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Advanced Surgical Training Models for Wrist Surgery

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Globally, surgical exposure for the trainee has become challenging due to changes in shift patterns, increasing medicolegal issues and the recognition of burnout. Simulation models are a crucial adjunct for the development of arthroscopic skills and open procedures. Advanced anatomically precise 3D-printed wrist models are used in our workshops. The models have pathological lesions within, allowing a range of arthroscopic and open procedures to be performed. Pathology can be ordered on-demand. Arthroscopic and open procedures can be performed, including fracture fixation and arthroplasty. For effective teaching, we use a lab-based environment with basic arthroscopic and open equipment and implants available. We use a specific structure in which to teach trainees, including pre-course material, videos, demonstrations, practice and feedback. Advanced surgical training models for wrist surgery allow for safe, repetitive surgical training to allow the trainee to accelerate their learning curve.

Level of Evidence: Level V (Therapeutic)

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INTRODUCTION

Surgical training has historically been the apprenticeship model. The 'see one, do one, teach one' philosophy has been a standard approach in most orthopaedic training programmes. Most training programmes in surgical specialties are based on case numbers, with a minimum number for 'core' procedures – usually involving open surgery. The learning curve for surgery, particularly arthroscopy, is steep, however, and exposure to arthroscopic surgery can be limited throughout training. Other challenges to the modern trainee include a global shift in work patterns with a reduction in training hours, part-time training and greater awareness of the avoidance of burnout.

Saw bones and cadavers have been traditionally used as a training aid, but each have their limitations. Cadavers have high costs in provision, transport and disposal. There is a risk of disease transmission, and there may be legislative or cultural barriers to their use. Saw bones lack soft tissues and are not suitable for arthroscopic training. Advanced training models have several advantages, as they are anatomically accurate, give realistic haptic feedback and avoid the barriers and risks with the use of cadavers. This technique article will outline the use of advanced training models for wrist surgery.

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SURGICAL TECHNIQUE

Surgical Training Models: The neurocognitive concepts of arthroscopic training are complex. The expert arthroscopist will have skills such as advanced visuospatial working memory, visuospatial ability and automaticity. They will apply less executive function when performing complex arthroscopic surgery. These specific cognitive functions can be practiced and improved with rehearsal and practice in a training lab.[1]

For our training labs, we have utilised wrist models manufactured by Fusetec. These are designed with precise anatomical features up to an accuracy of 0.014 mm, including carpal bones, distal radius, ulna, extrinsic radiocarpal and intrinsic ligaments and TFCC. Extensor and

flexor tendons are included with their anatomically correct spatial relationships. The wrists are 'pre-tractioned'; hence, they do not require further traction. This simplifies set-up in the lab. The wrist component is 'operable'. The forearm and digits are applied if required. The 'clear skin' model allows an appreciation of the surface anatomy and the deeper structures (Fig. 1). The models are radio-opaque with a trabecular structure – this makes them compatible for plain radiographs and CT. This has been valuable in creating a medical education presentation that is used as part of the teaching platform. Additionally, the trainee surgeon can use conventional fluoroscopy to assess the quality of the reduction and position of internal fixation.

Pathology on Demand: Pathology is provided to enable the wrist surgeon to perform several surgical techniques (Video 1). The standard models provided have a pre-existing tear of the TFCC, and tear of the scapholunate ligament. Pathology can be pre-requested in many different configurations, however. The bones are 'pre-fractured' with a single fracture line through the scaphoid and an intra-articular distal radius fracture. When the outer 'periosteum' is breached, then the fracture becomes visualised. The fracture fragments can be manipulated and reduced using open or arthroscopic instruments. Fluoroscopic-guided fixation can then be performed.

These models allow for accurate arthroscopic techniques to be practiced, together with arthroscopic-assisted open approaches in the context of distal radius management and TFCC foveal repairs, e.g. (Fig. 2). 'On-demand' pathology can be requested depending on the technical aims of the workshop and competency requirements of the surgeon. The models are mobile, and do not require set up in a formal facility. This allows small group practice at convenient locations such as an office or teaching room. As opposed to cadavers, no wet lab is required, and there are no risks of transmissible diseases. No expensive cleaning equipment such as autoclaving is required. There are no regulatory burdens to the use of these models and the design can be customised for training.

