

Development and evaluation of a low fidelity non-living bull's-penis model for simulated penile fracture repair

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Abstract

Objective Penile fracture is an uncommon urological emergency, limiting opportunities for trainees to gain operative experience. We developed and evaluated a novel low-cost, non-living bovine penile model for simulation training in penile fracture repair, assessing perceived realism, usefulness for training and impact on confidence.

Methods The model was evaluated during the 2023 and 2024 Advanced Urology Simulation Boot Camps. A bovine penis was modified to reproduce a corporal fracture and associated urethral injury, enabling trainees to practise surgical exploration and repair. Consultant faculty and delegates completed an anonymised post-course evaluation using five-point Likert scales. Responses were analysed descriptively and compared between faculty and delegates using two-tailed Mann–Whitney U tests with Holm adjustment for multiple comparisons.

Results Forty-eight participants completed the evaluation, comprising 4 consultant faculty and 44 delegates. Most delegates (36/44, 81.8%) had performed fewer than five penile fracture repairs, whereas 3/4 faculty had performed more than 20. Ratings were favourable across all measures of simulation realism, with corporal fracture realism receiving the strongest evaluation; 45/48 (93.8%) rated it realistic or very realistic. All participants agreed or strongly agreed that the model was useful for training, while 44/48 (91.7%) agreed or strongly agreed that their confidence in managing penile fracture had increased. No statistically significant differences between faculty and delegates remained following Holm adjustment across the questionnaire items.

Conclusions The bovine penile model demonstrated high perceived realism and usefulness for training, with comparable evaluations between faculty and delegates despite differences in previous operative experience. This low-cost biological model provides a practical simulation option for penile fracture repair where opportunities for operative training are limited.

Introduction

Penile fracture (PF) is an uncommon but important urological emergency resulting from rupture of the tunica albuginea and/or the corpus cavernosum during erection [1]. The injury most commonly occurs during vigorous sexual intercourse, which is due to excessive strain on the two outer, 'pressure', layers of the tunica albuginea [2]. Patients typically present with an audible "pop" sound, immediate loss of penile rigidity, penile pain, swelling, ecchymosis and penile deformity. Concomitant urethral injury may also occur and should be recognised promptly, as it influences surgical management [3].

Early surgical exploration and repair is the gold standard treatment for PF. Delayed intervention is associated with an increased risk of complications including penile curvature, erectile dysfunction, missed urethral injury, urethral stricture, and rarely, urethrocutaneous fistula [4]. Anatomically, the majority of tunical ruptures occur along the ventrolateral aspect of the corpus cavernosum, where the tunica albuginea is thinnest [5]. Surgical repair is commonly performed through either a circumferential

sub-coronal degloving, or a focussed transverse, incision over the fracture or, more commonly contemporaneously, a longitudinal, peno-scrotal, incision. Exposure of the fracture by division of Buck's fascia is followed by evacuation of the haematoma and closure of the tunical defect using interrupted, absorbable, sutures [6, 7].

Although prompt operative management is essential, PF is an uncommon emergency, resulting in limited operative exposure for many surgical trainees. This creates challenges in developing familiarity with the relevant surgical anatomy and acquisition of the technical skills required for effective repair so as to minimise longer-term complications. Simulation-based education is an increasingly important component of surgical training, providing trainees with opportunities to practise procedures, especially uncommon ones, in a safe, reproducible environment before needing to utilise those acquired skills clinically [8]. To date, few simulation models have been described specifically for PF repair. A validated circumcision simulator has previously been adapted to demonstrate the operative management of PF [9]. However, there remains a lack of high-fidelity models that accurately reproduce the tissue characteristics encountered during surgical exploration. Animal tissue models offer superior realism by allowing trainees to practice dissection, identification of a tunical defect and closure of the tunica albuginea under conditions that closely resemble those found during live surgery.

To address this educational gap, we developed a novel bull's-penis model for simulation-based training in PF repair. The aim of this study was to evaluate this new simulation model by assessing urological trainee's perceptions of the model's realism and usefulness for training, and to determine its impact on their confidence in managing PF clinically.

