Internal headless compression screw method for 4-corner fusion

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Abstract Midcarpal fusion and scaphoidectomy, also referred to as 4 corner fusion, is a common treatment for post-traumatic wrist arthritis, either scapholunate advanced collapse or scaphoid nonunion advanced collapse. Historically fixation for the fusion mass was performed with Kirschner wires. Bone graft was sometimes taken from the discarded scaphoid. More recently, articles have focused on the method of fixation and its potential role in causing high nonunion rates or specific complications. This article offers readers a reliable technique for midcarpal fusion designed to minimize both nonunion and hardware related complications.

Keywords Midcarpal · Fusion · Wrist · Arthritis · Screws · Technique

Introduction

Scapholunate advanced collapse (SLAC) stages II-IV and scaphoid nonunion advanced collapse (SNAC) stages II-IV are commonly treated with excision of the scaphoid and fusion of the lunate to the capitate, hamate, and triquetrum [1–5]. The operation has been referred to as a 4-corner fusion, midcarpal fusion, or SLAC procedure. The most commonly considered alternative procedure, proximal row carpectomy (PRC), is typically reserved for SLAC and SNAC stage II when the hyaline cartilage on the head of the capitate remains of good quality. In stage III, the capitolute junction has become involved and a modified PRC with capsular interposition may be required. Short-term results between the two procedures differ little in terms of range of motion, pain relief, and grip strength [6–8]. Long-term, PRC patients demonstrate radiographic arthritis at the radiocapitate articulation. One of the benefits in selecting a midcarpal fusion should be establishing a highly congruent radiolunate articulation for load transfer. This benefit is only realized if a number of specific technical points are accomplished. The lunate should be fused in neutral sagittal capitolute alignment with the capitate translated volarly. Either lunate extension or capitate dorsal translation can lead to impingement of the capitate on the dorsal rim of the radius causing both pain and limited extension. Likewise, prominent hardware placed dorsally can have the same effect (particularly dish shaped plates and staples used in the true sagittal plane). The method of fixation may play a role not only in creating impingement but in the rate of union [3, 6, 9, 10]. Recent discussion has centered on nonunion rates for midcarpal fusion with an attempt made to blame the hardware [3, 9, 10]. Other reports have pointed out that it is not the hardware at fault but rather the fundamental surgical technique that is responsible for achieving reliable union [11, 12].

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Surgical technique

Fundamentals

As with all surgical procedures, the specific technical details are driven by the need to satisfy the goals of the procedure while avoiding complications or morbidity inherent to the chosen method. The goal of a midcarpal fusion is to establish a stable, load bearing articulation at the congruent radiolunate interface. This requires a broad surface area of contact for fusion to occur, ample bone graft, compression, and stable fixation. The capitate must be positioned correctly relative to the lunate to avoid impingement on the dorsal rim of the radius (neutral capitolunate angle or slight overcorrection away from dorsal intercalated segment instability). There are many possible variations for this procedure, all perfectly valid and capable of producing good outcomes. Having tried most, I believe the method described in this article strikes the best balance between achieving the procedure's goals while minimizing complications and morbidity.

Approach and bone graft

A midcarpal fusion can be performed through a transverse wrist incision which may be considered more attractive once healed than a longitudinal incision. However, the proximal skin edge can interfere with establishing a guidewire or drill path at a low enough angle when drilling antegrade over the edge of the radius. A transverse skin incision does not provide sufficiently proximal access to obtain distal radius bone graft. A 6 cm longitudinal incision provides access to perform all of the tasks required in the case: remove the scaphoid, prepare the fusion surfaces of the other 4 carpals, harvest distal radius bone graft from the floor of the second compartment, and drill guide wires up the axis of the capitate without soft tissue interference.

Bone graft for the fusion must be of good quality and ample volume. The bone harvested from the scaphoid, although otherwise set to be discarded, may not be of adequate quality to promote fusion compared to bone from the iliac crest or distal radius. Bone from the iliac crest may be the best quality available, and is certainly available in sufficient quantity for wrist fusion. However, the donor site is quite painful and leaves an additional wound that must be cared for by the patient. Bone from the distal radial metaphysis appears to be of sufficient quality for sound healing of a midcarpal fusion. Harvest can be achieved through one incision, and the donor site is not nearly as painful as the iliac crest.

Method of fixation

More than any other topic, the method of fixation for midcarpal fusion has been debated. The traditional 4-

corner fusion used only Kirschner wires (K-wires) for fixation, but required the patient to be in an extensive long arm cast that came all the way out to the hand. K-wires carry the same traditional complications in a wrist fusion as elsewhere, primarily early migration and pin tract infection which can progress to osteomyelitis. As orthopedic device manufacturers began to offer a wider array of implant choices, some of these were applied to partial wrist fusion. The general theme trended toward permanent implant devices with greater fixation strength than K-wires with a view to less obtrusive postoperative splinting or casting. One device that quickly became popular was a circular plate. The plate needs a deep reaming to seat it fully down into the fusion site in order to avoid impingement on the dorsal rim of the radius. Technical details of application must be stringently adhered to, leading to excellent results in the hands of some surgeons, but poor results in the hands of others. Memory staples that change shape to exert compression when subjected to an electrical current can afford intercarpal compression. Most surgeons place the staple in the sagittal plane which can lead the proximal corner of the staple to impinge on the radius. I used to orient the staple in an oblique plane between sagittal and coronal to minimize this impingement (Fig. 1). Although compressive, the staple is not rigid in its fixation and needs some type of supplement. If K-wires are chosen, the case is subjected to the typical complications of K-wires. Alternatively, screws can supplement the staple, in which case screws can also just replace the staple altogether (Fig. 2). Headless, variable-pitch, cannulated compression screws are quite useful in the carpus in general and constitute the mainstay for fixation involving scaphoid fractures and nonunions. They are also valuable for the performance of midcarpal fusion. The screws are contained entirely inside the outer

Fig. 1 Although a memory compression staple can be oriented out of the sagittal plane into an oblique placement, the most proximal corner of the staple still risks some degree of impingement on the distal radius

dimension of the fusion construct and thus have no potential for impingement (Fig. 3). They offer excellent compression and are very rigid.

Transition to rehabilitation

Midcarpal fusions require 8 weeks of immobilization in either a cast or clamshell orthoplast splint at which point a computed tomography (CT) scan is needed to determine union [10, 13]. With proper bone grafting, the fusion interface will have the same appearance of a complete fusion at the first follow-up visit as at the 8-week visit. Only a CT scan can reveal the bridging trabeculae within each cut that represent the hallmark of union (Fig. 4).

Fig. 2 Headless compression screws can be combined with other methods of fixation such as a memory staple to meet the fundamental goals of stable fixation and good compression across the fusion site

Fig. 3 Headless compression screws are contained entirely within the outer dimensions of the carpal bones and are thus free from impingement. Fusion in this case is of only the capitolunate interface

Once fusion is confirmed, the patient immediately begins mobilization of the wrist in all planes with active, assisted, and passive techniques. No external immobilization is needed. The emphasis should initially be on restoring motion and then incorporate strength development after 3 months postoperative. Ongoing progress in both motion and strength will then occur over another year's time as the patient self-administers a home based therapy regimen.

Specific details of surgical technique

The 6 cm longitudinal midline incision affords a safe internervous approach between the superficial radial and

Fig. 4 Computed tomography is needed to accurately assess union of a midcarpal fusion by demonstrating bridging trabeculae crossing the fusion site

Fig. 5 A 4-corner fusion assembled with only headless compression screws and no supplemental K-wires requires compression and stability foremost across the capitolunate interface. The surgeon then also stabilizes and compresses the lunotriquetral relationship and the triquetrum to distal row relationship

dorsal cutaneous branch ulnar nerves. The extensor pollicis longus does not need to be transposed from its compartment. Capsulotomy runs along the rim of the radius from styloid until reaching the origin of the dorsal radiocarpal ligament. Further ulnar extension of the capsulotomy is performed in line with these ligament fibers, keeping the overlying fourth extensor compartment intact and shifting it in an ulnar direction.

The scaphoid is best removed by an approach between extensor carpi radialis longus and brevis. A curved periosteal elevator will strip the distal and proximal ligaments away, allowing the scaphoid to be removed as a whole unit. I prefer to split the scaphoid into a proximal and distal half with an osteotome directed parallel to the radioscapophcapitate ligament. This ensures protection of this ligament, critical to maintaining a stable relationship between the fusion mass and the radius, specifically in preventing ulnar translocation.

The next step is preparation of the surfaces at all interfaces selected for fusion (just capitulunate or full 4-corner fusion). It is at this step where most surgeries that go on to nonunion have failed. The surgeon must remove not only all of the hyaline cartilage that coats the surface designated for fusion, but all of the subchondral bone as well. The surgeon must expose the true spongy cancellous core of each carpal bone. Only the cancellous quality bone has the best fusion potential. To the degree possible, the surgeon should endeavor to accomplish the cartilage and bone removal with hand tools, since no heat is generated that can lead to thermal bone necrosis. A rongeur, osteotome, and curette are sufficient. In those cases where the concave surface of the lunate is responding poorly to hand tools, limited use of a power burr is acceptable to ensure reaching the cancellous core.

