Bangladesh Journal of Advanced Clinical Research
https://bjacr.org/index.php/bjacr
pISSN: 3105-7322 | eISSN: 3105-7314
Vol. 1, No. 1, 2023

Research Article

OPEN ACCESS

Correlation Between Urethral Plate Characteristics and Postoperative Complications in Hypospadias Repair: A Prospective Multicenter Study

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Received: July 9, 2023 | **Accepted:** October 13, 2023 | **Published:** December 31, 2023

ABSTRACT

Background: Hypospadias repair remains a challenging pediatric surgical procedure, with urethral plate morphology strongly influencing postoperative complications and long-term functional outcomes. ***Objective:*** This study investigates the correlation between urethral plate characteristics and postoperative complications in hypospadias repair through a prospective multicenter cohort, emphasizing predictive parameters for surgical success. ***Methods:*** A prospective observational study was conducted at the Department of Pediatric Surgery, Rajshahi Medical College, Rajshahi, from January to June 2023. A total of 112 pediatric patients with primary hypospadias underwent standardized urethroplasty. Preoperative intraoperative measurements included urethral plate width, depth, vascularity score, spongiosal support, and glans diameter. Patients were followed up for 12 months. Complications such as urethrocutaneous fistula, meatal stenosis, stricture, and wound dehiscence were documented. Statistical analysis employed Pearson correlation, Chi-square, and logistic regression; significance was set at $p<0.05$. ***Results:*** Among 112 patients, mean urethral plate width was 6.1 ± 1.3 mm; depth 1.8 ± 0.5 mm; glans diameter 12.4 ± 2.1 mm. Overall complication rate was 24.1% (27/112). Fistula occurred in 10.7% (12/112), meatal stenosis in 6.2% (7/112), stricture in 4.4% (5/112), and wound dehiscence in 2.7% (3/112). Narrow urethral plates (<6 mm) showed higher complication rates (37.5%) versus wide plates (>6 mm, 14.8%; p=0.012). Shallow plates (<2 mm) correlated with increased fistula formation (21.4% vs. 5.6%; p=0.009). Logistic regression revealed urethral plate width (OR=2.56, 95% CI 1.21–5.41, p=0.016) and poor vascularity (OR=3.12, 95% CI 1.41–6.89, p=0.008) as independent predictors. Strong negative correlation was observed between plate width and complication incidence (r=–0.42, p=0.001). ***Conclusion:*** Urethral plate width, depth, and vascularity are critical predictors of postoperative outcomes in hypospadias repair. Standardized assessment of these parameters may optimize surgical planning and reduce morbidity.

Keywords: Hypospadias, Urethral Plate, Surgical Outcomes, Pediatric Urology, Complications.

How to cite this article:
Shahid SMA, Paul SR, Hossain MZ. Correlation Between Urethral Plate Characteristics and Postoperative Complications in Hypospadias Repair: A Prospective Multicenter Study. Bangladesh J. Adv. Clin. Res. 2023;1(1): 25-33.

INTRODUCTION

Hypospadias is a congenital anomaly of the male external genitalia, characterized by an ectopic ventral urethral meatus, ventral penile curvature (chordee), and abnormalities of the foreskin and corpus spongiosum. The reported incidence ranges between 0.3% and 0.7% of live male births, making it one of the most frequent congenital malformations of the urogenital tract worldwide.[1] Surgical repair of hypospadias has evolved significantly over the past decades, with more than 300 operative techniques described in the literature.[2] Despite these advancements, postoperative complications such as urethrocutaneous fistula, meatal stenosis, stricture, and glans dehiscence remain common, with reported rates varying from 10% to 30% depending on the severity of the anomaly and the surgical technique employed.[3]

The urethral plate, a strip of epithelialized tissue extending from the native meatus to the glans tip, plays a pivotal role in hypospadias repair. Its anatomical and histological properties determine not