Methods

Setting

The model was trialled during an Advanced Urology Simulation Boot Camps (AUBCs), a national, four-day, simulation-rich educational programme designed for senior urology resident doctors in the UK approaching completion of training and transition to consultant practice [10]. The programme includes high-fidelity sub-specialty technical simulation, porcine and cadaveric procedural training and seeks to provide advanced clinical skills including those encountered in the emergency situation. The programme incorporated a 4-hour session using porcine simulation models for advanced emergency urological procedures, including penile emergencies such as PF. The penile fracture repair station formed part of this session. The station incorporated a structured briefing, hands-on simulation of the relevant operative steps, and faculty-led debriefing and feedback.

Educational need and learning objectives

The educational framework supported experiential, hands-on learning, allowing trainees to translate anatomical and operative knowledge into practical procedural skills. A 1:1 faculty-to-delegate ratio

enabled deliberate practice, individualised supervision and feedback during the practical sessions.

The intended learning outcomes were to enable participants to recognise the relevant surgical anatomy; obtain appropriate exposure of the penile shaft; identify the tunical defect and evacuate the simulated haematoma; identify and preserve the urethra and corpus spongiosum; and perform appropriate closure of the tunica albuginea. The station was also intended to improve confidence and preparedness for the clinical management of this uncommon emergency.

Simulation-based educational process

The programme provided delegates with pre-course educational material, including curated reading, videos and online learning modules on BJUI Knowledge, to establish a baseline level of knowledge before attending the practical sessions [11]. After a short 10-minute lecture, faculty-supported practical demonstration was used to introduce the operative technique before mentored participant practice. The intended sequence comprised:

- Exposure of the penile shaft
- Incision and dissection to expose the corporal structures and urethra
- Evacuation of the simulated haematoma
- Identification of the simulated fracture
- Assessment of the urethral injury
- Closure of the tunica albuginea with interrupted sutures
- Mobilisation of the urethral ends
- Repair of the urethra over a catheter

The station duration was 30 minutes. No formal competency assessment was done.

Development of the simulation model

The bull's penile body is composed of a dense fibroelastic tunica albuginea and trabeculae that surround the cavernous spaces of the corpus cavernosum penis (CCP). The penis is surrounded by elastic tissue, which is enveloped in hair-free skin. The glans, and distal part of the penis are free of elastic tissue. The corpus spongiosum surrounds the urethra which runs along its ventral surface [12].

The model was constructed using a bovine penis, with a simulated fracture, dressed with chicken skin (MedMeat Ltd - <https://www.wetlab.co.uk/default.aspx>).

The simulated fracture was created by a transverse incision across the ventral surface of the model using a 22 Swann Morton blade so as to divide the urethra and transect the ventral third of each corporal cylinder (Fig. 1).

A simulated blood clot was inserted into this incision. This model permitted direct incision, dissection and identification of the major penile structures, while allowing the trainee to identify a simulated tunical injury and evacuation of the simulated haematoma. Subsequently the tunica could be repaired with imbricating interrupted sutures and the urethra mobilised and repaired with interrupted absorbable suture material over a 12F Foley catheter (Fig. 2).

Outcome measures

A retrospective observational study was performed using anonymised post-course evaluation data collected during the 2023 and 2024 AUBCs.

Faculty and delegates completed an anonymised post-course evaluation questionnaire validated by the course directors and 2 andrology experts. Participant demographics, including training grade and previous operative experience in penile fracture repair, were recorded.

The questionnaire included eight items evaluating the perceived realism and educational utility of the model. It included the appearance of the whole model and fracture site, the realism of the feel and incision of the skin, corpora and corporal fracture site and the realism of suturing the penile fracture. The usefulness of the model for training, and its benefit in improving confidence in managing penile fracture were also assessed. For analysis, questionnaire items were categorised into simulation realism and educational utility.

Responses were recorded using five-point Likert scales. Appearance-related items were rated from very poor to very good, realism-related items from very unrealistic to very realistic, and educational utility items from strongly disagree to strongly agree.

Responses were evaluated overall and compared between consultant faculty and delegates to assess whether perceptions of the model differed between those delivering and receiving the simulation training. The validation procedure matched to Messick's framework [13].

