Abandoning functional fixedness: creative solutions in fracture surgery using widely available materials.

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Abstract

Purpose Functional fixedness is a well-known phenomenon in psychology and design, which may be described as the perception that a tool is linked to only one function. This article presents a collection of examples of the use of materials and instruments in fracture surgery, abandoning functional fixedness. The aim is to demonstrate practical examples on how surgical tools are being used effectively out of their "fixed" purpose. The most important goal is to reach surgeons that operate in remote areas in which there is a lack of surgical instruments and materials, and surgeons are forced to abandon functional fixedness in surgical problem-solving.

Design/methodology/approach A series of examples of surgical ingenuity was gathered by the authors during more than a decade of orthopaedic and general surgery training. Subsequently a Pubmed search was performed to evaluate if these tips and tricks could be substantiated by international literature.
Several surgical tips and tricks that may be used in surgery preparation, exposure, fracture reduction and fixation (use of Kirschner wires, plate and screw fixation and intramedullary fracture fixation) are presented.

Originality/value The surgical tips and tricks that are presented in this article may be useful anywhere, especially in resource-limited settings. As surgeons, it is useful to be aware of the concept of functional fixedness, and to realize the value of abandoning it and be creative, if possible. Parallels with non-medical professions like the automotive industry may be inspiring.
Keywords – fracture surgery, creativity in surgery, technical tips, technical surgery trick, functional fixedness
Paper type – Academic Research Paper

1 Introduction

Over the past few decades, surgical techniques in fracture surgery have evolved enormously. There is a rise in new techniques such as robotics-assisted surgery, three dimensional preoperative planning and 3D-printed patient specific materials. In many surgical specialties, including orthopaedic trauma surgery, implants and instruments have become more complex and are more often specifically designed for a certain surgical procedure. Many of these highly specific surgical tools and instruments may improve the surgical technique and patient outcomes.

Worldwide, over five billion people do not have access to safe and affordable surgical care when needed[20]. Complex innovations as described above are often not at hand in low-resource settings. Surgeons may be forced to use creative solutions if medical instruments fail or if expensive surgical solutions are inaccessible. Trauma is a leading cause of death and disability, and sharing knowledge in this field is of great importance.

"Functional fixedness" is the believe that a certain object may only be used in one functional role[23].

This article presents a collection of examples of the use of basic materials and instruments in fracture surgery out of their "fixed" context. In some situations, specific surgical tools may thus become unnecessary, reducing costs and materials.

The most important goal of this article is to reach surgeons that operate in remote areas in which there is a lack of surgical instruments and materials, and where surgeons are forced to abandon functional fixedness in surgical problem-solving. With the Christmas spirit in mind, we hope this article will be first in a series of medical professionals sharing their tips and tricks worldwide to help colleagues in settings where resources are limited.

2 Material and methods

This article comprises of a personal collection of surgical creative solutions that were encountered by the first author of this article, LCL, in a decade of experience in orthopaedic surgery.

For each example of surgical creativity, a Pubmed (Medline) search was performed to assess if there was any scientific evidence for the technique and to reveal surgical pearls and pitfalls.

Several orthopaedic surgeons, plastic surgeons and trauma surgeons were thereby consulted to contribute their experience to this article.

All images were drawn by LCL using Procreate, version 5.2.6, Savage Interactive Pty Ltd.

3 Results

Several articles could be found that describe technical or surgical tips in the field of fracture surgery. A selection was made of the most relevant and reproducible examples, that may be useful in remote settings.

3.1 Exsanguination and surgery preparation

A rubber band for a finger slauch may be created by cutting a finger of a rubber glove and hence create a ring of rubber. By rolling the “ring” down the finger, some exsanguination already takes place. Note that it is important to tension the band with a clamp and cut it before starting surgery as shown in the last image so it will not be forgotten after surgery (figure 1). An alternative to this trick is to cut of only the top of the finger that will be operated on off of the glove, and slide the hand of the patient into the glove. This way, the other fingers are covered during surgery and the remnant of the cut rubber finger may be slided down as a slauch.