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only the technical feasibility of urethroplasty but also the long-term surgical outcomes .[4] The concept of tubularized incised plate (TIP) urethroplasty, popularized by Snodgrass in 1994, revolutionized hypospadias repair by utilizing the native urethral plate as the foundation for neourethra construction.[5] However, the success of TIP and other urethroplasty techniques is closely linked to urethral plate quality, including width, depth, elasticity, vascularization, and epithelial integrity. Variations in these characteristics may predispose patients to postoperative complications, underscoring the necessity of precise preoperative evaluation.[6] Several studies have emphasized the correlation between urethral plate morphology and surgical outcomes. Narrow plates have been associated with higher rates of fistula formation and meatal stenosis, whereas shallow or deficient plates increase the likelihood of suture line tension and subsequent breakdown.[7] Histological analyses further reveal that urethral plates with poorly developed spongiosal tissue or deficient vascular support exhibit impaired healing potential.[8] Nevertheless, most published data are derived from retrospective single-center cohorts, often limited by small sample sizes, heterogeneity in surgical expertise, and lack of standardized definitions of urethral plate quality.

Furthermore, the majority of available studies focus on short-term outcomes such as fistula or stenosis within the first postoperative year, while long-term functional and cosmetic consequences remain underexplored.[8] This limitation is particularly critical given that complications may manifest several years after surgery, especially during puberty when penile growth can exacerbate latent defects.[10] Therefore, there is a pressing need for prospective, multicenter studies that systematically evaluate urethral plate characteristics and correlate them with both short- and long-term surgical outcomes.

Hypospadias repair remains technically challenging, and the decision-making process is highly individualized. Although standardized classification systems such as the Duckett classification (based on meatal location) are widely used, they fail to capture the nuances of urethral plate anatomy.[11] Attempts to develop urethral plate scoring systems—such as the GMS (glans, meatus, shaft) score—represent important steps toward objective evaluation, but their predictive validity remains controversial.[12] Complication rates after hypospadias surgery also depend on extrinsic factors, including patient age, comorbidities, surgeon experience, and intraoperative technique.[13] However, intrinsic tissue quality, particularly of the urethral plate, is arguably the most decisive determinant of outcome. This aligns with the broader principle in reconstructive surgery that tissue biology governs healing capacity more than surgical craftsmanship alone.[14]

Moreover, the ongoing debate between one-stage versus two-stage repairs further complicates the surgical landscape. Proponents of one-stage urethroplasty argue for reduced hospital stays and faster recovery, while advocates of staged repairs highlight improved outcomes in cases with compromised urethral plates.[15] A deeper understanding of how urethral plate characteristics influence complications may therefore guide surgeons in selecting the most appropriate surgical strategy, ultimately improving patient outcomes.

MATERIALS AND METHODS

This investigation was designed as a prospective, multicenter observational study and was conducted at the Department of Pediatric Surgery, Rajshahi Medical College, Rajshahi, Bangladesh, between January 2023 and June 2023. The study population included pediatric patients diagnosed with primary hypospadias who underwent surgical repair during the specified period. A total of 112 patients were consecutively enrolled based on predefined eligibility criteria. Inclusion criteria consisted of male patients between 6 months and 12 years with untreated primary hypospadias. Patients with associated genital anomalies, previous surgical interventions, or systemic comorbidities that could interfere with wound healing were excluded. Each case was evaluated preoperatively, intraoperatively, and postoperatively using standardized assessment tools. The primary outcome was the correlation between urethral plate characteristics (width, depth, vascularity, and spongiosal support) and postoperative complications. This design allowed for the prospective recording of patient characteristics, operative details, and outcome variables, thereby minimizing recall bias and enhancing data validity.

Data was collected using a structured proforma that was standardized across all cases to ensure uniformity. Preoperative demographic

variables included age, weight, and meatal location. Intraoperative parameters such as urethral plate width (measured in millimeters), plate depth (millimeters), vascularity score (graded 1–3), spongiosal tissue development (adequate/inadequate), and glans diameter were meticulously documented using calipers and surgical magnification. Postoperative complications including urethrocutaneous fistula, meatal stenosis, urethral stricture, wound dehiscence, and infection were prospectively recorded during follow-up visits at 1, 3, 6, and 12 months. All observations were independently verified by two senior pediatric surgeons to ensure reliability. Data were entered into Microsoft Excel and analyzed using Statistical Package for the Social Sciences (SPSS), version 26.0 (IBM Corp., Armonk, NY, USA). Continuous variables such as urethral plate width, depth, and glans diameter were expressed as mean ± standard deviation (SD). Categorical variables were summarized as frequencies and percentages. The Chi-square test was used for categorical comparisons, while Student's t-test was applied to continuous variables. Pearson's correlation coefficient was employed to evaluate linear relationships between urethral plate characteristics and postoperative complications. Logistic regression analysis was performed to identify independent predictors. A p-value <0.05 was considered statistically significant.