Statistical analysis

Questionnaire responses were analysed as ordinal data and are presented using frequencies, percentages, medians and interquartile ranges (IQR). Responses were compared between consultant faculty and delegates using two-tailed Mann–Whitney U tests. Exact *P* values were calculated and adjusted for multiple comparisons across the eight questionnaire items using the Holm method. A two-sided Holm-adjusted *P* value of < 0.05 was considered statistically significant. Statistical analyses were performed using GraphPad Prism version 9.3.1 (GraphPad Software, San Diego, CA, USA).

Ethical considerations

Animal tissue used during the simulation was obtained from commercially available sources, and no animals were sacrificed specifically for the purposes of this study. As the study only involved retrospective analysis of anonymised educational evaluation data the St. James's University Hospital Research and Ethics Committee concluded that ethical approval was not necessary because the study did not include patients or identifiable clinical data.

Results

Participant characteristics

A total of 48 participants, comprising 4 faculty and 44 delegates completed the questionnaire following delivery/ participating in the penile fracture simulation station. Delegates represented a range of training grades, which most delegates were ST7 (Specialty Trainee Year 7) trainees (n = 33, 75.0%), and the remainder comprising specialty, associate specialist and specialist (SAS) doctors, fellows and ST6 trainees (Table 1). Previous operative exposure to penile fracture repair was greatest amongst faculty; with 3 (75.0%) consultants who had performed more than 20 repairs and the remaining 1 (25.0%) had performed 6–10. In comparison, 36 out of 44 (81.8%) delegates had performed fewer than 5 repairs (Table 1).

Table 1
Participant characteristics (n = 48)

Characteristic	n (%)
Respondent	
Consultant	4
Delegates	44
ST6	2 (4.5)
ST7	33 (75.0)
Fellow	3 (6.8)
SAS	6 (13.6)
Previous penile fracture repair	
Consultant	
6–10	1 (25.0)
> 20	3 (75.0)
Delegates	
< 5	36 (81.8)
6–10	6 (13.6)
11–15	1 (2.3)
> 20	1 (2.3)
ST6 = Specialty Trainee Year 6, ST7 = Specialty Trainee Year 7, SAS = Specialty, Associate Specialist, and Specialist doctors	

Participant evaluation of simulation realism

Participants reported a high degree of perceived anatomical and procedural realism across all evaluated domains of the simulation model (Table 2). The overall appearance of the model was rated as good or very good by 47 participants (97.9%), while the appearance of the simulated fracture site received corresponding ratings from 45 participants (93.8%). With respect to procedural realism, the fracture site on the corpora cavernosa achieved the highest ratings, with 45 participants (93.8%) considering it realistic or very realistic. Similarly, the appearance and tactile characteristics of the corpora cavernosa and suturing of the penile fracture were rated as realistic or very realistic by 40 (83.3%) and 43 (89.6%) participants, respectively. Skin incision and tissue handling were perceived as realistic or very realistic by 35 participants (72.9%).

Table 2
Participant evaluation of simulation realism (n = 48)

Outcome	Very poor	Poor	Neutral	Good	Very good
Overall model appearance	0	0	1 (2.1%)	21 (43.8%)	26 (54.2%)
Simulated fracture appearance	0	0	3 (6.3%)	17 (35.4%)	28 (58.3%)
Outcome	Very unrealistic	Unrealistic	Neutral	Realistic	Very realistic
Skin incision and tissue handling	0	2 (4.2%)	11 (22.9%)	20 (41.7%)	15 (31.3%)
Corporal fracture realism	0	2 (4.2%)	1 (2.1%)	30 (62.5%)	15 (31.3%)
Corporal appearance and feel	0	1 (2.1%)	7 (14.6%)	25 (52.1%)	15 (31.3%)
Tunical suturing realism	1 (2.1%)	2 (4.2%)	2 (4.2%)	26 (54.2%)	17 (35.4%)
Values are presented as frequency (%). Responses were recorded using five-point Likert scales, with appearance domains rated from <i>very poor</i> to <i>very good</i> and procedural realism domains rated from <i>very unrealistic</i> to <i>very realistic</i> .					