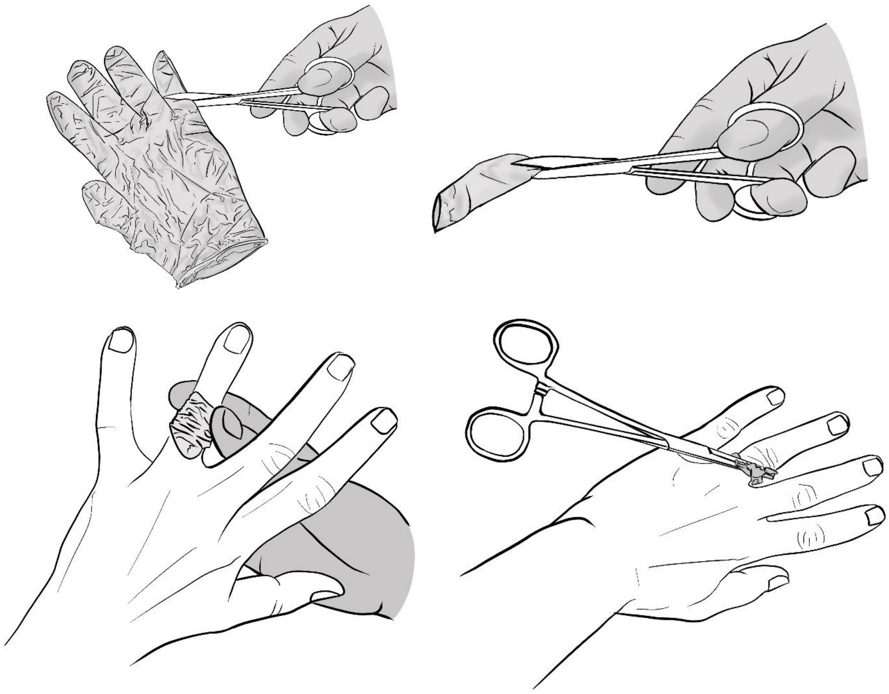

Figure 1: creating a slauch for finger surgery using a rubber band made from a sterile glove. Make sure to cut the band and remove it after surgery.

If no pneumatic upper tourniquets are available, a blood pressure band may be inflated to a significant pressure, whilst clamps are placed on the deflation tubes to preserve pneumatic pressure. Make sure to protect the tubes from damaging by placing a gauze underneath the clamp.

An alternative is to create a slauch by wrapping a (rubber) band around the upper arm or leg, apply some extra turns to secure the slauch and then open the bandage distally at the desired level of surgery. Care should be taken so that removal is still possible safely; an option to remove a tourniquet that was applied with this technique, is to cut it over a plastic card so the skin underneath remains intact.

In shoulder or elbow surgery, a gauze that is tied loosely under the surgical area may catch blood and prevent it from dripping down. It may also be used to prevent the arm from slipping during surgery.

3.2 Exposure

Hohman retractors are often used to lever the tissues around a fracture out of the surgical field and thus create a good exposure of the bone. Some of the tricks to use Hohman retractors that are widely used are summed up in figure 2.

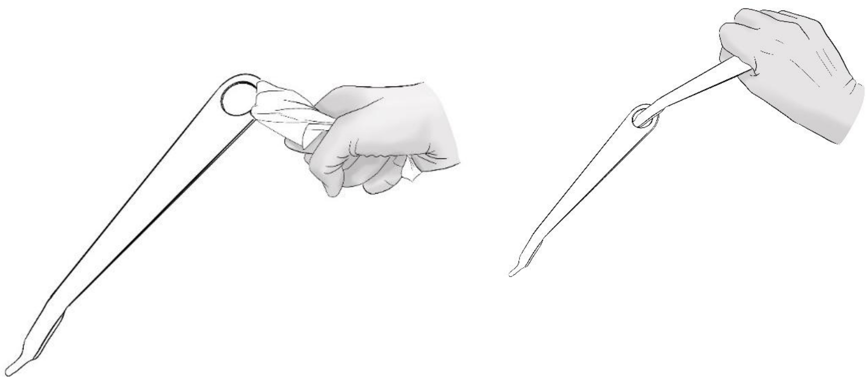

Figure 2: More efficient use of Hohman retractors. 1. By using a gauze to pull the Hohman down, less force is required in more natural poses. Variants tot this trick are tying a knot in the gauze, clipping a forceps to the gauze or pasting the gauze to drapes or the operation table. 2. Using a second Hohman to lever so less force is required and distance to the surgical field in increased.