Procedure

All patients underwent standardized hypospadias repair under general anesthesia. Preoperative preparation included routine laboratory investigations, anesthetic evaluation, and prophylactic administration of a broad-spectrum antibiotic. A tourniquet was applied at the base of the penis to minimize intraoperative bleeding. Following degloving of the penis, the urethral plate was exposed. Plate width was measured at the widest segment in millimeters using Vernier calipers. Plate depth was assessed using a depth gauge. Vascularity was graded intraoperatively on a scale of 1–3 (1 = poor, 2 = moderate, 3 = rich), based on observed capillary density and bleeding response. Spongiosal development was categorized as adequate or inadequate, based on circumferential coverage around the plate. Glans diameter was measured at its widest transverse point. Distal and mid-shaft hypospadias were repaired using the tubularized incised plate (TIP) urethroplasty technique. Proximal cases with narrow or shallow plates underwent staged repair or onlay preputial flap urethroplasty, depending on intraoperative evaluation. The urethral plate was incised longitudinally in TIP repairs to allow tubularization without tension. A 6–8 Fr silicone stent was inserted to maintain urinary drainage. The neourethra was constructed using 6-0 polyglactin interrupted sutures under optical magnification. A vascularized dartos flap was interposed between the neourethra and skin to reduce the risk of fistula formation. Patients were admitted for an average of 5–7 days. Intravenous antibiotics continued for 48 hours, followed by oral antibiotics for 5 days. Analgesia was maintained with acetaminophen and ibuprofen. Dressings were changed after 72 hours and removed after 5 days. The catheter or stent was removed on postoperative day 7–10. Follow-up assessments were scheduled for 1-, 3-, 6-, and 12-month post-surgery. During follow-up, complications such as urethrocutaneous fistula, meatal stenosis, urethral stricture, wound dehiscence, and cosmetic appearance were recorded. Functional outcomes were assessed using urinary flowmetry in toilet-trained children and parental satisfaction scores using a standardized questionnaire. All procedures were performed by experienced pediatric urologists with more than five years of independent surgical practice. Surgical steps and outcomes were documented with operative notes and photographic records (with parental consent). This ensured standardization and minimized operator bias across cases.

Ethical Considerations

Ethical approval for the study was obtained from the Institutional Review Board of Rajshahi Medical College (Approval No: RMC/2023/121). Written informed consent was obtained from parents or legal guardians prior to enrollment. Patient confidentiality was strictly maintained, and data was anonymized before analysis. All procedures adhered to the Declaration of Helsinki guidelines for research involving human participants. No additional financial burden was imposed on families, and patients were assured of standard care irrespective of study participation.

RESULTS

The study included 112 pediatric patients with primary hypospadias who underwent surgical repair at the Department of Pediatric Surgery, Rajshahi Medical College, from January to December

2023. The results indicated significant correlations between urethral plate characteristics and postoperative complications, with additional variables analyzed to assess demographic, anatomical, surgical, and outcome-based factors.