There was no statistically significant difference between consultant faculty and delegates in ratings of the simulation realism following Holm adjustment across all measured domains. Although faculty gave lower ratings for the appearance of the fracture site than delegates (median 3.5 vs 5.0; unadjusted $P = 0.032$), this difference did not remain statistically significant after adjustment (adjusted $P = 0.227$) (Supplementary Table 1).

Participant evaluation of educational utility

Participants reported a high perceived educational value of the model (Table 3). All participants agreed that the model would be useful for training, with 29 (60.4%) strongly agreeing and 19 (39.6%) agreeing. 44 participants (91.7%) agreed or strongly agreed that their confidence in the management of penile fracture had improved, comprising 23 (47.9%) who strongly agreed and 21 (43.8%) who agreed. Three participants (6.3%) reported a neutral response, while one participant (2.1%) strongly disagreed.

Table 3
Participant evaluation of educational utility (n = 48)

Outcome	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Model useful for training	0	0	0	19 (39.6%)	29 (60.4%)
Confidence in managing penile fracture	1 (2.1%)	0	3 (6.3%)	21 (43.8%)	23 (47.9%)
Values are presented as frequency (%). Responses were recorded using a five-point Likert scale ranging from <i>strongly disagree</i> to <i>strongly agree</i> .					

There was no statistically significant difference between consultant faculty and delegates in ratings of the model's usefulness for training following Holm adjustment. Faculty reported lower improvement in confidence than delegates (median 3.0 vs 4.5; unadjusted $P = 0.007$); however, this difference did not remain statistically significant after Holm adjustment for multiple comparisons across eight questionnaire items (adjusted $P = 0.058$) (Supplementary Table 1).

Discussion

Penile fracture is an uncommon urological emergency for which operative experience, particularly during early training can become limited [1]. This study describes the development and evaluation of a novel bull's-penis simulation model for penile fracture repair. Participants reported consistently favourable evaluations of the model. Despite substantially greater operative experience among consultant faculty, their assessment of the model was broadly comparable with that of delegates, with no statistically significant differences following adjustment for multiple comparisons. These findings support the potential role of the model as an adjunct to simulation-based urological training. Given the limited operative exposure associated with penile fracture repair, simulation offers a practical adjunct to surgical training [8].

Validity Evidence Within the Messick Framework

Anatomical fidelity and limitation of the bovine penile tissue

The strongest evidence in the present study relates to content, as there are important similarities between bovine and human penile anatomy that support the model's educational use. Both contain paired corpora cavernosa, a corpus spongiosum containing the penile urethra, and a tunica albuginea surrounding the erectile tissues. In addition, the model permits simulation of procedurally relevant aspects of penile fracture repair, including tissue dissection, tunical identification and handling, management of a simulated haematoma and suturing. The urethra and corpus spongiosum have an anatomical relationship that is essentially the same in both humans and bulls: the corpus spongiosum

functions as a concentric vascular cylinder that completely encloses and shields the urethra. The bovine penile shaft therefore provides recognisable tissue planes and structures relevant to the operative exposure and repair of a corporal injury. However, the anatomy is not identical. The bull has a fibroelastic penis, in contrast to the predominantly musculo-cavernous human penis. In the bull, the corpus cavernosum contains a greater proportion of fibrous tissue and contributes to structural rigidity, whereas human erection depends substantially on vascular expansion of the corpora cavernosa. The bovine model should be regarded as a procedural simulation model rather than an exact anatomical imitation. Its value lies in providing realistic biological tissue for practising the operative sequence, tissue handling, identification of key structures and repair technique. The model has also been used successfully in low- and middle-income countries [14].

Response-process evidence is provided by the participants' direct experience of the model and their assessment of its realism and educational utility, although formal cognitive interviewing or assessment of how participants interpreted individual questionnaire items was not undertaken. The high ratings provided by trainees and experienced faculty provide preliminary evidence of perceived realism and educational utility. These findings support that the participants considered the model sufficiently realistic and useful for the intended educational task. The inclusion of experienced faculty is particularly relevant because expert appraisal provides an additional perspective on whether the model reproduces features considered important for the procedure. Evidence regarding the internal structure of the bovine penile model is limited, as the questionnaire utilised was mainly for evaluation purposes. Furthermore, the lack of comparative simulation models or established external measures of technical performance makes the study's conclusions about relationships with other variables preliminary. Currently, the results only reflect perceived educational benefits and increased confidence, without evaluating objective skill acquisition, retention, transfer to clinical practice, or patient outcomes. Therefore, it is essential to view these results as a preliminary contribution to the validity argument for the model rather than as comprehensive validation. These findings should nevertheless be interpreted as evidence of perceived realism and educational acceptability, rather than evidence that the model improves operative performance. Subjective ratings cannot establish skill acquisition, technical mastery, skill retention or transfer of learning to clinical practice.

The cost of the model from the supplier (MedMeat Ltd - <https://www.wetlab.co.uk/default.aspx>) with bilateral simulated fractures was £9.50 per trainee. The basic instrument kit (scalpel and blades, fine and toothed dissecting forceps, Metzenbaum scissors, small artery/haemostatic forceps, needle holder, swabs, and retractors) was used for the simulation repair.

Existing simulation models

A wholly synthetic PF simulation model has previously been described. Four experts and twenty-two urology trainees took part in its assessment. 59% of trainees (n = 13) strongly agreed that the model was helpful for training, and 75% of experts agreed. Both trainees (68%, n = 14) and faculty (75%) thought the penile fracture appeared good and 23% of participants rated the model's ability to simulate the task realistically as excellent, while 64% rated it as good. Following that simulation, trainees reported having a

high level of confidence in their ability to handle a similar situation clinically. The urethra and fascial planes were the primary issues mentioned [9]. Whilst that synthetic model, costing approximately £200, demonstrated favourable educational outcomes, the authors acknowledged limitations relating to tissue realism and handling characteristics.

Bullock et al [15] used a fresh-frozen cadaveric model for simulation training in PF repair and reported significantly improved confidence. Unfortunately, the authors did not report the cost of the model.

Limitations

This study has several limitations. First, it represents a single-institution experience and relies on subjective measures of realism and educational utility. Second, the small consultant faculty sample limits the faculty-delegate comparison, which should be considered exploratory. Third, participants may have provided favourable responses because they were aware that the model was developed as an educational innovation or because they perceived that positive feedback would be valued by the faculty. Ceiling effects may also have limited the ability of the questionnaire to discriminate between different aspects of the model if most participants selected the highest response categories. Importantly, self-reported confidence should not be equated with objective performance. Learners may report increased confidence without demonstrating a corresponding improvement in technical ability.

Future studies should evaluate skill acquisition and retention, reproducibility across institutions, and whether training using this new simulation model translates into improved operative performance during clinical PF repair, further validating its role as an educational tool for this purpose. Fourth, biological variability is an additional limitation. Finally, the study's retrospective design introduces the possibility of selection and information bias and limits the ability to determine causality.

The present study should therefore be regarded as an initial evaluation of the bovine penile model (Class 1 b and c) [16]. A logical next stage would be prospective validation using objective technical-performance measures, ideally with pre- and post-training assessment and, where feasible, a comparator group using an established synthetic or alternative biological model. Longitudinal assessment would also be required to determine whether skills acquired during simulation are retained and subsequently transferred to clinical practice.

Conclusion

The bull's-penis model demonstrated high perceived realism and educational value, with comparable evaluations between faculty and delegates despite differences in previous operative experience. Most importantly, the cost of this model is inexpensive and can be utilised with commonly available materials for surgical simulation training. These findings support its use as a simulation model for training in penile fracture repair.

Declarations

Authors contributions

Study concept and design: CSB, TC

Acquisition of data: LC, MHE, MJ, PG, HWH

Analysis and interpretation of data: HWH

Drafting of the manuscript: HWH, SRP, MJ, CSB, MHE

Critical revision of the manuscript for important intellectual content: SRP, MJ, CSB, MHE

Statistical analysis: HWH

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Administrative, technical, or material support:

Supervision: SRP, MJ, CSB, MHE

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Informed consent - All participants in this study provided written informed consent.

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Figures



Figure 1

Longitudinal incision of the bull's penis with transverse incision through the corpora cavernosa and the urethra. The cut urethra is adjacent to the forceps.

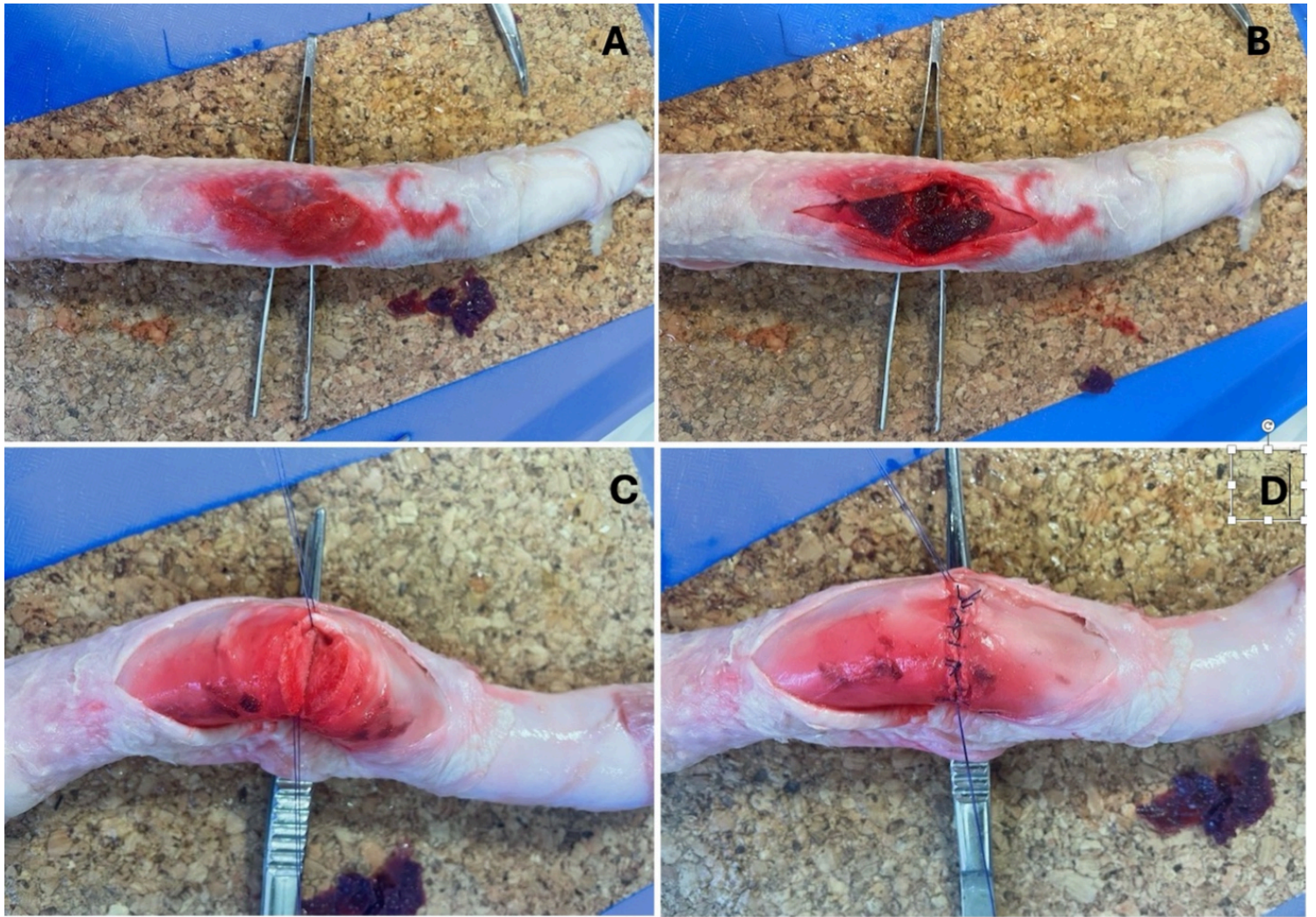


Figure 2

Simulated penile fracture with subcutaneous haematoma (A), Haematoma within the corpora after skin incision (B), penile fracture site before (C), and after repair (D).