Optimising Training in Wrist Arthroscopy: To optimise the ability to learn and perfect wrist arthroscopy, a lab-based approach with advanced wrist models is an important tool to augment exposure in the operating theatre. The advantages of this approach include:

- Surgical practice, stress-free, with a controlled learning curve
- Interaction with other learners and supervisors
- Removal of time-pressure
- Non-threatening environment
- Specific techniques can be repeated

The Lab: Instruments used include basic wrist arthroscopy equipment, needle for localisation and suture passage, scalpels, fine artery forceps and basic

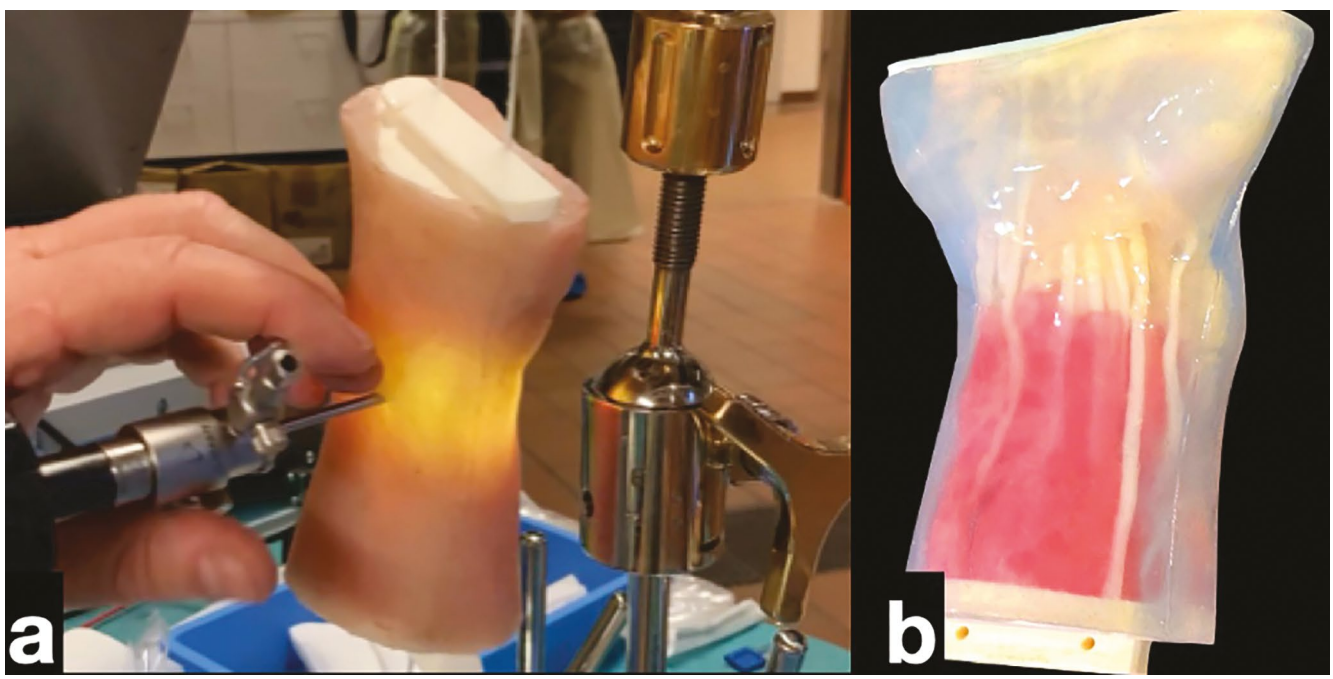

Fig. 1. Demonstration of the wrist units, both normal and 'clear skin'. (a) Tractioned wrist model without digits. (b) 'Clear skin' model.

sutures. For more complex procedures, suture anchors can be utilised. Arthroscopy towers are required, and arthroscopic shavers can be used for resection procedures (wafer, styloid tip resection, etc.). In general, a 2.7 mm arthroscope is sufficient. Smaller diameter scopes, such as a nanoscope (Arthrex) or nano-needle (Arthrex), can also be used. Distal radius sets and headless compression screws are used for fracture fixation. Fluoroscopy can be used. This is important when performing arthroscopic-assisted arthrodesis procedures or fracture fixation of the scaphoid or distal radius (Fig. 3). The wrist models are positioned on a Mayo table. For arthroscopy set-up, cord is used – which is extended onto a hook and drip stand. The lower cord can be secured to the table around a device such as a clamp. The models do not require fluid insufflation; hence, arthroscopy is 'dry'. Intermittent saline irrigation on a syringe can be used if necessary to remove debris.