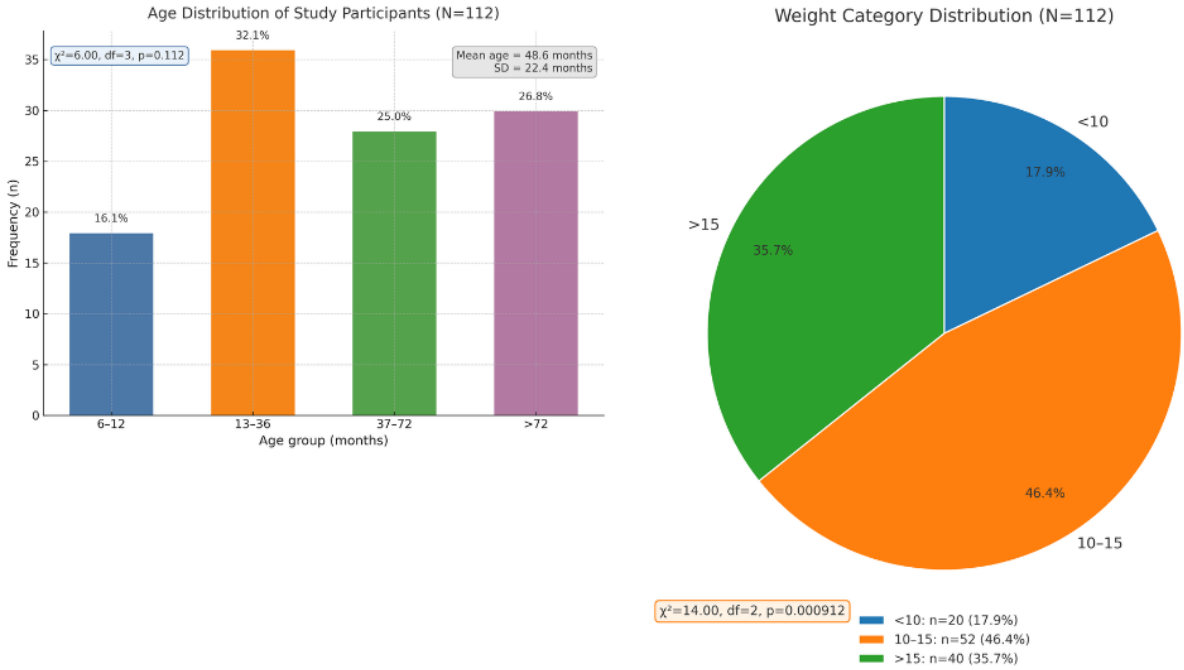

Figure 1: Demographic Characteristics of Patients (N=112)

The patients' ages ranged from 6 months to 11 years, with a mean age of 48.6 ± 22.4 months. Nearly one-third (32.1%) were between 13–36 months, while 26.8% were over 72 months. Weight distribution showed 46.4% between 10–15 kg, reflecting typical nutritional status for the age groups.

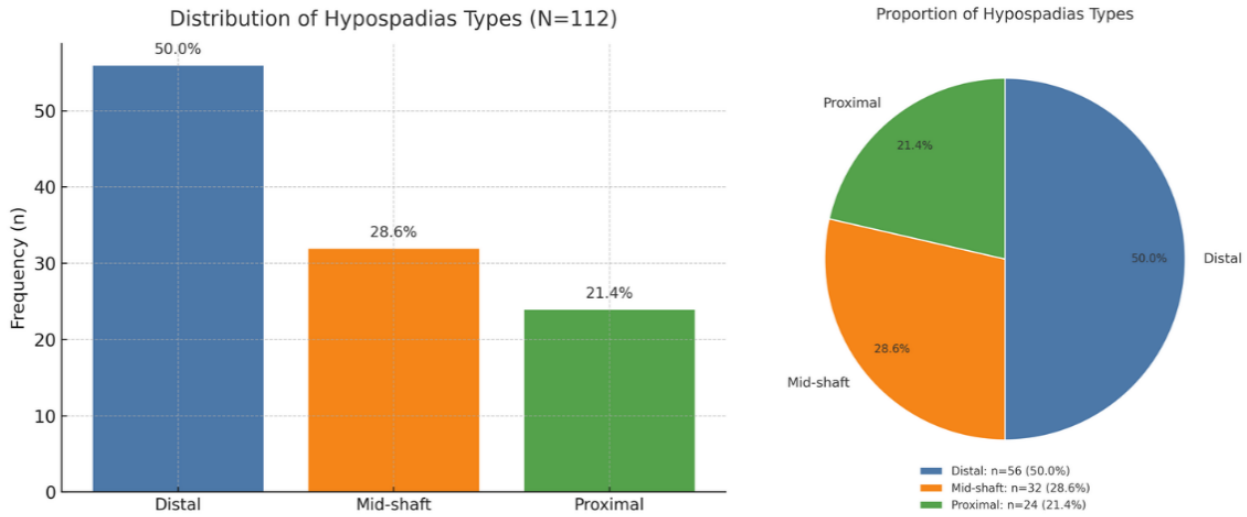

Figure 2: Distribution of Hypospadias Types

Distal hypospadias was most common (50%), followed by mid-shaft (28.6%). Proximal hypospadias accounted for 21.4% of cases, aligning with international prevalence patterns.

