Best Stay Out of That Joint!

In residency we are often given valuable advice by our mentors, such as, “stay out of that joint!” Orthopaedic surgeons spend years learning techniques to avoid problems, such as joint penetration, that can result in patient injury. After all, “I will abstain from all intentional wrong-doing and harm” is part of the Hippocratic oath. Eventually though, most of us will venture into places we later regret, such as a ‘joint’.

Unintentional joint penetration can be an error in technique. Usually, though, it is because the proper tools to prevent joint penetration simply do not exist. This limitation in surgical drills and tools leads to thousands of unintentional intra-articular penetrations by drill bits and screws every day in operating rooms around the world. *Unfortunately, one drill bit plunge or misplaced screw can change a patient’s life forever.*

Joint penetration, whether instantaneous and dynamic, as with the *dynamic plunge* of a drill bit or wire depth-gauge, or the *static plunge* of a protruding screw, should be *avoidable* with the proper technology. Existing drills, c-arms and other x-ray technology, even when used concurrently, are inadequate. Or, as stated by Tweet et al, “No combination of imaging allowed detection of all intra-articular screws.”

Figure 1, to the right, shows a screw protruding into the elbow joint after a routine open reduction and internal fixation surgery. This adverse outcome is the result of a *dynamic plunge* from the drill bit and wire depth-gauge followed by a *static plunge* due to the mismeasured screw.

Orthopaedic literature is replete with examples of these inadvertent joint penetrations during juxta-articular screw placements. This type of injury can lead to joint pain, stiffness, grinding, and premature arthritis. Joint penetration by drill bits and screws can cause, or worsen, post-traumatic arthritis.

Besides penetrating joints, drill bits and screws can penetrate into other vital structures in close proximity to bones, such as nerves, arteries, tendons, spinal cord and even the brain. We can do better. Bone drilling and measuring equipment needs to evolve.

Present surgical drills are very similar to the drills that are sold at the local hardware store. These are the surgical drills available in operating rooms today. Therefore, surgeons must rely upon other ways to prevent plunge injuries. Surgeons use safe zones and their extensive knowledge of regional anatomy to avoid dangerous situations. They also rely upon intra-operative imaging to try to
avoid joint penetration and other plunge related injuries. Because of patient variability in size, shape and bony anatomy, the surgeon, patient and operating room personnel often are exposed to significant amounts of radiation as the surgeon tries to ensure patient safety using multiple combinations of imaging studies.

While x-ray imaging, surgeons have to constantly be aware of the potential for image distortion while quickly and accurately interpreting the paths and depths of their drill bits and screws. Recent studies have suggested that 2D c-arm imagery is unreliable, even in the most common fracture, that of the distal radius. A new 3D c-arm study shows continued difficulties with image resolution, joint penetration, detection of joint penetration, and overall utility of the more advanced 3D c-arm. The increase in radiation exposure with this new imaging technology is also documented.

Generalizable anatomic principles do help to guide the surgeon. For example, in a spherical joint like the hip or shoulder, surgeons are taught that if the screw tip is seen in the joint on any of the c-arm images on the convex side, or round side, the screw is in the joint. Conversely, if the screw tip is seen out of the joint on any of the c-arm images on the concave side, or socket side, the screw is out of the joint.

Unfortunately, most joints are not simple ball and socket joints. Most joints have varied and angular geometries. For example, a recent study on the ankle shows the variance in patient anatomy and the difficulties with using imaging and wire depth-gauges to avoid screw misplacements, especially juxta-articular placements. Or, as Giordano et al, put it, “The routine intraoperative radiographic imaging of the ankle is difficult to interpret and unreliable for detection of intra-articular hardware penetration.”

This is such a difficult problem that for nearly every joint there are c-arm imaging studies that are continually defining new techniques to confirm safe juxta-articular screw placements. These techniques usually involve images done after the screw has been placed and therefore too late to prevent the initial damage associated with joint penetration. Many of these techniques require extreme positioning of the patient’s extremity by the surgeon, therefore, the surgeon remains alongside the c-arm beam, exposing him to additional radiation.

When the operation is done, the surgeon will perform a range-of-motion exam to detect “grinding” of the joint from mal-positioned bone fragments or misplaced screws. Of course, this is a subtle test and it is unreliable. Even worse, if the test is positive, and the surgeon detects grinding in the joint, the damage has already been done.
Unintentional joint penetration is a serious problem. How can surgeons avoid it? And, how can they also avoid the problem of plunge in general?

Smart Medical Devices, Inc. has developed the SMARTdrill® - a handheld robotic drill with variable depth control. The SMARTdrill® solves this decades old problem with plunge. The SMARTdrill® prevents plunge, measures depth, measures drilling energy and calculates bone density all in real-time.13

Figure 3, to the right, shows a CT scan of a Sawbones™ juxta-articular bone model. The SMARTdrill® was used to drill up to, and into, the distal cortex without penetration into the theoretical joint space.

Neither fluoroscopy nor x-ray imaging was used during the drilling. The surgeon simply followed the progress of the drill bit on the SMARTdrill® graphical user interface (“GUI”). On the GUI the drill bit starts at zero and its progress is reported as power vs. distance. The depth of the distal cortex penetration as measured by the CT scan, 5.3 mm, agreed with the SMARTdrill® GUI measurement of ~5.3 mm and a caliper measurement of 5.3 mm.

The test shown in Figure 4, above, is from a test block similar to the one in Figure 3. It was terminated just as the tip of the drill bit penetrated the distal cortex. Penetration of the distal cortex was about 0.4 mm. This model demonstrates that the SMARTdrill® can be used not only to detect the cortex and prevent plunge, but also to measure the widths of the cortices and the medullary bone.

To view the GUI in Figure 4 being produced in real-time as drilling occurs, visit: http://www.smartmeddevices.com/variable-depth-control-vdc-drilling/

The SMARTdrill® allows the surgeon to drill without x-ray, but still with full 3D situational awareness. The SMARTdrill® prevents the plunge and provides instantaneous depth data. In addition, it provides density information and drilling energy throughout the process. Most importantly, the drilling energy correlates with the POS of the implanted screws.14 The SMARTdrill® is a truly revolutionary tool, designed by surgeons for surgeons.
REFERENCES:


