Anatomically accurate 3D-printed models are effective simulators for RIRS training, improving procedural performance, instrument handling, and trainee confidence, with strong potential to shorten the learning curve and enhance patient safety.

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Introduction

Three-dimensional (3D) printing technologies are increasingly applied in medicine, enabling precise reproduction of complex anatomical structures. In urology, training for advanced endoscopic procedures such as retrograde intrarenal surgery (RIRS) requires a high level of accuracy and manual skill, often hindered by limited access to real surgical cases.

Anatomically accurate 3D-printed models offer a safe and effective solution for skill acquisition without involving patients.

Aim: evaluate the feasibility and effectiveness of anatomically accurate 3D-printed models as simulators for RIRS training.

Methods

Patient CT scans were used to generate 3D reconstructions of the upper urinary tract.

Kidneys, pelvicalyceal systems, and ureters were printed using composite materials.

Simulated stones (artificial) were placed in the models.

Ex vivo testing with flexible ureterorenoscopes and thulium fiber laser.

Pilot educational study: 30 trainees (residents and junior urologists) divided into:

Training group – 1 hour/day for 7 days.

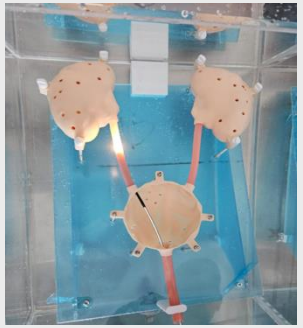
Control group – no simulator training.

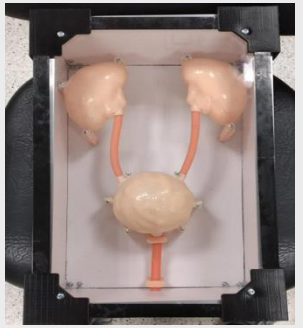
Outcomes: procedural time, instrument handling, self-reported confidence.

Results

The 3D-printed simulator accurately replicated key anatomical and procedural steps of RIRS.

Ex vivo validation confirmed anatomical fidelity and suitability for real calculi and laser lithotripsy. The printed components are currently being refined into an integrated upper urinary tract unit for enhanced training realism.





- Mean fragmentation time for 10 mm calculi – 30 min (trained) vs 45 min (control), $p < 0.05$.
- Trained participants demonstrated smoother instrument manipulation, higher procedural efficiency, and significantly increased confidence.
- Additional findings: 75% of trainees in the simulator group reported increased interest in further developing their skills in endourology.