Provisional fixation of the fusion position is made with 0.045 inch K-wires. The difficulty here is achieving adequate rotation of the lunate into flexion in the sagittal plane. It is helpful to place the first temporary wire through the head of the capitate and out the distal dorsal surface, then return it retrograde back into the lunate while holding the lunate manually reduced. The next two wires placed antegrade (from proximal to distal) through the lunate into the capitate are guide wires for the cannulated screws. The volume of bone graft needed is now easily determined and harvested from the distal radius through an interval between extensor carpi radialis and brevis, which places the donor site proximal to the unloaded scaphoid fossa of the radius as opposed to the loaded lunate fossa. Bone graft is then packed with a tamp into the defect between capitate and lunate as well as any other interfaces to be fused. I do not believe that it is important to attempt to fuse the capitate to hamate interface as there is essentially no motion there in a normal wrist. As long as a triquetrum to hamate fusion occurs, fusion of the triquetrum to the lunate is also not impor-

tant. Excessive preparation of the lunotriquetral interface can leave a route for bone graft to escape into the radiocarpal joint and should be avoided.

Once the bone graft is in place, the fusion site is reduced, compressed and the guide wires advanced from lunate to capitate. The position of the fusion and the wires is checked on image intensifier. Micro sized headless compression screws are then depth gauged, core drilled, and placed over the guide wires. For 4-corner fusion, additional screws are placed from triquetrum to lunate and from triquetrum to the distal row. The one obvious negative of this method of fixation is the entry of screws through the hyaline cartilage surface of the lunate. The negative impact can be minimized by using a very small size of screw that leaves a small 'footprint' for entry, and by strategically selecting the exact points of penetration away from the primary regions of cartilage loading. The best entry points are slightly dorsal and radial.

The joint is checked for smooth and congruent motion in all planes and to make sure there are no loose pieces of bone graft remaining to cause third body wear. The capsule is closed with a 4-0 absorbable monofilament. The same suture is used for intradermal closure of the skin with steristrips at the surface. A padded dressing with fiberglass splint across the wrist is applied, leaving the hand, forearm and elbow free for motion.

Discussion

Pain typically necessitates some form of treatment for patients who have progressed to SLAC or SNAC stages II to IV. The two most common treatments for earlier stages of arthritis are PRC and midcarpal fusion with scaphoidectomy. In advanced stages, the motion preserving procedure of choice is a midcarpal fusion. PRC has been compared several times with midcarpal fusion/scaphoidectomy in non-randomized series. Seventeen midcarpal fusion patients achieved better grip strength (72% of contralateral) than 30 PRC patients (50% of contralateral) [8]. The midcarpal fusion group achieved a mean arc of motion of 61 degrees compared to 75 degrees for the PRC group. Another comparative study that had well matched but non-randomized groups of 19 patients each found very similar ranges of motion with arcs averaging 80 degrees for the midcarpal fusion group and 81 degrees for the PRC group [7]. Grip strengths were 79% of the contralateral side for midcarpal fusion compared to 71% for PRC. Additional and larger case series of only midcarpal fusions have documented the range of results that may be achieved. Total arc of motion has been reported to range from a low of 53 degrees to a high of 95 degrees, and grip strength from a low of 65% of contralateral to a high of 79% of contralateral [1–8].

These results are not without complications. Nonunion has been reported between 25% and 33% [3, 6, 9, 10]. Other frequent complications include dorsal hardware impingement (22–25%) and pin tract infections [3, 9, 10]. It has been reported that complication rates differ based on the hardware used for the procedure [3, 9, 10]. Duration of immobilization may also play a role [10, 14]. Other articles have shown that low complication rates can be achieved by adherence to strict principles of surgical technique independent of hardware choices [11, 12]. Nevertheless, various authors have developed preferred techniques based on such reports as well as personal experience. Alternatives to K-wires or circular plates include compression staples and headless variable pitch screws [15–17].

There are many techniques that can lead to good results with midcarpal fusion and scaphoidectomy. A surgeon should use the one with which he is comfortable in his own hands. The focus should be on complete preparation of the surfaces for fusion down to the cancellous core, dense packing of good quality cancellous bone graft, proper alignment of the capitulate relationship, and solid compression. As long as these goals are met, union should reliably be achieved by 8 weeks. Any differences between methods, at that point, should relate primarily to hardware associated complications. It is this issue that has caused the author to currently prefer the reported technique, as it simply obviates any problems with K-wire migration, pin tract infection, or the need for subsequent removal. Hardware impingement that is possible with plates and staples does not occur with an implant that is buried entirely inside the outer dimensions of the carpal bones.

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