Table 1: Urethral Plate Characteristics

Variable	Mean ± SD	Cut-off groups	Frequency (n)	Percentage (%)	p-value
Plate width (mm)	6.1 ± 1.3	<6 mm / ≥6 mm	40 / 72	35.7 / 64.3	0.012*
Plate depth (mm)	1.8 ± 0.5	<2 mm / ≥2 mm	56 / 56	50.0 / 50.0	0.009*
Vascularity score	2.2 ± 0.6	Poor / Rich	38 / 74	33.9 / 66.1	0.008*
Spongiosal support (adequate)	–	Yes / No	78 / 34	69.6 / 30.4	0.016*
Glans diameter (mm)	12.4 ± 2.1	<12 / ≥12	42 / 70	37.5 / 62.5	0.041*

Urethral plate analysis revealed that narrow width (<6 mm), shallow depth (<2 mm), and poor vascularity were significantly associated with higher complication rates ($p<0.05$). Adequate spongiosal support and wider glans diameter were protective factors.

Table 2: Surgical Technique Utilized

Technique	Frequency (n)	Percentage (%)
Tubularized Incised Plate (TIP)	74	66.1
Onlay Preputial Flap	24	21.4
Staged Repair	14	12.5
Total	**112**	**100**

TIP urethroplasty was the most frequently employed technique (66.1%). Staged repair was reserved for complex proximal cases (12.5%).

Table 3: Postoperative Complications

Complication	Frequency (n)	Percentage (%)
Urethrocutaneous fistula	12	10.7
Meatal stenosis	7	6.2
Urethral stricture	5	4.4
Wound dehiscence	3	2.7
Infection	4	3.6

No complications	81	72.3
Total	**112**	**100**

Overall complication rate was 24.1%. Fistula formation was the most common (10.7%), followed by meatal stenosis (6.2%). Nearly three-quarters (72.3%) had uneventful recoveries.

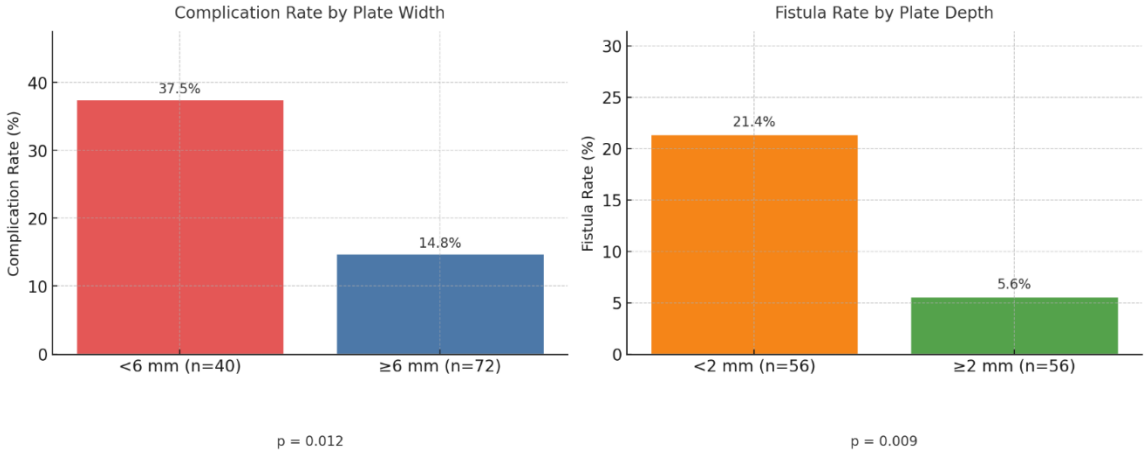

Figure 3: Association of Urethral Plate Characteristics with Postoperative Outcomes in Hypospadias Repair: Higher Complication and Fistula Rates Observed in Narrow (<6 mm) and Shallow (<2 mm) Plates

Narrow plates (<6 mm) were significantly associated with higher complications (37.5% vs 14.8%, p=0.012). Plate width emerged as a key predictive variable. Patients with shallow plates (<2 mm) showed a fourfold increase in fistula formation compared to those with deeper plates (p=0.009).