A vast amount of retractors, forceps and clamps exists, which are not always necessary to reach a successful exposure. Thereby, it is important to realize that retraction of skin or nerves may lead to traction injury, or the tip of the retractor may cause damage to underlying tissue due to pressure. The calcaneus is an example, many examples of wound problems have been described following traction to the skin. This may be prevented by drilling Kirschner wires (K-wires) into the calcaneal bone and bend them so that the skin may be folded out of the way (figure 4). A variant to this trick is the use of sutures that pull the skin away.

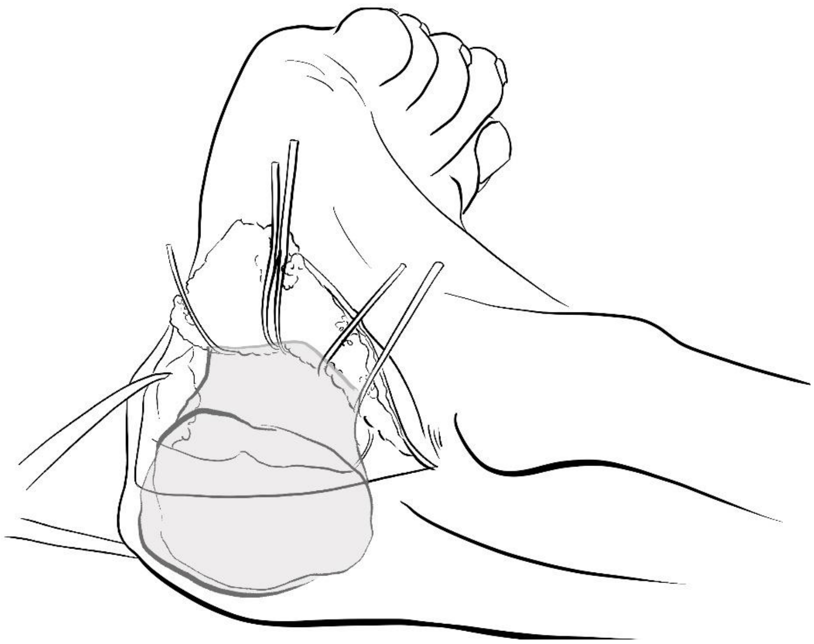

Figure 4: Using Kirschner wires drilled into the calcaneus bone, and bent to fold the skin back without traction injury to the skin or subcutaneous tissue.

K-wires may also be bent so that they have a small hook. This way, it may function as a one-toothed hook that may be used to obtain exposure in fine surgery. A simple needle may be used in the same way.

Kitchen garments may also be helpful in wound exposure. A household spoon may for example be used to obtain adequate exposure in the posterior knee, and the curve of the spoon may help guide stitches and prevent neurovascular damage[19].

3.3 Fracture reduction

In external fixator placement, care should be taken to place the pins while anticipating on future plate fixation. Another tip is to anticipate the direction of the pins with the desired reduction move (for example converging/diverging for varus/valgus effect[6]. The pins that are present may thereby be used to apply a distractor device that aids fracture reduction during definitive fixation.

K-wires may also be helpful in fracture reduction. A threaded K-wire may be drilled into a part of the fracture; which may then be connected to a T-handle that may help manipulate fracture fragments (figure 5). A K-wire that is placed through the bone as such, may also be used to confirm intramedullary position of the guidewire or nail[2] metal-on-metal ticking may be felt and heard), or function as a temporary substitute for a Poller screw[11,15,17,22]. A pin-puller may be used in the same fashion. In smaller fractures, the same principle may be applied using common K-wires, always taking caution not to damage surrounding neurovascular structures.