Procedures Arthroscopic: Routine arthroscopic procedures or arthroscopic-open procedures which can be practiced include:

- TFCC repair: 'Inside-out-', 'Outside in' and arthroscopic-assisted foveal repairs can be performed (Fig. 2).
- SLL repair: The models are created with a scapholunate ligament avulsion from the lunate. Arthroscopic capsuloligamentous repair can easily be performed,[2] as can other suture anchor techniques.

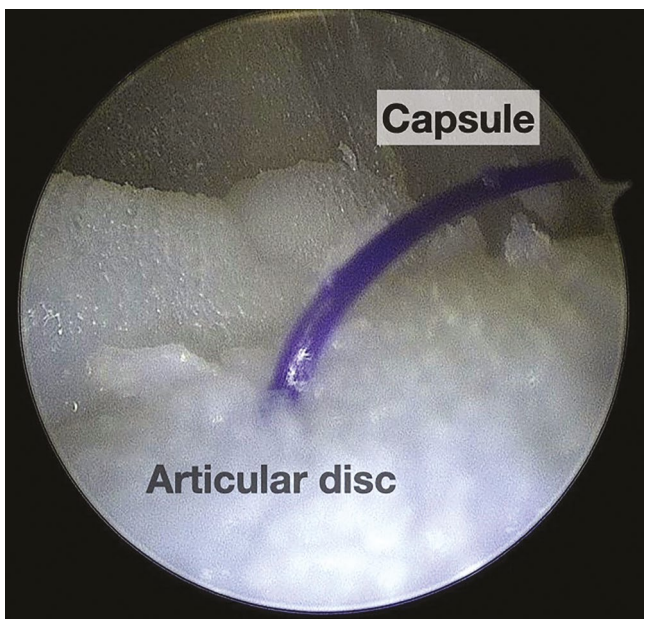

Fig. 2. Arthroscopic peripheral TFCC repair.

- Arthroscopic-assisted scaphoid fixation: Viewing from MCU or MCR portal allows visualisation of the scaphoid fracture line. A further portal can be created in line with the fracture (distal to MCR) where the fracture can be probed. Arthro-assisted pinning or screw fixation can be achieved using fluoroscopic guidance.
- Arthro-assisted distal radius fracture fixation: The pre-fractured specimens allow the trainee to probe and reduce the fracture fragments. Fluoroscopy can be used to confirm implant placement.
- Resection procedures: Resection procedures that can be practiced include wafer procedure for ulnocarpal abutment, resection of the proximal hamate for HALT syndrome, resection of the lunate for Kienbock disease.
- Open procedures: Accurate volar and dorsal anatomy allow for open procedures to be practiced. For example, scapholunate ligament repair, scaphoid ORIF, distal radius fracture fixation, limited wrist fusion, osteotomies of the distal radius and ulna and distal ulna salvage procedures. Arthroplasty can also be performed (Fig. 3).

Planning a Workshop: When planning a wrist surgery workshop, first define the reason or requirement for the course. Define the learners and the learning aims. Objectives should be 'SMART' (specific, measurable, achievable, relevant and time bound).[3] Realistic goals should be set, depending on the defined cohort of trainees and the time allowed. For the first course, allow 'catch-up' time during breaks and at the start and end of the day. Ensure that there is sufficient faculty and industry support. We believe two delegates per model is sufficient to ensure that each delegate gets enough exposure throughout the course/session. Each lab should utilise a chairperson and/or course organiser, educational advisor, administrator, AV and IT coordinator and ideally a Treasurer.

Model of Training: We have carried out several courses using the wrist models and have received valuable feedback from delegates and faculty. The model of training we use includes:

- Provide pre-workshop videos and reading material.
- Define learning goals – focussed session on a single procedure.
- Presentation on the concepts – applied anatomy, exposure, procedure and preventing complications.
- Video of technique.
- Demonstration by instructor.

