used to reconstruct the urethra after its rupture in pelvic fractures. The authors were the first to show that with such urethral discharge in children, the urethra can be elongated by 2–2.5 cm [81].

Publication by Hamdy et al. who used urethral mobilization and its displacement for treating hypospadias including proximal forms is of some interest. They used a combination of techniques suggested by Koff and de Sy. In the postoperative period, three meatostenosis resolved by urethral dilatation and one case of ventral curvature were revealed among 46 patients with distal forms of hypospadias. In 10 children with proximal forms of hypospadias, 3 urethral fistulas and 1 meatostenosis that required recorrection were obtained after using this technique.

Empirically, they determined the optimal ratio of the necessary urethra mobilization according to the results of an artificial erection test conducted during the surgery. Their recommended ratio was 1:3, that is, the urethra was isolated over a length of 3 cm to elongate the latter by 1 cm. The authors recommended urethral mobilization and displacement to treat both distal and proximal forms of hypospadias [33].

In 2007, Chrzan et al. published a paper showing the results of treating children using the most popular methods for hypospadias correction. Although the authors did not set the main aim of comparing different correction methods, in the group of distal hypospadias, they received significantly fewer complications when using displacing urethroplasty compared with tubularized incised plate (TIP) urethroplasty and Mathieu techniques. Among 128 patients who underwent surgery by replacing the urethroplasty technique, 21 (16.4%) experienced complications including 10 (7.8%) urethral fistulas and 2 (1.5%) meatostenosis. Moreover, among patients with granular hypospadias, they did not report any complications [82]. In general, such results are confirmed by other authors who compared different methods of hypospadias correction [83, 84].

A study conducted by a team of authors from Egypt who performed a comparative assessment of displacing urethroplasty technique and TIP surgery comes under notice. The authors noted the decisive role of the idea of extensive urethra mobilization, first proposed by Belman, and in the course of their research, they used the technique of "moving the anterior urethra" proposed by Chang. They compared the results obtained with the results of other authors using these techniques. The authors obtained good functional and cosmetic results and believed that displacing urethroplasty serves as a safe

and reliable way to correct distal forms of hypospadias [85].

Similar results were obtained by Gite et al. using Chang's technique in 20 patients. They reported good cosmetic results, and only one complication of meatal stenosis required periodic dilation of the urethra. The authors noted that mobilization of the urethra at a distance three times greater than the distance from the meatus to the apex of the glans is sufficient for successful correction [53].

A similar length of mobilization was recommended by Hammoud and Hassan et al. They performed a deep incision of the glans on the ventral surface of the penis and wide mobilization of the glans to provide a wide slit shape of the meatus. They associated the successful use of replacing urethroplasty with careful patient selection and strict adherence to the surgical technique [86, 87].

In 2008, a team of authors from Tehran led by Mollaeian presented their results of long-term research over 10 years. The authors proposed a modification of displacing urethroplasty, and one feature of which is triangular flap dissection in the distal part of the urethral plate. In total, they performed surgery in 251 boys aged 2 to 16 years, and 201 patients had ventral chordee. In the postoperative period, no case of urethral fistula and meatal stenosis was reported. Only two cases of chordee recurrence were recorded. The authors believe that displacing urethroplasty is an expedient and preferable surgery for distal forms of hypospadias and, in some cases, for medial penile forms of hypospadias with or without chordee [88].

Also, Elemen and Tugay did not face serious complications when using "limited urethral mobilization" in their patients. The peculiarity of the technique is the isolation of the urethra over a short distance, which is sufficient so that the urethra could reach the apex of the glans without tension. In this study, the ratio of the length of the mobilized urethra to the distance from the initial location of the meatus to the apex of the glans was calculated [34]. After processing the results, the authors concluded that a threefold mobilization of the urethra is sufficient for a successful surgery. At the same time, there were no complications in the form of urethral fistulas, meatus retractions, and chordee. Meatostenosis required repeated surgery only in 1 (2.1%) patient, which is comparable with the results of similar publications. Today, the technique of limited urethral mobilization and its modifications are popular and show good postoperative results [89–91].

A team of authors led by Seibold proposed their modification of limited urethral mobilization. The authors used the meatal mobilization technique 218 patients. The incidence of postoperative complications was 3%, and the authors did not note postoperative meatostenosis [31,92]. These results are confirmed by other publications [93]. In general, the technique is based on the same principles and is similar to techniques using limited urethral mobilization to correct distal forms of hypospadias (UGPI, GRAP, and GUD) [78, 94–96].