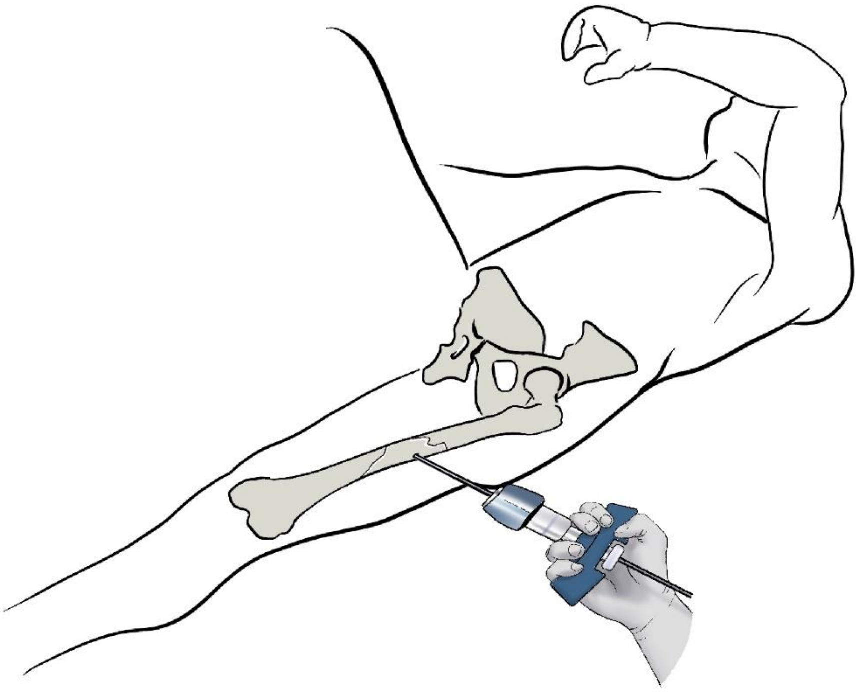

Figure 5. A threaded K-wire may be drilled into a part of the fracture; which may then be connected to a T-handle that may help manipulate fracture fragments

In intramedullary fixation of the femur, the threaded K-wire that is provided for gaining access to the femur may be drilled into a fracture fragment and then connected to the T-handle that is available for guidewire handling. The fracture fragment may then be manipulated and fracture reduction may be facilitated. While drilling the K-wire, caution should be taken not to damage surrounding neurovascular structures.

A K-wire that is placed as demonstrated in figure 5 may also confirm intramedullary position of the guidewire (metal-on-metal ticking sound when guidewire is progressed) or function as a Poller screw.

Intramedullary use of K-wires may support fracture reduction, if the K-wire tip is bent to strut a fracture of the fifth metacarpal[26] or the radial neck[4].

3.4 K-wire fixation

K-wires or pins are steel wires that are traditionally drilled into the bone to pin one bone fragment to another. Many creative ways of use are known, some common general principles of K-wire-use involve levering[1], joystick techniques or pre-drilling with a simple needle to prevent K-wire slippage[7]. No advanced instrumentation is required for bending K-wires; a surgical marker from which the marker felt has been removed, may function as a lever when slid over the wire.

A commonly seen principle in arthrodesis surgery in the distal interphalangeal joint is a technique that is referred to as the inside-out principle[7], where the osteotomy is held open, the K-wire is then drilled into the bone, in an antegrade direction, while the surgeon is able to ensure K-wire position in the center of the bone. Then, the K-wire is cut at the level of the osteotomy and advanced retrogradely into the proximal bone fragment. This way, the surgeon can observe intramedullary positioning of the Kwire, and hence the risk of missing the bone is nullified.

3.5 Cerclage wires

In situations where expensive suture retrievers are absent, small cerclage wires or transosseous sutures may be easily placed through bone using a large venous catheter (figure 6). The same principle may be applied in cannulated screws[5]. A large diameter needle may also be loaded into the K-wire drill bit and drilled like a K-wire, after which a cerclage or suture wire may be easily feeded through the bone.