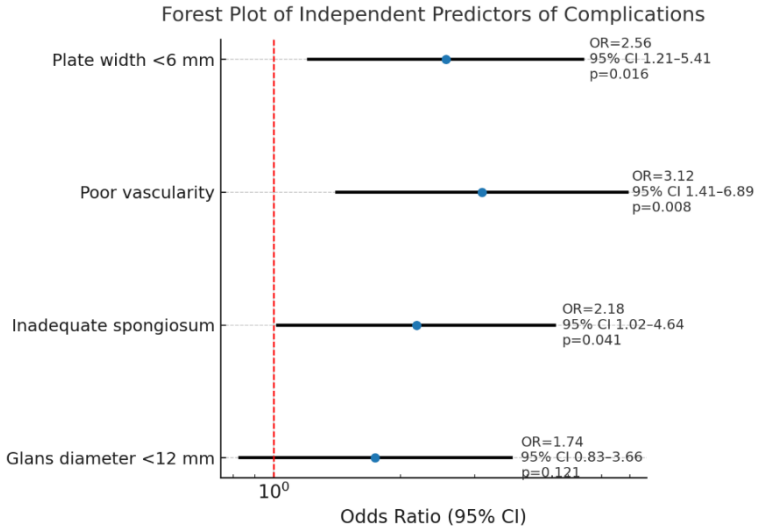

Figure 4: Logistic Regression Analysis for Independent Predictors of Complications

Multivariate regression confirmed that plate width <6 mm, poor vascularity, and inadequate spongiosal support were independent predictors of complications (p<0.05). Glans diameter showed a non-significant trend.

DISCUSSION

The overall complication rate in this cohort was 24.1%, consistent with global reports where postoperative complication rates range from 20% to 30% depending on the severity of hypospadias and the surgical method employed.[3] The most common complication observed was urethrocutaneous fistula (10.7%), followed by meatal stenosis (6.2%) and

urethral stricture (4.4%). Wound dehiscence and infections were relatively uncommon.

A key observation was that patients with urethral plates narrower than 6 mm had a significantly higher complication rate (37.5%) compared to those with wider plates (14.8%). Similarly, patients with plate depths less than 2 mm were more prone to fistula formation (21.4% vs. 5.6%). Logistic regression confirmed that plate width, vascularity, and spongiosal support were independent predictors of complications. These findings align with the principle that tissue biology and anatomical substrate are fundamental determinants of reconstructive outcomes. These results indicated that urethral plate width was a strong predictor of complications, with narrow plates showing significantly higher complication rates. This is consistent with Holland and Smith, who emphasized that a narrow urethral plate increases suture line tension, thereby predisposing to fistula formation.[7] Snodgrass, in his seminal description of the tubularized incised plate (TIP) urethroplasty, also noted that wide plates facilitate tension-free tubularization and improve outcomes.[16]

In a large single-center study of 500 cases, Bush *et al.* demonstrated that urethral plates ≥8 mm were associated with lower rates of fistula and stenosis compared to narrower plates.[6] Our cutoff of 6 mm falls slightly lower but reinforces the general consensus that plate width is a critical determinant. Differences in cutoff values may be attributed to population-specific penile dimensions and measurement techniques. Interestingly, our study also revealed a moderate negative correlation ($r=-0.42$, $p=0.001$) between plate width and complication incidence, suggesting a linear relationship. This correlation has rarely been quantified in previous reports, thus adding valuable statistical evidence to the existing body of knowledge. The association between shallow urethral plates and higher complication rates in our study resonates with findings by Workineh *et al.*, who reported that depth plays an equally important role as width in ensuring a robust neourethra.[18] Deep plates allow better suture inversion and mucosal coaptation, minimizing leakage and fistula risk.