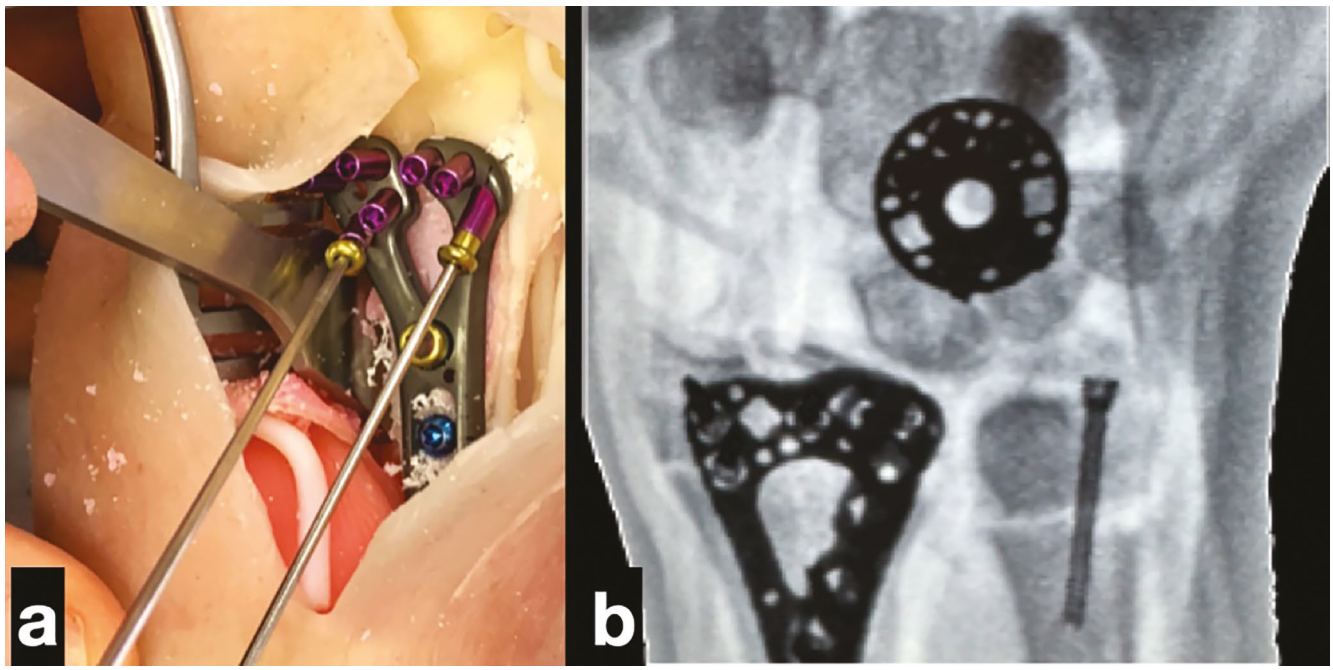

Fig. 3. Open distal radius plate fixation (a) with the radio-opaque material of the model visible under fluoroscopy (b).

- Trainees work together and outline their plan; what they expect will be difficult.
- Trainees perform the procedure together.
- Group debrief – trainees create a PPT of their case including photos of imaging, exposure, present how did it go and what was difficult. Teach the others from their experiences.
- Group discussion.
- Next group of trainees presents their case.

DISCUSSION

Moving forward, wrist models should become refined, reusable and robust enough to allow repetitive practice of multiple surgical techniques. For models to be fully reusable, materials should be tough enough to allow insertion and removal of sutures and implants, multiple times. Replaceable parts are now available, which can be changed by the trainee. These 'mini cassettes' can be swapped in and out for wrist arthroscopy, thumb CMC joint arthroplasty and wrist arthroplasty. These models can then become validated by surgical programmes as a training tool and used for certification. When certified on an advanced surgical model, the supervised trainee can then transition his practice into the operating theatre. This will allow the trainee to accelerate their learning curve before independent surgical practice.

Advanced training models for wrist surgery continue to evolve. Current designs have become anatomically precise, portable and provide pathology 'on-demand'. Accurate haptic feedback accelerates the learning curve for the trainee arthroscopist. Open procedures can be performed on the same model. The models avoid some of the ethical issues of the use of cadavers and are of lower cost.

REFERENCES

1. Testa EJ, Green A. Neurocognitive concepts of arthroscopic surgical training. *JBJS Rev*. 2024;12(7):eCollection. https://doi.org/10.2106/JBJS.RVW.24.00058
2. de Villeneuve Bargemon JB, Mathoulin C, Jaloux C, et al. Wide arthroscopic dorsal capsuloligamentous repair in patients with severe scapholunate instability. *Bone Joint J*. 2023;105:307–314. https://doi.org/10.1302/0301-620X.105B3.BJJ-2022-0906.R1
3. Akan HK, Espregueira-Mendes Jo, Karahan M. *Motor Skills Training in Orthopedic Sports Medicine*. 1st ed. Springer Berlin Heidelberg;2017.

Supplementary Files: The supplementary files for this manuscript (listed as follows) are online only and can be accessed at http://www.worldscientific.com/doi/suppl/10.1142/S242483552597001X

Video 1: Advanced Manufacturing Surgical Training Models.