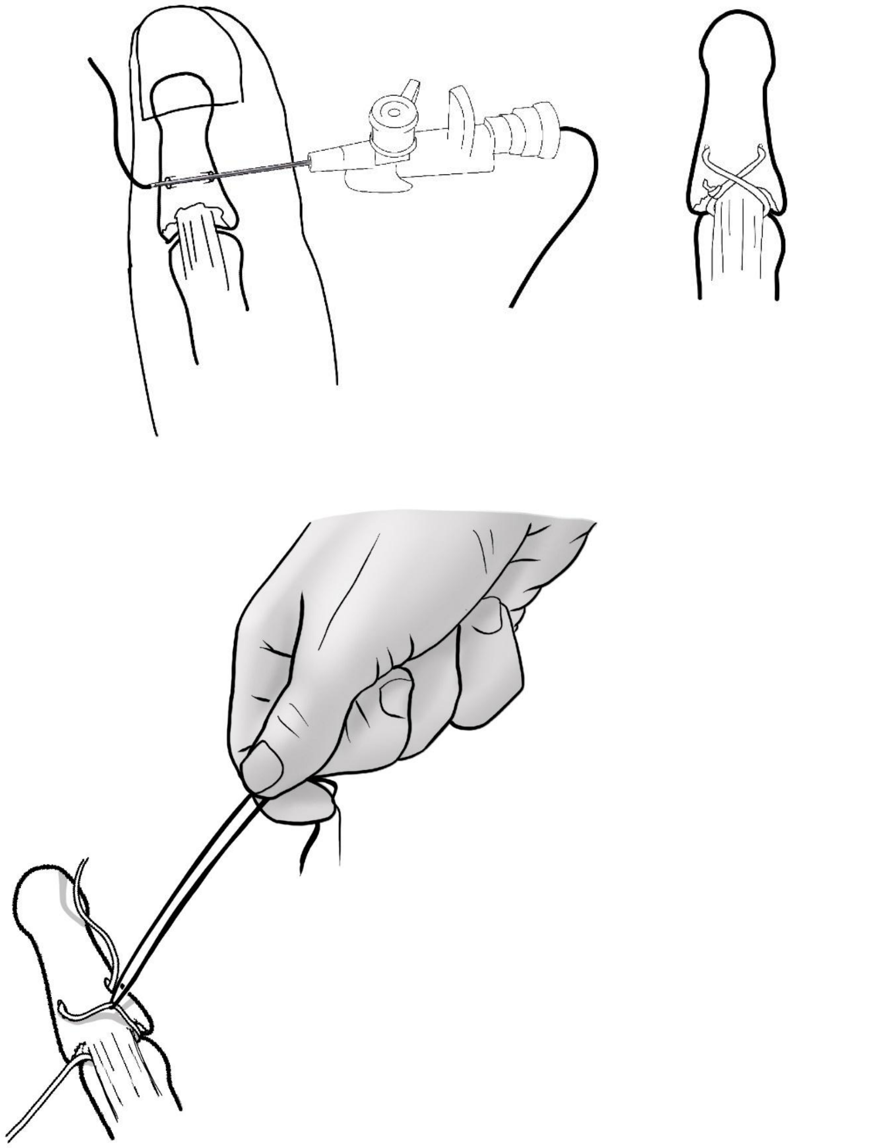

Figure 6. Above: A large catheter for intravenous infusion may be used as a guide for passing wires or cerclages through bone. Below: a suture wire passed underneath a cerclage wire may be used to maneuver the cerclage in the desired position without damaging the cerclage wire.

It may be challenging to manipulate cerclage wires, since they may break when they are grasped with a clamp. A trick to provide this from happening but to be able to shift the wire around, is to pull a suture wire underneath the cerclage wire and pull the wire to maneuver the cerclage into its desired position.

Cerclage wires and needles that need to be pulled (for example drain needles), may be grasped safely with the non-cutting part of scissors without damaging the material (figure 7).

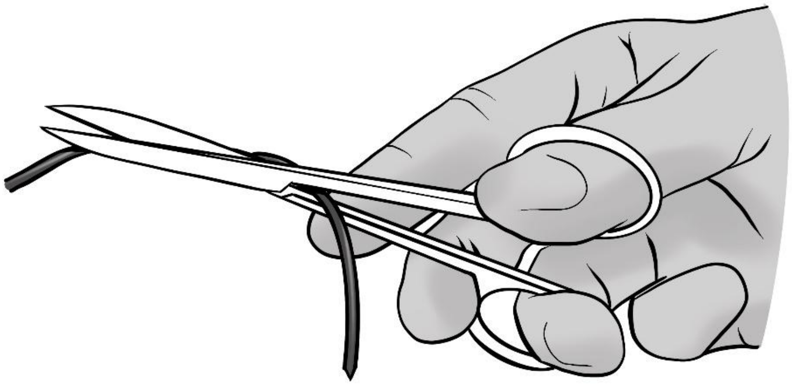

Figure 7. Pulling needles or drains without risk of injury or damage to materials is possible using the non-cutting part of scissors.

