SIMULATOR PRODUCTION USING 3D PRINTING

As shown in Fig. 1, the three-dimensional (3D) printing simulator was manufactured through five processes as described below:

1. **Segmenting**
   The basement of simulator’s kidney anatomy was extracted by segmenting computed tomography Digital Imaging and Communications in Medicine (DICOM) images using MEDIP (Medical IP, Seoul, Korea), a reconstruction and rendering program for segmentation, with Stereolithograph (STL) file extension (Fig. 1A).

   Structures of renal major and minor calyces, renal pelvis, and ureters were primarily rendered through segmentation and transformed into a form suitable for training based on anatomical information. The authors in this article confirmed kidney structures several times through 'Visual printing'. This is an efficient real-time confirmation platform between urologists and Medical IP. Once a web address of a rendered object was uploaded to the server, it was sent to the authors (Fig. 1B). The authors could then annotate directly on the web page via text or drawing to give feedback using a smartphone or a computer.

2. **3D Mesh modeling**
   After the anatomy was confirmed, an acrylic plate was designed equipped with a tubing line and a water tank for application of a water circulation system (Fig. 1C). Classification and Boolean operation were performed using a modeling program for no overlapping part of the designed STL file. We then extracted each STL file and uploaded it to GrabCAD (Stratasys 3D Printer Slicing program, Stratasys, Eden prairie, MN, USA) (Fig. 1D).

   For each STL file of each structure transferred to GrabCAD, the desired material and color transparency were independently selected. Then a transparent clear resin was used to the exterior so that the inside structure could be seen with naked eyes from the outside. In the case of calyces and pelvis, a pink translucent material (Vero clear plus Vero magenta v mixture, Stratasys, MN, USA) was used (Fig. 1E).

3. **3D printing**
   After selecting all materials, 3D printing was performed using a Polyjet printer J750 (Stratasys) as shown in Fig. 1F.

4. **Post-processing**
   The supporter on the printed material was removed. Locking rings were attached onto both sides to fasten anterior and posterior sides. The sling ring was then fixed with silicon on the bottom to prevent leakage while water circulated. A mold of sling ring was printed out of acrylonitrile butadiene styrene copolymers using FlashForge (Zhejiang Flashforge 3D Technology Co., Ltd., Zhejiang Province, China), a Fused Deposition Modeling type printer (Fig 1G). After that, fumigation was performed to remove the lattice-shaped hard support and smoothen the surface. After assembling the mold according to the position, a silicon of Shore A10 was injected and molded.

5. **Assembly**
   The completed module was fixed to a custom-made acrylic plate and connected to the tube line. The whole procedure was finished by connecting a water pump to the end of the inlet tube and installing it in a water tank.

6. **Design and the structure of the simulator**
   Because the module had its own water circulation and water-proof systems, it only needed an endoscopy system for retrograde intrarenal surgery (RIRS) training. The tank and kidneys were filled with water and circulated with an electronic pump to create similar environment to the real practice of RIRS. LithoVue™ (Boston Scientific, Marlborough, MA, USA) was used for experiments to reduce total volume of the training set as shown in Fig. 2E. The kidneys can be split into two anterior and posterior pieces and stone fragments can be put inside the calices. The training of stone fragmentation and basketing technique is available.