In 2009, Adorisio et al. presented their modification of Koff's technique, complementing it with a ventral Y-shaped incision on the glans. The study included patients without or with slight chordee, without dysplasia of the distal urethra, diastasis between the apex of the glans and the meatus not more than 10 mm, and normal structure of the glans penis. In total, 90 patients with distal forms of hypospadias underwent surgery. Among the complications, only one urethral fistula that required repeated surgery and one meatostenosis that was treated conservatively were identified. Compared with the data of other authors who used Koff's technique, the authors obtained a significant decrease in the level of postoperative meatostenosis, which is due to a deep ventral Y-shaped incision, glanuloplasty, and refusal from tunnel the glans [97].

In 2017, El Darawany and Al Damhogy presented their results of treatment in boys with distal forms of hypospadias. A total of 60 patients who underwent surgery by urethral mobilization and displacement were included in the prospective study. The study group included patients with diastasis less than 1 cm, and the urethra was mobilized in a ratio of 1:3 from the initial distance to the apex of the glans penis. The authors considered urethroplasty as a good alternative technique for correcting distal forms of hypospadias. "Urethral mobilization is an easy and simple procedure with excellent cosmetics and functionality with minimal complications" [18].

One of the most discussed issues during urethra mobilization and displacement to correct hypospadias is the maximum possible degree of urethra distension and displacement and the degree of its isolation. According to various authors, the urethra can be mobilized only partially within its penile part [92,98], up to the penoscrotal angle [51,99]. There are publications in which the authors allow even the mobilization of the bulbar part of the urethra [38,45,81].

Extensive urethra mobilization can damage the urethral blood supply, which can lead to sclerotic changes in the spongy tissue, and insufficient mobilization will lead to secondary chordee or suture failure and meatus retraction. At the moment, there are no generally accepted recommendations in the

literature on how far the urethra can be isolated and moved.

In 2002, Da Silva and Sampaio published their fundamental studies. They performed experiments on cadavers and determined the maximum degree of urethra distension. Based on their findings, they recommended urethra distension up to 75% of its original length, that is, in a 1:4 ratio, that allows safe urethra displacement and minimizes complications [35]. The authors' work has confirmed previous studies that the urethra has greater extensibility than the penis, which is limited by the extensibility of the tunica albuginea covering the cavernous bodies and neurovascular bundles of the penis [100, 101].

In 2002, Atala presented his experience in treating hypospadias using displacing urethroplasty. He applied wide urethral mobilization and displacement in 73 patients with various forms of distal hypospadias. According to the author's technique, the urethra was mobilized four to five times longer than the distance from the dystopic meatus to the apex of the glans, that is, in a ratio of 1:5 or 1:4. According to the author's opinion, this ratio ensures the absence of tension and reduces the potential of meatus retraction and secondary chordee. Excellent cosmetic and functional results were obtained with only one patient requiring repeated surgery due to meatus retraction. The author concluded that displacing urethroplasty is the method of choice for treating distal forms of hypospadias, and complete urethral mobilization to its bulbar section is required for the success of this procedure [102].

Based on their studies, Dindar et al. concluded that complete mobilization of the spongy part of the urethra provides elongation of the urethra without additional tension by 1.5–2 cm in adolescents and by 0.7–1.5 cm in preschool children [103]. The movement of the urethra varied within the same limits in the publication presented by Hassen and Abdelateef; it ranged from 0.6 to 2.1 cm [87].

Since the end of the 20th century, there has been a significant increase in the number of publications devoted to distension methods for hypospadias correction. In general, the use of various techniques for replacing urethroplasty and their modifications is approved by specialists. Many modifications of the classical techniques of displacing urethroplasty generally based on the same principles have been proposed.

Distensional methods of urethroplasty are considered a good option for correcting distal forms of hypospadias, which, in our opinion, should be in the arsenal of every pediatric surgeon and urologist. These techniques allow to perform procedure for distal forms of hypospadias without the formation of a "neourethra" and the use of "grafts." Of course, this becomes a great advantage because the possibility of postoperative urethral fistula formation decreases and the use of extragenital tissues can lead to urethral incompetence [104]. This is because these tissues were retarded in growth from the normal urethra [105].

Replacing urethroplasty is a safe and reliable way to correct distal hypospadias. This technique has many competitive advantages such as short surgery time, excellent functional and cosmetic results, and fewer complications.

Contribution of authors. N.R.A.—work leader, study idea, formulation of conclusions, and editing of the text of the manuscript; I.M.K.—review of publications on the topic of the article and editing of the text of the manuscript; E.I.Kh.—study idea, review of publications on the topic of the article, and writing of the text of the manuscript.

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