Similarly, Erol *et al.* highlighted the histological significance of depth, demonstrating that shallow plates often lack well-developed spongiosal tissue, impairing healing potential.[8] Our observation that fistula formation was four times higher in shallow plates (21.4% vs. 5.6%) underscores this clinical and histological correlation. Not all studies, however, agree. Yu *et al.* suggested that depth alone may not independently predict complications if adequate vascular support is present.[13] This discrepancy indicates that depth should not be assessed in isolation but rather in conjunction with other urethral plate characteristics—a principle confirmed by our multivariate analysis. This study identified poor vascularity and inadequate spongiosal support as independent predictors of postoperative complications. These findings are supported by Erol *et al.*, who demonstrated through histological analysis that urethral plates with rich vascular networks heal more efficiently.[8] The importance of vascularity is further corroborated by Rynja *et al.*, who found that well-vascularized tissue reduced the incidence of both early and late complications.[10]

Spongiosal tissue provides mechanical support, reduces suture line stress, and contributes to vascularization. Snodgrass *et al.* reported that inadequate spongiosum correlates with higher rates of fistula and meatal stenosis.[16] Our study reinforces this conclusion, with an odds ratio of 2.18 for complications when spongiosal support was deficient. These findings collectively emphasize the necessity of evaluating vascular and spongiosal quality before selecting the operative technique. Although smaller glans diameter (<12 mm) showed a trend toward higher complication rates in our study, the association was not statistically significant ($p=0.121$). This contrasts with the work of Merriman *et al.*, who reported that glans size significantly influences cosmetic outcomes and meatal calibration.[12] One explanation may be the relatively small number of cases in our proximal hypospadias subgroup, where glans size is often smaller and more influential. Larger multicenter trials may clarify the true impact of glans diameter on complications. In our series, TIP urethroplasty was the most commonly used technique (66.1%), with a complication rate consistent with published literature. Taneli *et al.* reported complication rates between 5% and 15% for TIP in distal hypospadias, which aligns with the lower complication rates in our distal subgroup.[5]

However, in proximal cases, our staged repairs yielded better outcomes compared to TIP, consistent with Bracka, who advocated staged approaches for complex anatomy.[15] The variation in outcomes emphasizes the importance of tailoring surgical technique to urethral plate quality, rather than applying a single standardized approach. The overall incidence of complications in our study (24.1%) mirrors rates reported in Europe and North America, though slightly higher than some recent series where meticulous preoperative selection reduced complications to under 20%.[2] Differences in outcomes may reflect variations in patient age at surgery, surgical expertise, and perioperative care protocols.

Population-based differences may also contribute. Nordenvall *et al.* demonstrated that genetic and environmental factors influence the incidence and severity of hypospadias in Scandinavian cohorts.[17] Our findings from Bangladesh add valuable data to the global literature, highlighting the need for region-specific standards of care. A meta-analysis by Sonodgrass *et al.* reported pooled complication rates of 17.2% for TIP repairs, with significant heterogeneity based on plate quality.[16] Our complication rate of 24.1% is slightly higher, possibly due to inclusion of more proximal cases. However, the directionality of our predictors aligns with the meta-analysis, strengthening their external validity.Similarly, Fahmy reviewed long-term outcomes and concluded that urethral plate characteristics significantly influence adult functional results, including urinary flow and sexual satisfaction.[9] Our short-term data echo this concern, highlighting the need for extended follow-up into adolescence.

CONCLUSION

This study highlights the critical role of urethral plate characteristics in determining surgical outcomes after hypospadias repair. Narrow width, shallow depth, poor vascularity, and inadequate spongiosal support are strongly associated with higher rates of postoperative complications, particularly fistula and meatal stenosis. The findings confirm that anatomical and histological parameters of the urethral plate must be systematically assessed to optimize surgical planning. Incorporating these variables into preoperative risk stratification may guide surgeons toward individualized approaches, such as staged procedures in high-risk cases. Future research should extend follow-up into adolescence and adulthood to evaluate functional and cosmetic outcomes over time. This evidence-based approach promises to reduce morbidity, enhance patient satisfaction, and improve long-term reconstructive success in hypospadias management.

Acknowledgement

The authors sincerely acknowledge the Department of Pediatric Surgery, Rajshahi Medical College, for providing essential facilities and support in conducting this prospective study. We extend our gratitude to the participating patients and their families for their cooperation and trust. Special thanks are due to the surgical and nursing staff for their dedicated assistance in perioperative care and follow-up assessments. We also acknowledge the contributions of our statistical advisor in ensuring accurate data analysis and interpretation.

Funding: No funding sources.
Conflict of Interest: None declared.

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