3.6 Plate fixations

Hook plates may be used to provide compression to a bony fragment. They may easily be created by the surgeon by cutting and bending a simple Drittelrohr plate[16], which may be useful in Mallet finger surgery[24], Trochanter major avulsions[21], distal lateral malleolus fractures[16] or avulsions of the tuberculum majus[27].

A simple Drittelrohr plate may still be providing fracture compression if the plate; a commonly used technique is excentric drilling. The amount of compression can however be better controlled using a trick in which the plate is first fixed to one of the fracture fragments, then a diagonally aimed Kwire is placed in the hole most distal to the fixed fragment (figure 8.1), and then bent away from the screws (figure 8.2). The effect is a sliding movement of the plate that compresses the bone fragments together (figure 8.3). The remaining screws may now be drilled and placed, maintaining the compression. Note that the K-wire may wobble when it is extracted, oscillated drilling is advised.

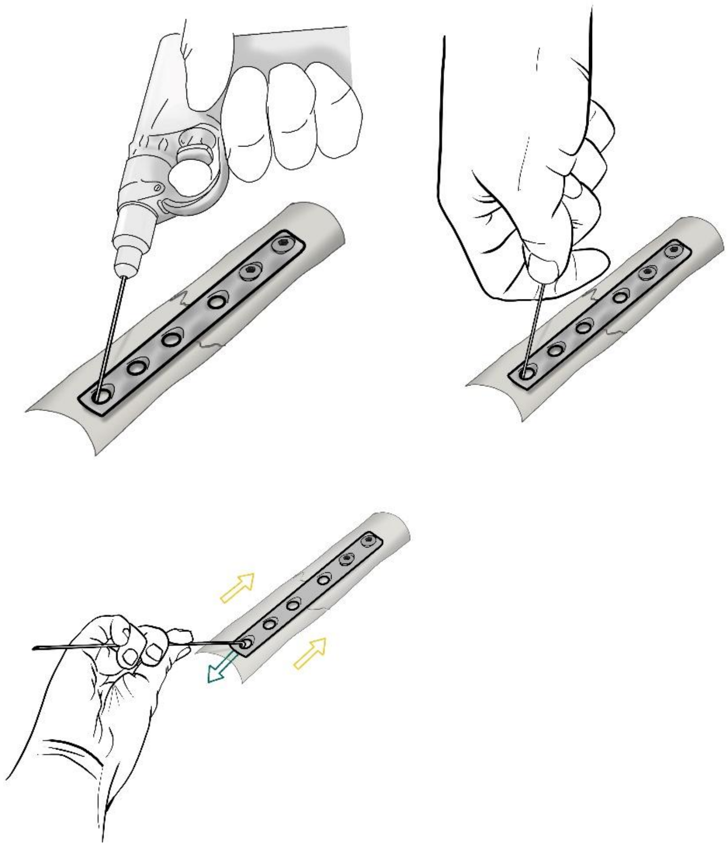

Figure 8. Using a K-wire to provide compression: 1. Following screw fixation of the plate to the bone with at least two screws, a K-wire is drilled into the bone in a diagonal direction. 2 and 3. The K-wire is bent away from the fracture, thus providing compression in a controlled way. This technique may be an alternative to excentric drilling, but yields more control and allows correction.

External fixators for finger injury may be costly or difficult to obtain. If there is an option to use bone cement; a ventilator tube filled with cement that holds K-wires may yield a solution[12]. An alternative is drilling the K-wires through a syringe[28].

3.7 Tips for removal of surgical hardware

If a screw head is damaged, removal may be challenging[10]. A glove that is firmly pressed between screw head and screw driver may help to obtain better grip. Heating a screw using the diathermic knife loosens the screw and facilitates removal. In the absence of fluoroscopy, screws may preoperatively be marked with ultrasound and a drop of methylene blue[25]. Another option is to perform a preoperative X-ray with paperclips taped to the skin.

Washers may be easier to remove using a specific technique that steers the washer onto the thread of the screw[8].

If an intramedullary nail is broken, introduction of double ball tipped guidewires may be a solution to enable nail removal[13]. Potentially this is also a solution for nail removal in low-resource settings.

3.8 Splinting and casts

Reusable splints can often be made of PVC pipe that is softened in an oven. As the fumes may harm your health this should always be done in a well ventilated environment and thus preferable in the open air. A splint for a finger or a nail fracture may be cut from the plastic from a syringe that is then taped to the finger.

Plaster of low quality may be enhanced in strength by adding triangular shapes to prevent it from breaking while using as few material as possible.

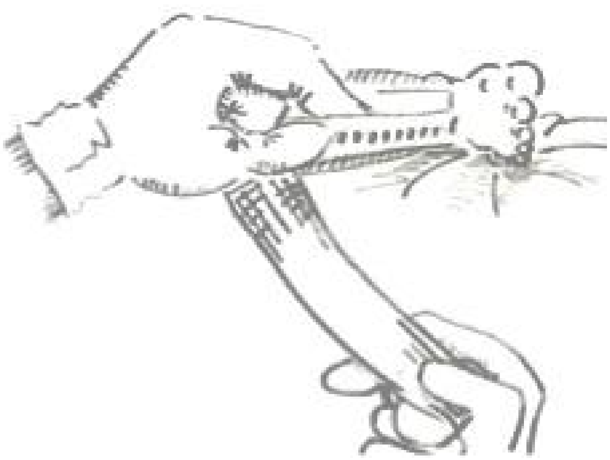

Figure 9. Plaster may be enhanced in strength by molding triangular shapes to prevent it from breaking.

4 Discussion and conclusions

When surgical materials are used "outside their fixed function", it is always important to realize that the quality and safety of surgery should not be jeopardized. K-wires may break or migrate, and when they are bent they may be difficult to remove. In exposure, it is always important to be aware of surrounding neurovascular structures and to make sure not to cause any injury when drilling K-wires or when positioning retractors. It is always the surgeon's responsibility to ensure the safety of the patient and to prevent complications during surgery. The solutions that are presented in this article should not replace a decent training in surgery, and a disclaimer is in place to prevent complications or suboptimal surgical results.

The surgical profession is learnt through a teacher-apprentice model based on copying behavior. It is thereby important to comply with protocols and adhere to golden standards. However, it is only through "non-copying behavior" that innovative thinking may arise[3]. Improvisation is needed to address unexpected situations in the operation room[18], which may increase knowledge and technical skills. It is hence important that surgeons are aware of the concept of functional fixedness, and to realize the value of abandoning it, if possible.

Surgical techniques are evolving rapidly and it is common that a surgical procedure has a " technical guide" that instructs the surgeon how to use the materials that are often designed specifically for one type of procedure. If surgeons are able to find multiple purposes for a single tool, material costs and environmental impact may be reduced.

Surgeons may also be more inspired by industries outside the medical field. Some tricks for screw removal that are known from the automotive industry for example, may also be useful in surgery. The "general purpose puller" that is described by a manual for maintenance of classic cars enables pulling and twisting a resistant screw in one move[9]. It bares great resemblance to a device that is used in surgery for non-tapping screws that are difficult to remove. While sterilizing garage tools for surgical use is strongly discouraged, it would be interesting to expand our horizons and learn from other professions that show overlap in material use.

Especially in low income settings, these surgical tips and tricks may be useful. For medical doctors with a specialization in tropical medicine, King's primary surgery is still a commonly used reference book, even though it dates from 1987[14]. It yields a wittily and humorously written overview of inventive solutions to common trauma surgery pathology and challenges in remote settings. Many new materials and techniques have since been introduced to the surgical theatre. It would thus be interesting if this article may pose as a first step to collect surgical technical tips from all over the world, that may then be of use for colleagues in remote settings.

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